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department of
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FREE STATE PROVINCE

Climate Change Adaptation Response Strategy for Free State

environmental affairs
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ABBREVIATIONS and ACRONYMS

AR4 and AR5	Fourth and Fifth Assessment Reports of the IPCC
ARC	Agricultural Research Council
CBO	Community based organisations
CCRS	Climate Change Response Strategy
CCAM	Conformal-cubic atmospheric model
CMIPP5	Coupled Model Intercomparison Project Phase 5
CO_2	Carbon dioxide
CORDEX	Co-ordinated Regional Downscaling Experiment
CR	Critically Endangered
CSIR	Council for Scientific and Industrial Research
CVD	Cardiovascular Disease
DAFF	National Department of Agriculture, Forestry and Fisheries
DARD	Free State Department of Agriculture and Rural Development
DEA	South African Department of Environmental Affairs
DESTEA	Free State Department of Economic, Small Business Development, Tourism & Environmental Affairs (DESTEA)
DOH	National Department of Health
DMR	National Department of Mineral Resources
DST	National Department of Science and Technology
DWS	National Department of Water and Sanitation
EC	Electrical conductivity
ECD	Early childhood development
EE	Energy efficiency
FS	Free State
GCCM	Global Coupled Climate Model.
GCM	General circulation model
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
IDP	Integrated Development Plan
IFPRI	International Food Policy Research Institute
INDC	Intended Nationally Determined Contributions
IPCC	Intergovernmental Panel on Climate Change
ISO / IEC Guide	International Standard operation certification of products, processes and services
Km	Kilometre
LTAS	Long Term Adaptation Scenarios
LTMS	Long Term Mitigation Scenarios
mm	Millimetre
MEC	Member of Executive Committee
na	Not Available
NCCRP	National Climate Change Response Policy
NDP	National Development Plan
NGO	Non-governmental organisations
RCP	Representative Concentration Pathways
SAEON	South African Environmental Observation Network
SANAS	Situational Analysis and Need Assessments
SANBI	South African National Biodiversity Institute
SANParks	South African National Parks
SARVA	South African Risk and Vulnerability Assessment
SAWS	South African Weather Service
SDF	Spatial Development Framework
SDG	Sustainable Development Goals

SGP	Small Grants programme
SPLUMA	Spatial Planning and Land-use Management Act
StatsSA	Statistics South Africa
SV	Social Vulnerability
UCT	University of Cape Town
UFS	University of Free State
UKZN	University of KwaZulu-Natal
UNFCCC	United Nations Framework Convention on Climate Change
VA	Vulnerability Assessment
VBD	Vector Borne Disease
WMAs	Water Management Areas
WRC	Water Research Commission
ZD	Zoonotic Disease
^{o}C	Degrees Celsius

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Glossary

Adaptation
Adaptation is an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory, autonomous and planned adaptation. There are different ways in which adaptation can be framed; an inventory has been made by the Dutch Climate Changes Spatial Planning research programme.

Adaptive capacity (in relation to climate change impacts)
Adaptive capacity describes the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. Adaptive capacity can be framed in many different ways; an inventory has been made by the Dutch Climate Changes Spatial Planning research programme.

Climate
Climate in a narrow sense is usually defined as the 'average weather', or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system. The classical period of time is 30 years, as defined by the World Meteorological Organization (WMO).

Climate change
The Inter-governmental Panel on Climate Change (IPCC) defines climate change as: “a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use”. Whereas, the United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as “a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods”. (NB: For disaster risk reduction purposes, either of these definitions may be suitable, depending on the particular context. The UNFCCC definition is more restricted one as it excludes climate changes attributable to natural causes. The IPCC definition can be paraphrased for popular communications as “A change in the climate that persists for decades or longer, arising from either natural causes or human activity.”)

Climate sensitivity
In IPCC reports, equilibrium climate sensitivity refers to the equilibrium change in the annual mean global surface temperature following a doubling of the atmospheric equivalent carbon dioxide concentration. Due to computational constraints, the equilibrium climate sensitivity in a climate model is usually estimated by running an atmospheric general circulation model coupled to a mixed-layer ocean model, because equilibrium climate sensitivity is largely determined by atmospheric processes. Efficient models can be run to equilibrium with a dynamic ocean. The effective climate sensitivity is a related measure that circumvents the requirement of equilibrium. It is evaluated from model output for evolving non-equilibrium conditions. It is a measure of the strengths of the climate feedbacks at a particular time and may vary with forcing history and climate state. The climate sensitivity parameter (units: °C (W m–2)–1) refers to the equilibrium change in the annual mean global surface temperature following a unit change in radiative forcing. The transient climate response is the change in the global surface temperature, averaged over a 20 year period, centred at the time of

atmospheric carbon dioxide doubling, that is, at year 70 in a 1% per year compound carbon dioxide increase experiment with a global coupled climate model. It is a measure of the strength and rapidity of the surface temperature response to greenhouse gas forcing.

Climate system
The climate system is defined by the dynamics and interactions of five major components: atmosphere, hydrosphere, cryosphere, land surface, and biosphere. Climate system dynamics are driven by both internal and external forcing, such as volcanic eruptions, solar variations, or human-induced modifications to the planetary radiative balance, for instance via anthropogenic emissions of greenhouse gases and/or land-use changes.

Climate variability
Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability).

Dry-spell
Five or more consecutive days without rainfall (units are number of days per grid point per year).

Emission scenario
An emission scenario is a plausible representation of the future development of emissions of substances that are potentially radiatively active (e.g. greenhouse gases, aerosols), based on a coherent and internally consistent set of assumptions about driving forces (such as demographic and socioeconomic development, technological change) and their input to a climate model to compute climate projections. In IPCC (1992) a set of emission scenarios was presented which were used as a basis for the climate projections in IPCC (1996). These emission scenarios are referred to as the IS92 scenarios. In the IPCC Special Report on Emission Scenarios (Nakienovi and Swart, 2000) new emission scenarios, called the SRES scenarios, were published, some of which were used, among others, as a basis for the climate projections presented in TAR-IPCC (2001) and 4AR-IPCC (2007).

Exposure
Exposure relates to the extent of climate stress upon a particular unit of analysis and may be represented as either long-term change in climate conditions, or by changes in climate variability, including the magnitude and frequency of extreme events.

Extreme rainfall event (thunderstorms and lightning)
More than 20 mm of rain falling within 24 hrs over an area of 50 x 50 km^2. The occurrence of extreme convective rainfall is used as a proxy for the occurrence of storms that produce lightning. Units are number of events per grid point per year.

Extreme weather event
An extreme weather event is an event that is rare at a particular place and time of year. Definitions of rare vary, but an extreme weather event would normally be as rare as or rarer than the 10^{th} or 90^{th} percentile of the observed probability density function. By definition, the characteristics of what is called extreme weather may vary from place to place in an absolute sense. Single extreme events cannot be simply and directly attributed to anthropogenic climate change, as there is always a finite chance the event in question might have occurred naturally. When a pattern of extreme weather persists for some time, such as a season, it may be classed as an extreme climate event, especially if it yields an average or total that is itself extreme (e.g. drought or heavy rainfall over a season).

Greenhouse gas (GHG)
Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere. Moreover, there are a number of entirely human-made greenhouse gases in the atmosphere, such as halocarbons and other chlorine- bromine-containing substances, dealt with under the Montreal Protocol. Beside CO_2, N_2O and CH_4, the Kyoto Protocol deals with the greenhouse gases sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs).

Heat-wave days
The maximum temperature exceeds the average temperature of the warmest month of the year by 5°C for at least 3 days.

High fire-danger days
McArthur fire-danger index exceeds a value of 24. Units are number of events per grid point per year.

Measures/options
Adaptation measures/options are technologies, processes, and activities directed at enhancing the capacity of a vulnerable system to adapt (building adaptive capacity) and at minimising, adjusting to and taking advantage of the consequences of climatic change (delivering adaptation).

Mitigation
An anthropogenic intervention to reduce the anthropogenic forcing of the climate system; it includes strategies and measures to reduce greenhouse gas sources and emissions and enhance greenhouse gas sinks. Examples of mitigation measures are renewable energy technologies, waste minimization processes and public transport commuting practices.

Projection
The potential evolution of a quality or set of quantities, often computed with the aid of a model. Projections are distinguished from predictions in order to emphasise that projections involve assumptions — concerning, for example, future socio-economic and technological developments, that may or may not be realised — and are therefore subject to substantial uncertainty.

Resilience
Resilience describes the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change. There are different ways in which resilience can be framed; an inventory has been made by the Dutch Climate Changes Spatial Planning research programme.

Risk
Risk is a combination of the probability of an event and its negative consequences. Comment: This definition closely follows the definition of the ISO/IEC Guide 73. The word "risk" has two distinctive connotations: in popular usage the emphasis is usually placed on the concept of chance or possibility, such as in "the risk of an accident"; whereas in technical settings the emphasis is usually placed on the consequences, in terms of "potential losses" for some particular cause, place and period. It can be noted that people do not necessarily share the same perceptions of the significance and underlying causes of different risks. There are

different ways in which risk can be framed. See for example inventories made for the disaster reduction community or for the Dutch Climate Changes Spatial Planning Programme.

Scenario
A plausible and often simplified description of how the future may develop based on a coherent and internally consistent set of assumptions about driving forces and key relationships. Scenarios may be derived from projections, but are often based on additional information from other sources, sometimes combined with a narrative storyline.

Socio-economic scenarios
Scenarios concerning future conditions in terms of population, gross domestic product and other socio-economic factors relevant to understanding the implications of climate change.

Threshold
A threshold is a level of magnitude of a system process at which sudden or rapid change occurs. A point or level at which new properties emerge in an ecological, economic or other system, invalidating predictions based on mathematical relationships that apply at lower levels.

Uncertainty
An expression of the degree to which a value (e.g. the future state of the climate system) is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from quantifiable errors in the data to ambiguously defined concepts or terminology, or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures, for example, a range of values calculated by various models, or by qualitative statements, for example, reflecting the judgement of a team of experts.

Very hot days
A day when the maximum temperature exceeds 35°C. Units are number of events per grid point per year.

Vulnerability
Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity. There are different ways in which vulnerability can be framed; an inventory has been made by the Dutch Climate Changes Spatial Planning research programme.

Executive Summary

Free State Province, together with the rest of the country, is highly vulnerable to climate change and its impacts. The South Africa government, through the National Climate Change Response Policy (2011) as well as the Intergovernmental Panel on Climate Change (IPCC, 2013) have acknowledged the importance of responding to and adapting to these changes. Responding to climate change requires a multi-stakeholder and multi-sectorial approach, given the wide ranging impacts to be expected as a result of increases in temperatures, heat waves, very hot days and dry spell days. While many efforts are on-going at different scales to mitigate the production of greenhouse gases, climate change will continue to be felt for decades to come. The Free State provincial government has undertaken a proactive approach to respond to and adapt to the challenges posed by climate change. The impacts of and vulnerabilities to climate change vary across regions, economic sectors, social groups and types of systems, and as such there is need for case specific vulnerability assessments (we Adapt, 2014). The impacts on the following sectors are discussed in the report:

- Water resources (rivers, wetlands and groundwater); Terrestrial biodiversity; Agriculture; Tourism; Mining; Human settlement; Built environment (infrastructure); and Human health and social vulnerability.

This report presents a summary of the projected changes in climate for Free State Province for the short to medium term (2020-2050) as summarised in Chapter 3, as well as the risk and vulnerability assessment of the vulnerable sectors and areas as summarised in Chapter 4.

Adaptive Capacity

Adaptive capacity refers to the ability of a system or community to change or modify itself to reduce potential damage or cope with the consequences of shocks or stress such as climate variability and extremes. It is a dynamic process. Adaptive capacity is influenced by factors such as availability of natural, financial and skilled human resources; social and institutional networks; technology; level of human development; and political will of governments (UNEP, 2011). The adaptive barriers/constraints that result from external factors often become reinforced by the internal institutional processes, norms and values that are held by officials. Institutional structures, policies and other legal instruments at national and province level are essential in responding to climate change and in building the resilience of sectors such as water, agriculture and disaster management. High levels of social vulnerability create challenges that compromise adaptive capacity in the province in sectors such as water and environmental management. Addressing these social vulnerabilities will promote resilience to climate change and its impacts.

The changes in climate will have wide ranging impacts in the province and responding to these changes will require changes in processes, practices, and structures to reduce potential damage and maximise opportunities associated with climate change. These responses are best carried out at the local level, which is where most impacts will be felt and also where the tools necessary for mitigation and adaptation, as well as the planning instruments, are found. Vulnerability to climate change is complex and dynamic and is a function of exposure, sensitivity and adaptive capacity.

The evidence of projected changes in climate variables as modelled by the CSIR is presented in table below.

Climate Variable	**Current (1970-2015)**	**Medium Term (2020-2050) under high mitigation**	**Medium Term (2020-2050) under low Mitigation**
Average temperature	29.5°C	+ 1.6°C new average 31.1°C	+ 2.3°C new average 31.8°C
Very hot days	88	+ 41.1 new total 121.1	+ 54.15 new total 142.15
Heat-wave events	13.9	+ 14.7 new total 28.6	+17.5 new total 31.4
High fire-danger days	145	+ 57.4 new total 202.4	+ 74.1 new total 219.1
Average annual rainfall	527mm	+/25.07/ - +/-112.2mm (rainfall will either increase by 25.07mm or decrease by 112.2mm)	+35mm / -65.9mm (rainfall will either increase by +/-35mm or decrease by +/65.9mm)
Extreme rainfall events (thunderstorms & lightning)	22.8	+ 0.27 (increase is less than 1, meaning the total is likely to remain the same)	+ 0.23 increase is less than 1
Dry-spell days	93.5	+ 11.5 new total 105	+ 18.6 new total 112.1

The vulnerabilities of the different critical sectors in the Free State are summarised in the tables below.

Sector	**Exposure**	**Sensitivity**	**Adaptive Capacity**	**Vulnerability**
Water Resources (Rivers, dams and groundwater)	High • Increase in temperature of 2.3°C • Increase in number of hot days - 121.1-142.15 • Increase in heat wave days - 28.6- 31.4 events/year • The increase of extreme rainfall events is less than 1 Dry spell days to increase to between 105- and 112.1 days	High • Increases in evaporation from rivers, wetlands and dams • Increased water demand by plants on the water systems are already under pressure from high irrigation and consumption • Water systems affected by pollution from mining	Medium • The climate change adaptation strategy for the water sector is in place • The institutional and policy frameworks for better management of water resources are in place Water conservation efforts are being undertaken (awareness, hydrate Frees State expo, drought relief promotion, etc).	High The vulnerability of surface water resources is regarded as high. The demand for water, for all economic sectors as well as human consumption is expected to increase as a result of increases in temperature. The uncertainty in the projection of rainfall, which is expected to increase or decrease under different climate scenarios will exacerbate the future planning for the management of water resources in the province.
Agriculture - Farming – Crops, high value produce and livestock,	High • Increase in temperature of 2.3°C	High (types of crops and changes in climatic zones)	Medium • Plant breeding and cultivars more resilient to climate change	High • The crop production sector of agriculture is

	• Increase in number of hot days - 121.1-142.15 • Increase in heat wave days - 28.6- 31.4 events/year • Decrease in rainfall Dry spell days to increase to between 105 and 112.1 days	• Animal productivity is reduced by heat stress; • Rangeland productivity is reduced by heat stress • Most crops are temperature and rainfall-dependent for best productivity Increase in temperature, reduced rainfall, possible increase in pests and diseases	• Climate-smart technologies Animal breeding and research for more resilient animal breeds such as indigenous breeds • Research on rangelands and the grasses used for fodder improvement Research and development on climate change-adaptable cultivars	highly vulnerable to climate change. Despite the research on more drought and disease tolerant cultivars, the cost of these cultivars are beyond the reach of many farmers. This has been worsened by the lack of access to financial credit being currently experienced in the country.
Terrestrial and wetland ecosystems	High • Increase in temperature of 2.3°C • Increase in number of hot days - 121.1-142.15 • Increase of extreme rainfall events is less than 1 • Dry spell days to increase to between 105 and 112.1 days High fire danger days to increase to between 202.4 and 219.1 days	High • Most of the biomes are highly sensitive to changes in rainfall and temperature • Some biomes will benefit while other will be replced • Grasslands are most threatened followed by Nama-Karoo • Increase in the number veld fires Impacts on birds and other animal and reptiles	Medium • The province has completed a critical Biodiversity and ecology assessment report, which will help identify priority areas for conservation • Biodiversity Education Programmes, help to raise awareness of the school learners and the communities	Medium • The biodiversity sector is classified as having medium vulnerability to climate change. The sector has high exposure and sensitivity to projected changes in climate. However, the biomes that are endangered are in protected areas with the exception of some parts of the vast grasslands. There are plans in place to protect and conserve biodiversity through the establishment of biodiversity protected corridors.
Mining	High • Increase in temperature, Plausible increase in extreme rainfall events e.g. flooding	Medium • Construction materials and equipment will be affected by increases in temperature • Susceptible to flooding, resulting in soil movement and instability Mining industry currently has a poor safety record and climate change will	Low • Slowdown in the mining sector affecting its contribution to the country's economy and employment • Proliferation of illegal mining operations causing damage to the environment Water Shortages	Medium • The vulnerability of the mining sector is regarded as medium. While not much research has been done on the impacts of climate change on the sector in the province or at national level, the vulnerability of

		increase the safety risks		mining equipment as well as the vulnerability of mine workers are a source of concern and there needs to be plans in place to respond.
Tourism	High • Increase in temperature • Reductions in rainfall, (affecting water availability) • Increase in heat waves and very hot days Increases in diseases and pathogens)	High • Dependency on vulnerable biodiversity, e.g. for Golden Gate National Parks • Heat stress beyond human comfort levels • Water security is compromised Destruction of hotel and other infrastructure	Low • The tourism industry is undertaking water conservation and recycling measures • Energy efficiency appliances and energy saving measures are in place in the major hotel chains Vulnerability and Impacts of Climate Change on Major Tourism Attractions and Activities (2012)	High • The Tourism sector in the province is regarded as being highly vulnerable to climate change. The provincial department has no plans or measures in place to address climate change. • Changes in climate will reduce the length of the tourism period thus affecting revenue.
Human Health	High • Increase in temperature • Reduction in rainfall, affecting water availability • Increase in diseases and pathogens • Increase in heat waves and very hot days Increase in extreme weather events	High Reduced water will affect the health of poor communities • Heat stress will worsen existing health conditions such as communicable diseases. • Heat stress will increase demand for energy for cooling Pre-existing condition such as HIV/AIDS and TB will exacerbate human health systems	Medium • Health system infrastructure is in place and accessible at both provincial, district and local government (in the form of hospitals, clinics and NGO care facility centres). • Policies and legal instruments available at national level that can be adapted to province level. National Climate Change and Health Adaptation Plan (2014 – 2019)	Medium • Human health and social vulnerability are regarded as having medium vulnerability to climate change. Despite the high exposure the provincial government is reducing the backlog in the provision of basic services, including in informal settlements. • There are social development project in place which assists to reduce unemployment and poverty but these are not enough.

Human Settlements and Built Environment	High • Increase in temperature • Reduction in rainfall, affecting water availability • Increase in heat waves and very hot days Increase in extreme weather events	High • Informal settlements are most at risk • Old and low cost houses and residences will be highly affected Other residential infrastructure such as school and clinics will be damaged	Medium • Budget has been allocated to eradicate pit and bucket toilets. • Urban settlement development grants to develop and upgrade infrastructure that supports human settlements. • Informal settlements upgrading strategy document in place. • Water recycling. Low cost housing project is using solar geyser and houses being retrofitted for energy conservation.	Medium • The vulnerability of the built environment and human settlements is considered medium. • Efforts as well as planning and budgeting have been made available to upgrade informal and old settlements in the province. • Efforts to upgrade and maintain infrastructure are being implemented for the various type of infrastructure that support settlements • It is important to keep a watchful eye on migration and its possible impacts on urban settlements.

1 Introduction

Adapting to climate change requires both human and natural systems to adjust to actual or expected changes in climate and the associated effects, and build resilience through better decisions about managing the built and natural environments and taking advantage of opportunities (UNFCCC, 2014). It requires an understanding of and planning for the current risks and vulnerabilities as well as the projected changes/risks in the future. Developing sustainable adaptation options also relies on information of past events, their effects and measures put in place to respond which illustrates a system's adaptive capacity.

At national level there has been a concerted effort to deal with issues of climate change. Among these efforts are the following milestones:

- The National Climate Change Response Policy highlighted the need for all government departments to review all policies, strategies, legislation, etc. within their jurisdiction to ensure full alignment with this policy. This alignment will allow for more effective interaction between municipal, provincial and national government. It will further ensure that there is alignment between national flagship programmes, provincial and municipal focus areas, enabling the provincial and municipal programmes to contribute to national targets. This also allows for access to national and international funding streams that will benefit South Africa as a whole. Provincial mandate from NCCRP in section 10.2.6
- The National Development Plan (NDP) further recognises that in the long-term the country should be able to manage its transition to a low-carbon economy without negative consequences for economic growth (RSA, 2011b).
- The Long Term Adaptation Scenarios (LTAS) research study provided national and sub-national adaptation scenarios for South Africa as well as evaluating the socio-economic and environmental implications of potential impacts of anticipated climate change across three time frames, namely short (<2030), medium (<2050) and long term (<2100) for the water, agriculture and forestry, human health, fisheries, biodiversity, disaster risk reduction and human settlements (urban, rural and coastal) sectors at a national level. In addition, this project developed a logical view of South Africa's climate change trends, current variability and future projections to provide a set of climate change scenarios based on the latest available methodologies, downscaled for the South African context. The scenarios considered climate trends and variability, climate change projections and impacts in selected sectors and the development growth pathways for these sectors.
- During the past ten years, modelling scenarios have predicted that there will be significant climate change impacts in South Africa (Hewitson et al., 2006). Recent studies by the South African Weather Service (SAWS) to develop national and provincial climate change scenarios focusing on the 21st century changes demonstrate some of these probable trajectories (SANAs, 2015). According to SAWS the following are likely to happen to the South African climate (SANAS, 2015):
  - The strongest warming is projected over inland areas including North West, Northern Cape, Limpopo, Mpumalanga, Gauteng and **Free State** Provinces.
  - Warming by 4% compared to the 2% IPCC average aggravated by local positive feedback over the area extending from Northern Cape and North West Provinces towards Namibia.
  - Differential warming between the coastal and inland areas will create strong temperature gradients, conditions favourable for strong winds, and storms.
  - Despite disagreement on climate modelling and probable variability, much of South Africa, notably Western Cape, Northern Cape, North West, Limpopo and **Free State** are projected to become drier.

- The rain season is likely to shift and start later, characterised by a shorter rainy season, with the duration of the dry spell likely to increase, resulting in drought and negative implications for the agriculture and water sectors. At the same time, intensified rainfall is projected to increase, with the likelihood of heavy downpours punctuated by longer dry spells. The heavy rainfall is likely to result in flash flooding and land degradation.

Variability in climatic conditions is already being observed (e.g. recent heat waves, drought, and severe floods in some parts of the country) and is likely to continue into the future along with wide ranging impacts. The changing parameters, whether it's extreme temperature, rainfall, or climatic events, will impact on wide ranging sectors, and across the spectrum from social to biophysical. Unless, innovative adaptation measures are put into place, this will have dire consequences for human, socio-economic, environmental and physical infrastructure. Even more challenging is the variable nature of climate change and its impacts. South Africa's nine provinces are likely to experience different climate change impacts depending on their exposure, sensitivity and adaptive capacity, exacerbated by social, biophysical characteristics and adaption mechanisms.

This will most likely put the country on a negative developmental trajectory, joepardising the aspirations of the National Development Plan (NDP). Notwithstanding these efforts, research shows mixed outcomes at provincial levels. The recent Situational Analysis and Needs Assessment (SANAS) study that was conducted by the Department of Environmental Affairs (DEA) at the sub-national level in order to better understand the needs and levels of provincial capacity in terms of climate change response presents the following provincial climate change response status quo (SANAS, 2015):

Overcoming the effects of climate change variability can only be achieved through effective climate change response strategies at national, provincial and local levels based on evidence and a good understanding of the status quo. Whilst this has been done at national level and in some provinces, in other provinces there is still work to be done. This project was undertaken in an effort to support Free State Department of Economic, Small Business Development, Tourism and Environmental Affairs (DESTEA) in the development of provincial adaptation response strategies (built upon the LTAS study). The work was technically guided by the Department of Environmental Affairs (DEA) and its technical partner GIZ.

1.1 Policy Framework

Table 1.1 below provides an overview of the international, national and provincial instruments that are currently available to guide and coordinate the implementation of climate response strategies of the various sectors.

Table 1.1: Overview of the policy instruments available to guide and coordinate the implementation of climate response strategies for various sectors within the FS province

International governance and scientific bodies	• Intergovernmental Panel on Climate Change • United Nations Convention on Biological Diversity • United Nations Convention to Combat Desertification • United Nations Framework Convention on Climate Change

National Acts and Policies	• Constitution of the Republic of South Africa 1996 • National Climate Change Response Policy 2011 • Mountain Catchment Areas Act 1970 • Municipal Systems Act 2000 • National Energy Act 2008 • National Environmental Management Act 1998 • National Environmental Management: Air Quality Act 2004 • National Environmental Management: Biodiversity Act 2004 • National Environmental Management: Integrated Coastal Management Act 2008 • National Environmental Management: Protected Areas Act 2004 • National Environment Management: Waste Act 2008 • National Forest Act 1998 • National Long Term Adaptation Scenarios 2014 • National Long Term Mitigation Scenarios 2007 • National Water Act 1998 • Renewable Energy White Paper 2003 • Spatial Planning and Land Use Management Act 2013
National Plans and Strategies	• Energy Efficiency Strategy 2005 • Environmental Protection and Infrastructure Programme • Integrated Energy Plan 2011 • National Development Plan 2010 • National Framework for Disaster Risk Management 2005 • National Strategy for Sustainable Development and Action Plan (2011) • National Transport Master Plan 2012 • Public Transport Strategy and Action Plan 2007 • National Water Resource Strategy 2013 • National Waste Management Strategy 2010 • Draft National Tourism Strategy and Climate Change Plan (2011)
Provincial Plans and Strategies	• Agriculture Integrated Growth and Development Policy (IGDP) • Agriculture Policy Action Plan (APAP) • Biodiversity Management/Action Plans • Disaster Management Plan • District Municipality Integrated Development Plans • Implementation guideline for climate change strategy • Local Economic Development Strategy • Free State Province State of the Environment Report • Tourism Strategy • Spatial Development Framework • SPLUMA

1.2 Analytical Framework used in this Study

The analytical framework used in this study provides a lens of analysis on how the information and data on climate change vulnerabilities and adaptation plan / strategy was captured, analysed and presented for the province. Figure 1.1 represents the process of analysing data with the intention of providing a framework for strategy development and implementation.

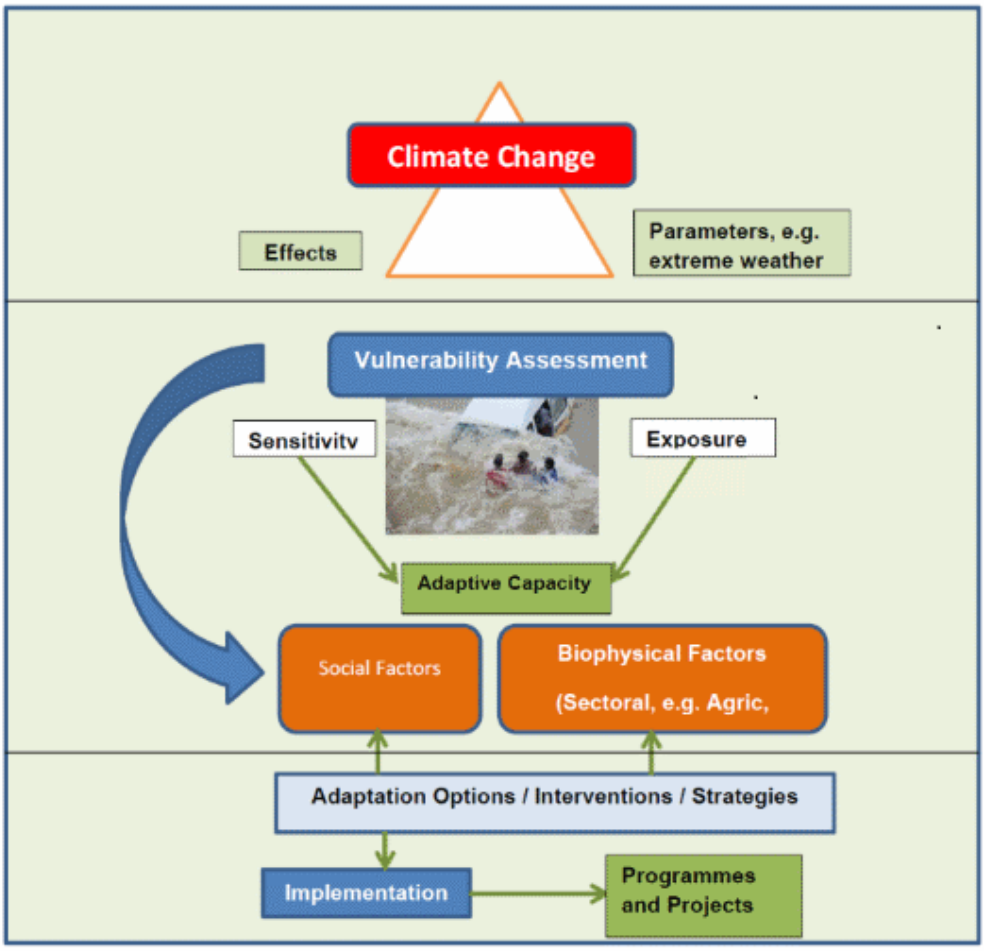


Figure 1.1: Analytical Framework used for strategy development (IPCC, 2007)

1.3 Objectives of the Study

The main objective of this work is to provide technical support for the development of the Climate Change Response Strategy for Free State Province, through:

a) Conducting a Climate Risk and Vulnerability Assessment for Free State Province for the near and medium (2020-2050);
b) Evaluating existing adaptive capacity in the province, examining best practices and case studies, identifying effective strategies for resilience and preparedness (including early warning systems and disaster management), and recommending appropriate new adaptation responses and strategies; and
c) Facilitating capacity building and knowledge-transfer throughout the process so as to enhance implementation of the prioritised adaptation options.

2 Status Quo

The first step towards developing the Free State climate change response strategy is to undertake a Status Quo Analysis of the province to better understand its social, economic and biophysical attributes. The following items are covered in this chapter:

- Stock-take of existing information on climate change in Free State
- An initial vulnerability analysis - climatic and non-climatic (the analysis is supported by all necessary data and information, where possible).

2.1 Overview of the Free State Province

Free State is located in the **geographical centre of South Africa**, bordered by Northern Cape, Eastern Cape, North West, Mpumalanga, KwaZulu-Natal and Gauteng provinces, as well as Lesotho. Free State is a rural province of farmland, mountains, goldfields and widely dispersed towns. Although it is the third-largest province in South Africa, it has the second-smallest population and the second-lowest population density. It covers an area of 129 825km² and has a **population of 2 745 590 – 5.3% of the national population**. Its capital is Bloemfontein, which is South Africa's judicial capital. Other important towns include Welkom, Kroonstad, Sasolburg and Bethlehem.

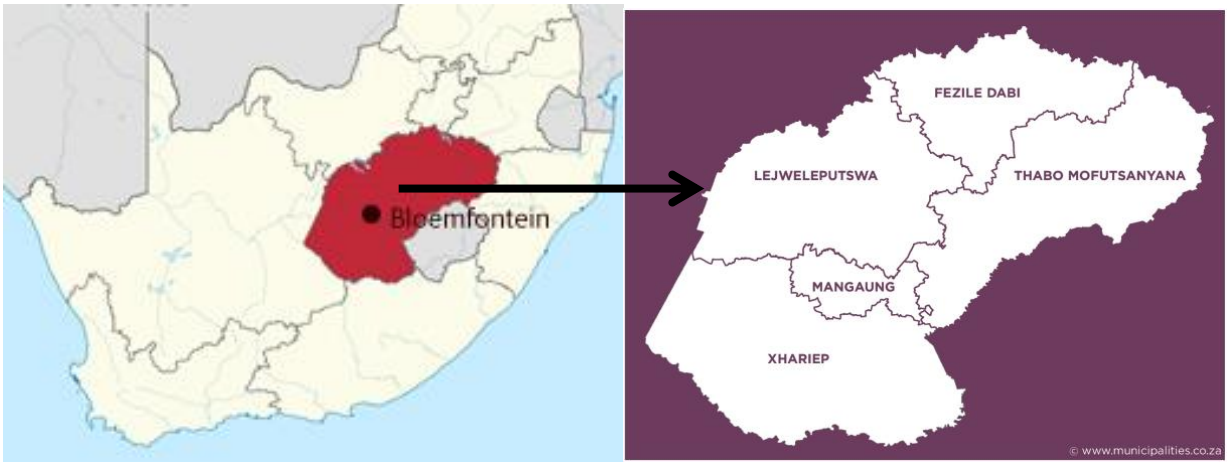


Figure 2.1: Maps of South Africa showing the location of the FS province within SA (left marked in red) and one metropolitan and four district municipalities within the province (right map) (Source: www.municipalities.gov.za)

Free State is divided into one metropolitan municipality (Mangaung Metropolitan Municipality) and four district municipalities; namely Fezile Dabi, Thabo Mofutsanyana, Lejweleputswa, and Xhariep. Table 2.1 provides an outline of population size and area of the municipalities. These four district (and one metropolitan) municipalities are further subdivided into 19 local municipalities.

Table 2.1: Free State District Municipalities (Population and area coverage) – census 2011

District Municipality	Mangaung	Fezile Dabi	Thabo Mofutsanyana	Lejweleputswa	Xhariep
Population	850 000	466750	725 932	657 019	146,259
Area (km²)	6 263	240,190	33,269	31,930	37,674

Free State (FS) is almost uniformly at about 1,300m above sea level, with the climate being typical

of the interior plateau with summer rainfall, cold winters and lots of sunshine. Almost all precipitation falls in the summer months, with aridity increasing towards the west. Frost occurs throughout the region usually from May to early September in the west and up to early October in the east. To the north, the Vaal irrigation area nourishes the small assortment of farming towns below it, and the Free State countryside is often green. Areas in the east experience frequent snowfalls in winter, especially on the higher ranges, whilst the west can be extremely hot in summer. The south brings hot, dry summer days and long, cold winter nights. This semi-desert area also experiences fluctuations of temperature from day to night. The west is warm and cold in equal measure, its inhabitants making use of the many artificial water recreation facilities to endure the heat, and use heating facilities in winter's low temperatures. FS has a generally hot, arid climate with the strongest warming for South Africa being projected in Free State and other inland provinces

The rain season is likely to shift, starting later and characterised by a shorter rainy season with the duration of the dry spell likely is to increase, resulting in drought and negative implications for agriculture and the water sector. At the same time, intensified rainfall is projected to increase, with the likelihood of heavy downpours punctuated by longer dry spells. Heavy rainfall often results in flash flooding and land degradation.

The Free State economy is dominated by agriculture, mining and manufacturing, and is known as the 'bread basket' of South Africa, where about 90% of the province is under cultivation for crop production. . It produces approximately 34% of the total maize production of South Africa, 37% of wheat, 53% of sorghum, 33% of potatoes, 18% of red meat, 30% of groundnuts, and 15% of wool. Therefore, agriculture is the most vulnerability sector in the Free State from a food security and water availability and usage point of view.

The impacts of climate change on water resources in the country indicate a reduction in soil moisture and runoff. In FS, large-scale agriculture as well as small-scale farmers and the rural poor who practice rain-fed agriculture rely on water for irrigation purposes. There is likely going to be incidences of dry spells due to increase in temperatures, or extreme floods and hailstorms, which could damage agricultural produce (www.freestate.gov.za).

The province is the world's fifth-largest gold producer and the mining sector is the major employer. It is a leader in the chemicals industry, being home to the giant synthetic-fuels company, Sasol. The Vredefort Dome, 10km in diameter, about 100km south-west of Johannesburg, is South Africa's seventh World Heritage Site. FS has enhanced its capacity to adapt to extreme climate events, by preparing for disaster risk reduction and management (i.e. Disaster Management Plan in place, early warning systems available, Disaster Management Centre and Research input from University of Free State and other research institutions).

2.2 Approach

A combination of bottom up and top down approaches were used to develop the status quo chapter. The status quo highlights the underlying development context in which people experience and must respond to the impacts of climate change. It includes an analysis of how and why people are sensitive and exposed to climate change impacts.

The Status Quo is based on key engagement principles and presented using the analytical approach summarised in Figure 2.2 below, which covers:

1) Identification of various key players within and outside the province;

2) Undertaking an overview of the province, sector mapping and research exercise, which informs the conceptual approach;
3) Quantitative analysis of the data;
4) Requesting sector specific documents from key stakeholders for use in describing the current profile of the province. This included reaching out to these sectors through meetings and interviews;
5) Undertaking initial capacity building and stakeholder engagement workshops (November 2015 and January 2016); and
6) Consolidation of the above information into this status quo report, including several open reviews.

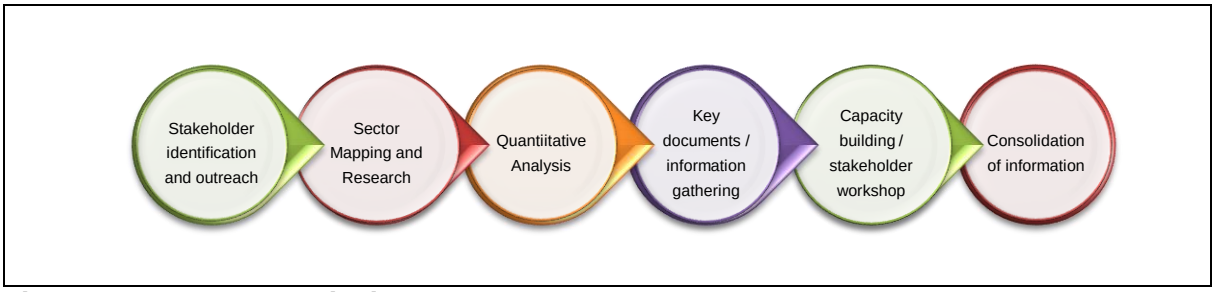


Figure 2.2: Status quo design process

The Free State provincial government has eleven departments, some of which have policies, plans, frameworks, and projects in place that are linked to climate risk and resilience, including the adaptation perspective. Their focus is on the water, biodiversity, human settlements, health, livelihood, infrastructure and other related social and biophysical activities within the province.

The provincial government has various departmental sectors (these include water, agriculture, biodiversity, tourism, mining, human settlements and built environment, social and human health) which are mostly highly vulnerable to the impacts of climate change. These sectors and their vulnerability assessments are discussed in detail in Chapter 4.

3 Climate Change Model Projections for the Free State

3.1 Introduction

The impacts of climate change are already a measureable reality in South Africa. Together with the rest of Southern Africa, the country is expected to be the worst affected by the drastic changes in temperature and large uncertainties about rainfall seasonality as a result of climate change. Climate change will affect economic activities and the future development of the country, especially in provinces such as Free State that are dependent on agriculture. The projected change in rainfall for the province indicates that the total seasonal rainfall has large uncertainties with no clear signal, an exception being under the highest representative concentration pathway (RCP8.5). In addition,

Free State's rain season is likely to shift and start later, with a shorter rainy season and an increase in the duration of dry spells, resulting in drought and negative implications for the agriculture and water sectors. At the same time, incidents of intense rainfall, as well as hailstorms, are projected to increase, with heavier downpours punctuated by longer dry spells, a situation that often results in flash flooding and land degradation (SANAS, 2015).

The projected change in climatic variables will have wide ranging impacts within FS. The changes in climate modelled under both the low mitigation (business as usual) and high mitigation scenarios indicate consistent trends of a hotter and drier climate over the interior of the country, including Free State (James and Washington, 2013; Engelbrecht et al., 2015). The impact of a change in rainfall seasonality on water resources is crucial, as evidenced by the drought that gripped the country in 2015/2016. The drought has had devastating impacts on the economy of FS, which is dependent on large-scale agriculture as well as small-scale farmers who practice rain-fed agriculture. The farming sector was hard hit by the recent drought, with entire the province being declared a disaster area. Climate change will exacerbate the frequency and intensity of such extreme climatic events in the future, as projected for the province and country.

The purpose of this report is to provide an overview of the most recent insights and evidence available regarding future changes in climatological averages and extreme events over South Africa, with a focus on changes that are likely to impact on Free State's key sectors.

3.2 Experimental design and model verification

Recent downscalings of global circulation model (GCM) projections of the Coupled Model Intercomparison Project Phase Five (CMIP5) and Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), obtained at the Council for Scientific and Industrial Research (CSIR) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO), were used to model changes in climate and extreme weather related events over Southern Africa as presented in the Fourth Assessment Report (AR4) and AR5 of the IPCC (Christensen et al., 2007; Niang et al., 2014), and in the Long Term Adaptation Scenarios Report (LTAS, 2013) of the Department of Environmental Affairs (DEA). The regional climate model used to obtain the downscalings is the conformal-cubic atmospheric model (CCAM) of the CSIRO. Six GCM simulations of CMIP5 and AR5 of the IPCC, obtained for the emission scenarios described by Representative Concentration Pathways 4.5 and 8.5 (RCP4.5 and RCP8.5) were downscaled to 50 km resolution globally for the periods 1971-2100 for RCP4.5 (high mitigation scenario), and RCP8.5 (low mitigation scenario). In these simulations CCAM was forced with the bias-corrected daily sea-surface temperatures (SSTs) and sea-ice concentrations of each host model, and with CO_2, sulphate and ozone forcing consistent with the RCP4.5 and RCP8.5 scenarios (Malherbe et al., 2013; Winsemius et al., 2014; Engelbrecht et al., 2015).

3.3 Model projections of the changing patterns of climate and extreme weather events over South Africa under enhanced anthropogenic forcing

The projected changes in a number of climatological variables (Table 3.1), including extreme weather-events, are modelled, beginning with the simulated baseline state over Free State calculated for the period 1971-2000, shown as the first map in each Figure presented below. The projected changes in the metric are subsequently shown, for the time-slab 2020-2050 relative to the baseline period 1971-2000, for the RCP4.5 and then for RCP8.5, presented as the second and third map in each Figure respectively.

Box 1: Free State declared disaster area as drought continues

Free State farmers are battling to keep their animals and crops alive as a crippling drought continues. Only one percent of Free State farmers report their fields are fit for grazing and planting. The devastating drought experienced in the Free State has affected the socio-economic climate, and has resulted in job losses and increased food inflation. News 24, ENCA2015.

Box 1: Free State declared disaster area as drought continues

Table 3.1: Relevant climate variables

Variable	Description and/or units
Average temperature	°C
Very hot days	A day when the maximum temperature exceeds 35°C. Units are number of events per grid point per year.
Heat-wave events	The maximum temperature exceeds the average temperature of the warmest month of the year by 5°C for at least 3 days.
High fire-danger days	McArthur fire-danger index exceeds a value of 24. Units are number of events per grid point per year.
Average Annual Rainfall	mm
Extreme rainfall Type I event (also a proxy for lightning)	More than 20 mm of rain falling within 24 hrs over an area of 50 x 50 km^2. The occurrence of extreme convective rainfall is used as a proxy for the occurrence of storms that produce lightning. Units are number of events per grid point per year.
Dry-spell	Five or more consecutive days without rainfall (units are number of days per grid point per year)

The changes below are presented for Free State Province, summarised in Table 3.2, for the baseline period 1970-2000, and the future time slab of 2020-2050.

Table 3.2: The Summary of projected changes in climate variables mid- term (2020-2050)

Climate Variable	Current (1970-2015)	Medium term (2020-2050) under high mitigation	Medium term (2020-2050) under low mitigation
Average temperature	29.5°C	+ 1.6°C new average 31.1°C	+ 2.3°C new average 31.8°C
Very hot days	88	+ 41.1 new total 121.1	+ 54.15 new total 142.15
Heat-wave events	13.9	+ 14.7 new total 28.6	+17.5 events new total 31.4

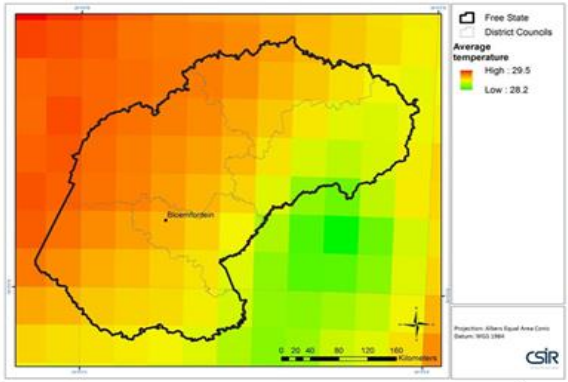
High fire-danger days	145	+ 57.4 new total 202.4	+ 74.1 new total 219.1
Average annual Rainfall	527mm	+ 25.07 - 112.2mm	+ 35mm / -65.9mm
Extreme rainfall events (lightning & thunder storms)	22.8	+ 0.27 (the increase is below 1)	+ 0.23 (the increase is below 1)
Dry-spell days	93.5	+ 11.5 new total 105	+ 18.6 new total 112.1

Rapid rises in the annual-average near-surface temperatures are projected to occur over Southern Africa during the 21st century. Temperatures over the South African interior, which includes Free State, are projected to rise at approximately 1.5 to 2 times the global rate of temperature increase (Engelbrecht et al., 2015). The drastic changes in temperature are associated with increases in other climate variables such as very hot days, and the increase in the number of very hot days occurs in association with a projected increase in the annual frequency of heat-wave days and high fire-danger days, especially over the western grasslands of the province. Heat-wave days are associated with prolonged periods of oppressive temperatures, which will have detrimental impacts on human and animal health and crop yield, and are conducive for the occurrence of veld and forest fires.

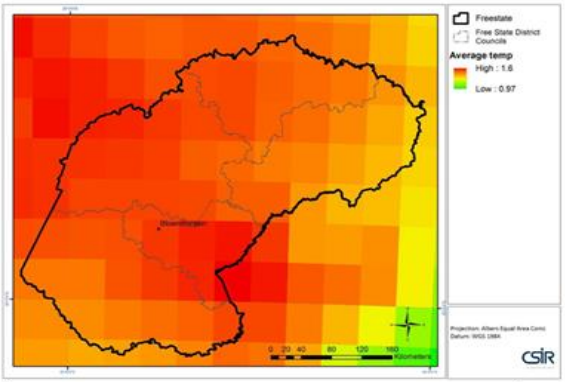
The in-depth analysis of climate variables under the different climate change scenarios (low and high mitigation) are presented below with maps highlighting only the worst case (low mitigation) and the best case (high mitigation) over Free State. The following maps show the current climate and projected changes in the different climatic variables under low and high mitigation scenarios.

3.3.1 Average Temperatures

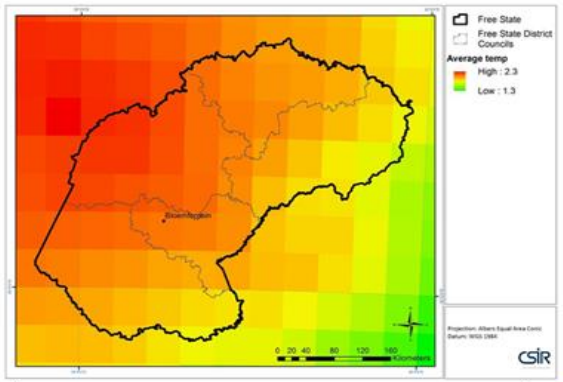
The model-simulated annual average temperatures (°C) are displayed in Figure 3.1a for the baseline period 1971-2000. The hottest regions are the western parts of Free State with high average temperatures of 29.5°C in the west and low average temperature of 28.2°C in the eastern areas of the province.



Figure·3.1a:·Average·Temperature·baseline·period·1970-2000¶



Figure·3.1b:·Average·Temperature·for·period·2020-2050:·RCP·4.5·High·Mitigation¶



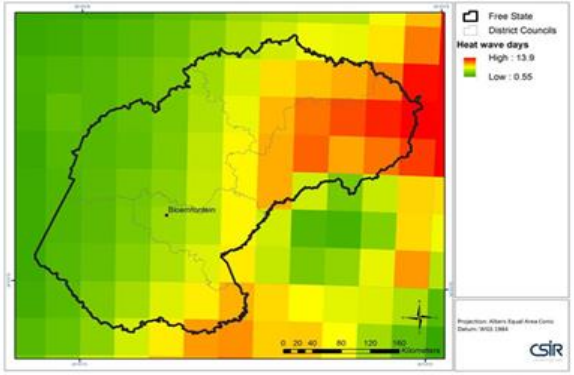
Figure·3.1c:·Average·Temperature·for·period·2020-2050:·RCP·8.5.·Low·Mitigation¶

Figure 3.1: Average temperature for the base period (1970-2000) and projections for Free State province (2020 – 2050) under high and low mitigation scenarios

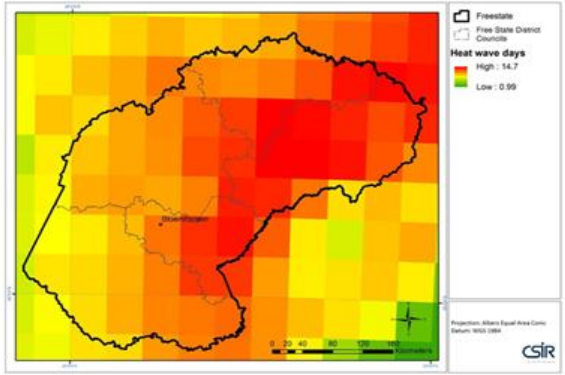
- Under high mitigation, temperature increases over the Free State province will be somewhat less, between 0.97 to 1.6°C increases with high increases in the western part of the province (Figure 3.1 b).
- For the period 2020-2050 relative to the period 1971-2000, temperature increases of 1.3 – 2.3 °C are projected to occur over the Free State under low mitigation (Figure 3.1 c).
- By the end of the century, temperature increases of 4 to 7 °C are projected to occur over the Free State province under the RCP8.5 scenario (map not shown).

3.3.2 Heat Wave Events

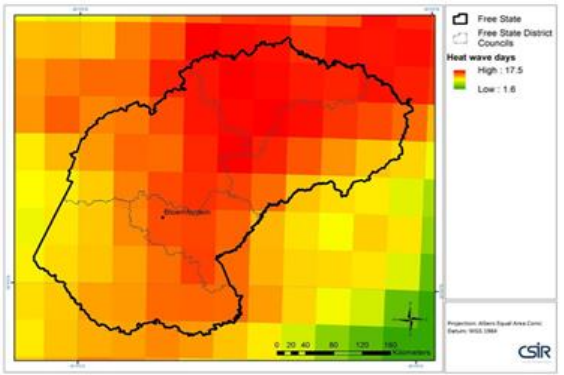
A heat-wave is defined as an event when the maximum temperature at a specific location exceeds the average maximum temperature of the warmest month of the year at that location by 5°C, for a period of at least three days. Heat-waves are rare in the Free State. The highest heat-wave day frequencies occur over the eastern parts of the province.



Figure·3.2a:·Heat·Wave·Events·baseline·period·1970-2000¶



Figure·3.2b:·Heat·Wave·events·for·period·2020-2050:·RCP·4.5·High·Mitigation¶



Figure·3.2c:·Heat·Wave·Events·for·period·2020-2050:·RCP·8.5.·Low·Mitigation¶

Figure 3.2: Heat wave days for the base period (1970-2000) and projections for Free State (2020 – 2050) under high and low mitigation scenarios

- The model-simulated annual-average numbers of heat-wave days (units are number of days per model grid point) are displayed in Figure 3.2a, for the baseline period 1971-2000. The high numbers of heat wave days are recorded at 13.9 days.
- In association with drastically rising maximum temperatures (Figure 3.2 b), the frequency of occurrence of heat-wave days is also projected to increase drastically under climate change.
- For the period 2020-2050 relative to 1971-2000, under low mitigation, heat-wave days may increase by as much as 17.5 days, resulting in overall increases of 28 days per year over large parts of Free State (Figure 3.2 c).
- Even under high mitigation, the increase in the number of heat-wave days may reach 14.7 days or more over the eastern parts of the province (Figure 3.2b).
- Increases in the occurrence of heat-wave days occur in association with projected changes in the frequency of very hot days and high fire-danger days.

3.3.3 Very Hot days

The model-simulated and bias-corrected annual average number of very hot days (days when the maximum temperature exceeds 35°C, units are number of days per model grid point).

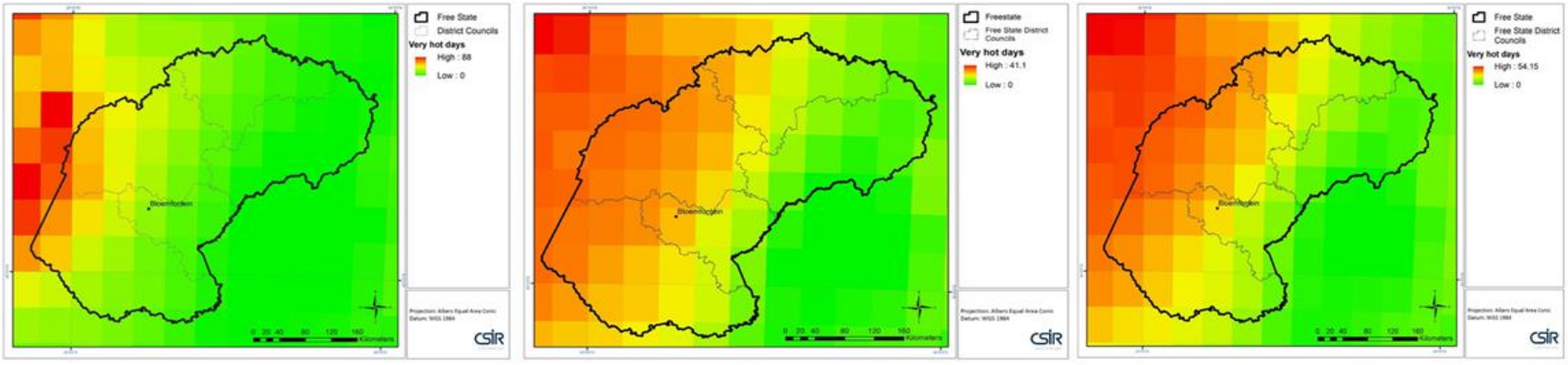


Figure 3.3a: Very Hot Days baseline period 1970-2000

Figure 3.3b: Very Hot Days for period 2020-2050: RCP 4.5 High Mitigation

Figure 3.3c: very Hot Days for period 2020-2050: RCP 8.5. Low Mitigation

Figure 3.3: Very hot days for the base period (1970-2000) and projections for Free State (2020 – 2050) under high and low mitigation scenarios

- The number of very hot days for the baseline period 1971-2000 is 88 (Figure 3.3a) occurring over the western Free State, on average annually.
- For the period 2020-2050 relative to 1971-1990, under low mitigation, very hot days are projected to increase by as many as 54.15 days per year in the western part of the Free State (Figure 3.3c). More modest increases are projected for the eastern parts.
- Even under high mitigation, the increase in the number of very hot days may be as high as 41.1 days over the western Free State (Figure 3.3b).
- Increases in the occurrence of very hot days occur in association with projected changes in the frequency of occurrence of heat-wave days and high fire-danger days.

3.3.4 High Fire danger days

The model-simulated annual average number of high fire-danger days is displayed in Figure 4a, for the baseline period 1971-2000. Over the western grasslands of the Free State, 146 high fire-danger days occur on the average per year.

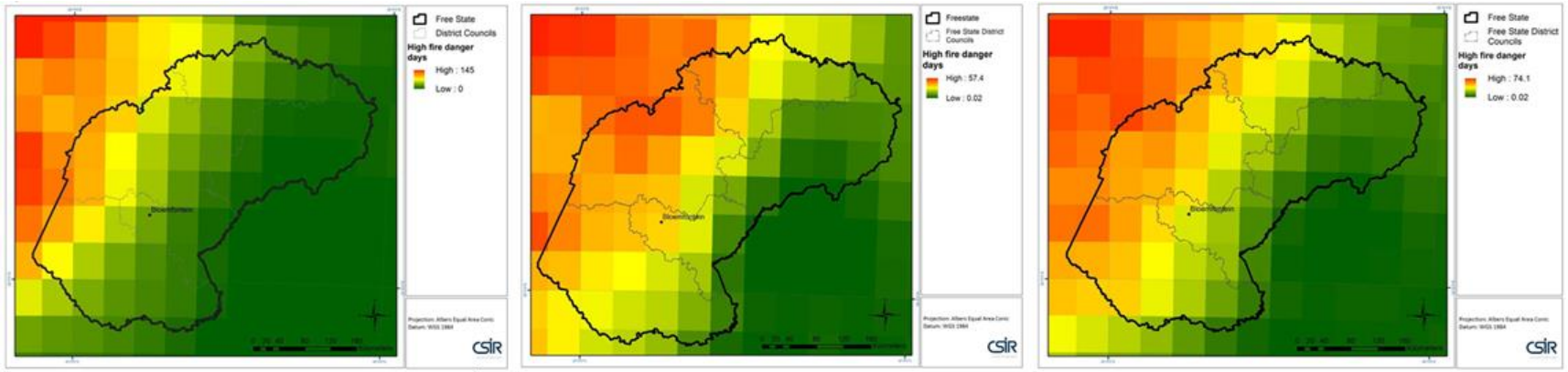


Figure 3.4a: High Fire Danger Days baseline period 1970-2000

Figure 3.4b: High Fire Danger Days for period 2020-2050: RCP 4.5 High Mitigation

Figure 3.4c: High Fire Danger Days for period 2020-2050: RCP 8.5. Low Mitigation

Figure 3.4: High fire danger days for the base period (1970-2000) and projections for Free State (2020 – 2050) under high and low mitigation

- In association with drastically rising temperatures, the frequency of occurrence of high fire-danger days is also projected to increase drastically under climate change.
- For the period 2020-2050 relative to 1971-2000, under low mitigation, it is plausible that high fire-danger will increase by 74 days per year (or more) over the western Free State grasslands (Figure 3.4c).
- Even under high mitigation, the increase in the number of high fire-danger days may approach 57 days over the western parts of the province (Figure 3.4b).
- Increases in the occurrence of high fire-danger days occur in association with projected changes in the frequency of occurrence of heat-wave days and high fire danger days.

3.3.5 Total Rainfall

The model-simulated annual average rainfall totals (mm) are displayed in Figure 3.5a, for the baseline period 1971-2000, showing highs of 527mm and low of 431 mm. There is a pronounced west-east rainfall gradient over the country, which also extends over Free State. Uncertainty surrounds the projected rainfall future of Free State.

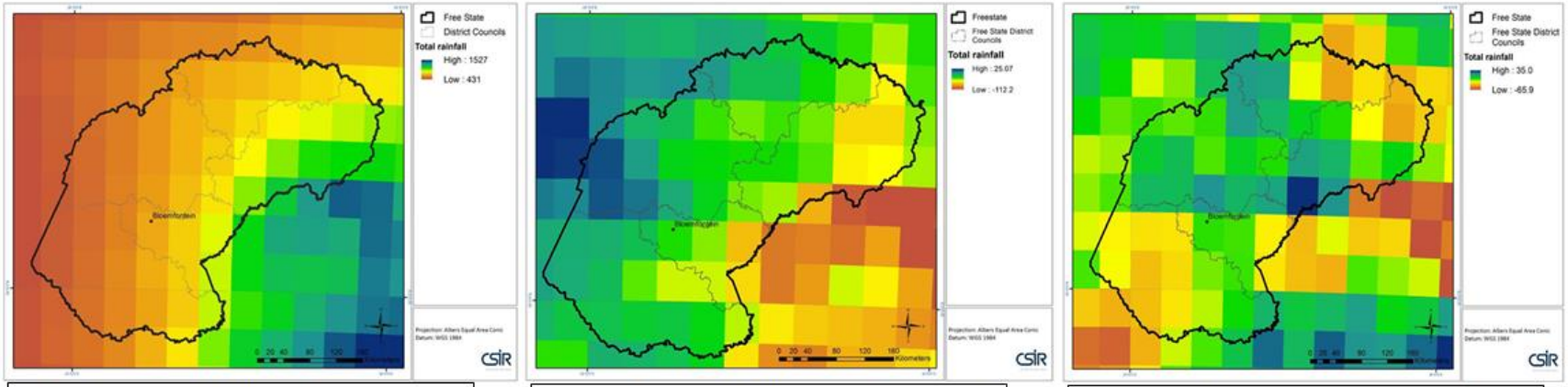


Figure 3.5a: Total rainfall- baseline period 1970-2000

Figure 3.5b: Total rainfall for period 2020-2050: RCP 4.5 High Mitigation

Figure 3.5c: Total rainfall for period 2020-2050: RCP 8.5. Low Mitigation

Figure 3.5 Rainfall for the base period (1970-2000) and projections for Free State (2020 – 2050) under high and low mitigation scenarios

- For the period 2020-2050 relative to the period 1971-2000, under low mitigation rainfall is projected to decrease significantly (more than 35 mm per year) by some ensemble members, whilst others project rainfall increases of more than 40 mm per year (Figure 3.5c).
- The projected changes in rainfall patterns under high mitigation are very similar to the patterns projected under low mitigation, with highs of 25 mm (Figure 3.5b).
- The projected changes in rainfall patterns over Free State in the ensemble of downscalings described here, and more generally in AR4 and AR5 projections, display more uncertainty than in the case of projected changes in temperature.

This implies that adaptation policy makers need to take into account a range of different rainfall futures, often of different signals (i.e. drier and wetter) during the decision making process.

3.3.6 Extreme Rainfall Events

The model-simulated annual average extreme rainfall event frequencies (units are number of events per model grid box per year) are displayed in Figure 6 a, for the baseline period 1971-2000. Here an extreme rainfall event is defined as 20 mm of rain occurring within 24 hours over an area of 50 x 50 km^2).Over the eastern parts of the province up to 16 extreme rainfall events occur annually on average.

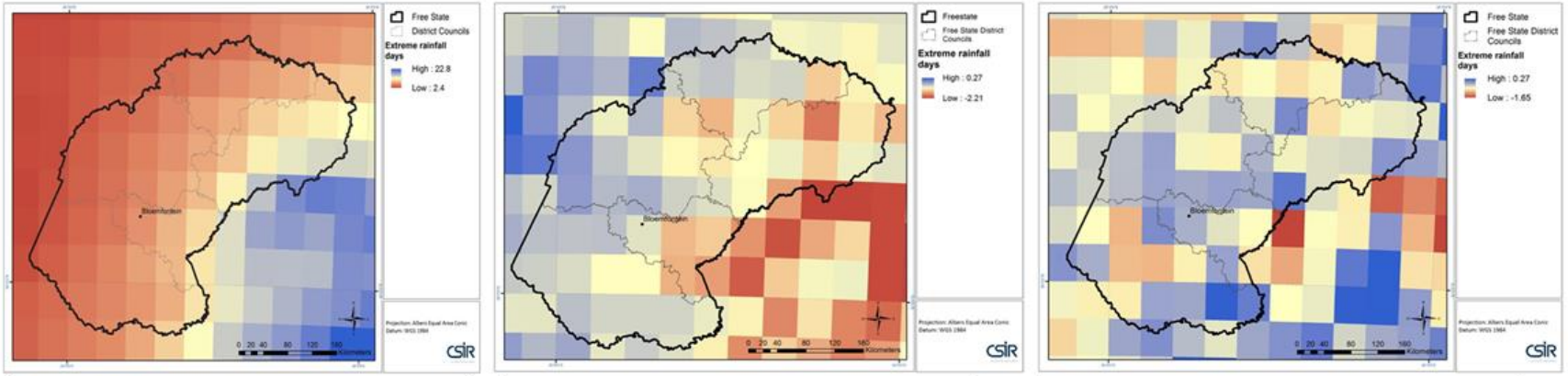


Figure 3.6a: Extreme Rainfall Events - baseline period 1970-2000

Figure 3.6b: Extreme Rainfall Events - period 2020-2050: RCP 4.5 High Mitigation

Figure 3.6c: Extreme Rainfall Events - period 2020-2050: RCP 8.5. Low Mitigation

Figure 3.6: Extreme rainfall days for the baseline period (1970-2000) and projections for Free State (2020 – 2050) under high and low mitigation scenarios

- Extreme rainfall events are projected to decrease in frequency over Free State under low mitigation, for the period 2020-2050 relative to 1971-2000, by most ensemble members (Figure 3.6c).
- A minority of ensemble members project increases in extreme rainfall events over Free State (Figure 3.6c).
- The projected changes in extreme rainfall events under high mitigation are very similar to the patterns projected under low mitigation (Figure 3.6b).

  Extreme rainfall events are mostly caused by intense thunderstorms, which are often also the cause of lightning, hail, damaging winds and flash floods. The climate change projections analysed here are indicative that decreases in these events are plausible over most of Free State while, a minority of ensemble members indicate increases in such events.

3.3.7 Dry Spell Days

In this context a dry spell is defined as a period of five consecutive days without rainfall (or a longer dry period) occurring over an area of 50 x 50 km^2. The days that constitute a dry spell event are termed “dry spell days”. South Africa receives seasonal rainfall over most of the country, implying that most locations experience a dry season exhibiting many dry spell days. The dry spell day gradient over South Africa resembles the rainfall gradient.

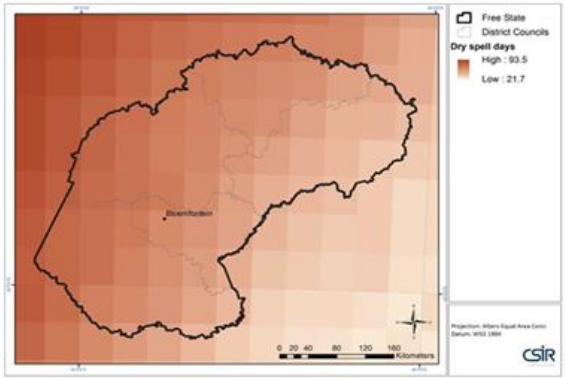


Figure 3.7a: Dry Spell Days - baseline period 1970-2000

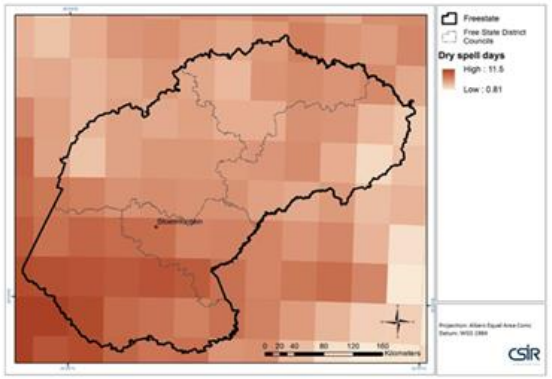


Figure 3.7 b: Dry Spell Days - period 2020-2050: RCP 4.5 High Mitigation

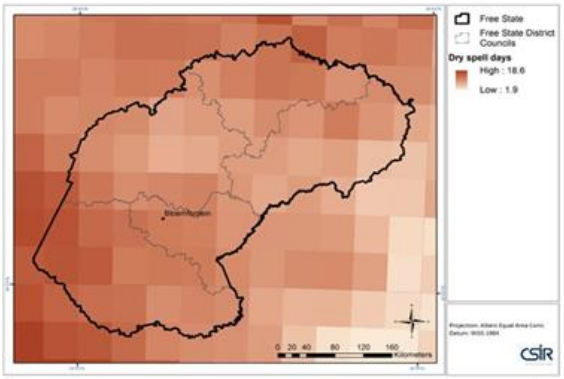


Figure 3.7 c: Dry Spell Days - period 2020-2050: RCP 8.5. Low Mitigation

Figure 3.7: Dry spell days for the base period (1970-2000) and projections for Free State (2020 – 2050) under high and low mitigation scenarios

- The model-simulated annual average dry-spell day frequencies (units are number of days per model grid box per year) are displayed in Figure 3.7a for the baseline period 1971-2000 and are recorded at 93 days.
- The ensemble of downscalings is robust in projecting an increase in dry spell days over Free State for the medium term period 2020-2050 relative to 1971-2000, under low mitigation (Figure 3.7b).
- The projected changes in dry spell day frequencies under high mitigation are very similar to the patterns projected under low mitigation (Figure 3.7c).

Other climate variables such as dust storms, frost and snow also affect the province. While these were not directly modelled for this project the following descriptions and assumptions have been given:

- ***Dust storms*** *– Dust storms are normally caused by thunderstorms. Indirect projections of dust storms can be provided through examining the projections of thunderstorms and the chances of them causing or resulting in dust storms. Given the projected increase in the occurrence of thunderstorms, dust storms are expected to increase, albeit slightly.*
- ***Snow and frost*** *– Snow and frost can also be projected indirectly by looking at their linkages with temperature changes. Where drastic drops in temperature are expected, snow and frost may be plausible. The most anticipated change is increase in temperature, not decrease, and therefore snow and frost are not likely to increase.*

3.4 Conclusion

Drastic climatic changes and impacts anticipated by the turn of the century, under both high and low mitigation scenarios will negatively affect Free State's economy. Temperature increases are expected across the province with the highest increases in the western areas - 1.6°C and 2.3°C under high and low mitigation scenarios respectively for the medium term in comparison to the baseline period. The increases in temperatures will directly influence the increases in other climate variables such as heat wave days, very hot days and high fire danger days across Free State. The rainfall variability expected for the province as well as the extreme weather events such as dry spell days, contribute evidence towards an increased drying trend being experienced in the province.

The projected changes in climate variables discussed in this chapter will contribute directly to the exposure of the different sectors in Free State to climate variability and change and the consequences of that exposure. The next chapter will highlight the impacts of the projected climatic changes on the different sectors in Free State which include agriculture, biodiversity, tourism, mining, health, human settlements, build environment (infrastructure) as well as social. The impacts of climate on cross-cutting sectors such as water are also discussed. The risk and vulnerability assessments of the sectors will contribute to the development of the Free State adaptation strategy which will focus on planning responses to the impacts of climate change on the sectors that are vulnerable to the negative impacts of the projected climate variables.

4 Climate Risks and Vulnerability Assessment

The vulnerability assessment framework used in this report defines vulnerability as a function of three elements: exposure, sensitivity (potential impacts), adaptive capacity (and vulnerability of the entity or system (which could be a population, ecosystem or sector affected by climate change)) (Table 4.1 and Figure 4.1). Vulnerability is generally understood as a function of a range of biophysical and socio-economic factors.

Table 4.1: Vulnerability Assessment Framework (Allen Consulting, 2005)

Exposure	***Sensitivity***	***Adaptive Capacity***
Whether a built, natural or human system is likely to face change and if so, the magnitude and rate of change is assessed based on projections.	Whether a built, natural or human system is directly or indirectly affected by or susceptible to changes in climate conditions (such as temperature and rainfall) or specific climate change impacts such as sea level rise, or increased water temperature. If a system would undergo changes as a result of climatic changes and variability, it is considered sensitive to climate change.	Whether a system has the ability to adjust to climate variability and change, across the range from extreme events to moderate potential damages, to take advantage of opportunities, or cope with the consequences.

The interaction of the three components of vulnerability can be illustrated as shown in Figure 4.1 below.

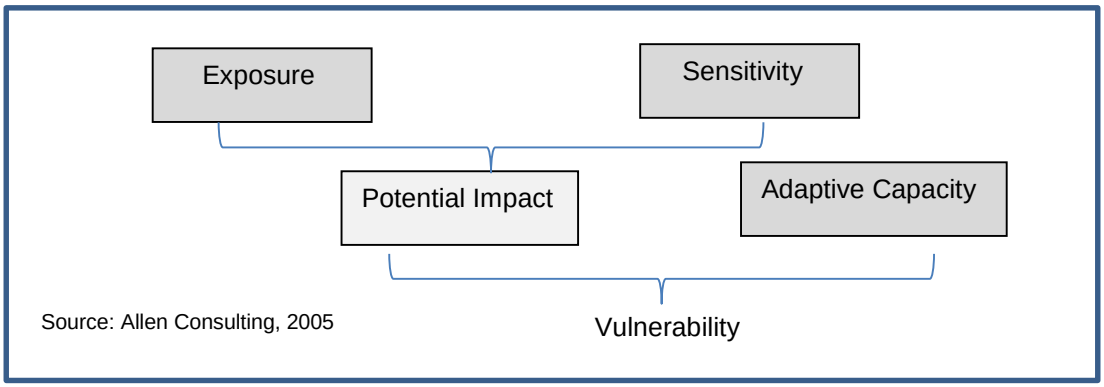


Figure 4.1: Assessment framework: step-based approach to assess vulnerability in each of the sectors highlighting relationships between components of vulnerability

Vulnerability assessments collate, evaluate and summarise what is known nationally and locally, and identify what is unknown about the ways in which a system, sector, or population will be affected by climate change. The Vulnerability Matrix used in this chapter was based on a qualitative analysis of the climate variables. The impacts of the projected climatic changes are based on the extensive work done under the LTAS, as well as other province specific studies carried out to investigate the sector impacts of climate change.

Exposure was based on the understanding of whether the systems in question (for example, agriculture, water, or biodiversity) will be affected by projected changes in climate variables such as temperature, rainfall and extreme weather events, as illustrated in Chapter 3 on projections for Free State. The magnitude and rate of exposure were calculated based on the future projections presented in Chapter 3. Increases in average temperatures above 30°C were considered to be high. Any projections that indicated reduced rainfall, and increase in extreme events, would result in exposure to the systems in question being high. Given that the projected changes in temperature across the province will be above 30°C, the exposure across the province in terms of temperature will be high.

Sensitivity was based on the understanding of how resilient the system is to changes in climate variables as well as the current physical state and location of the systems in question, which increases or reduces their sensitivity to climatic changes.

Adaptive Capacity was based on information about what the different sectors of the provincial government are currently doing to adapt or reduce their vulnerability to climate change. Where policies and institutional or legal instruments, finance and capacity are available, the adaptive capacity is ranked as medium, however their presence does not guarantee that action is taking place. In sectors where there are known adaptive actions taking place, for example agriculture, the adaptive capacity is recorded as high.

This chapter discusses the vulnerability assessment based on changes in temperatures, rainfall and extreme weather events as described in the climate science model projections in Chapter 3. The exposure, which is directly linked to the projected climate variables, and sensitivity of each of the Free State sectors are assessed to determine the level of risk. The adaptive capacity of the various sectors is also analysed to determine the level of vulnerability for the sectors and population groups in the province. The sectors assessed in this report are listed in Table 4.1 below.

Table 4.1: Sectors assessed for climate change vulnerability in the Free State Province

SECTOR	SUB SECTOR
Water Resources	Surface Water (Rivers and Dams) Groundwater
Biodiversity	Terrestrial Ecosystems Wetland Ecosystem
Agriculture	Crop Farming and Horticulture Livestock
Economic	Tourism Mining Energy Transport

Built Environment and Human Settlements	Infrastructure (Water) Human Settlements (Urban, Rural and Informal)
Social and Human Health	Human Health Livelihoods Economic Status

The subsequent risk and vulnerability assessment based on feedback from the monitoring and evaluation process will ensure currency of priorities for concern and action.

4.1 Water Resources

Free State, like the rest of South Africa is a water stressed province and faces numerous challenges regarding the management of this scarce resource, especially for its substantial agricultural sector. The province has to contend with climate change and variability which affect availability, quality and quantity of both surface water and groundwater. The extensive system of rivers, dams and wetlands contribute to water availability and quality, with wetlands playing a key role in the purification and retention of surface water. Groundwater provides an additional valuable source of fresh water used for livestock and human consumption in some rural and remote towns in the province. Key economic sectors in the province that will be impacted by water shortages include Agriculture (reduced water availability for rain fed agriculture, irrigation and livestock); Human Health (malnutrition, sanitation, spread of diseases); Tourism (human consumption, facilities etc.) and Biodiversity (increased demand for water by plants and animals).

4.1.1 Surface Water (Rivers and Dams)

The main sources of surface water in Free State are the Orange and the Vaal River and their tributaries. The Orange River and its sub-catchments comprise of the Upper and Lower Orange catchment areas, and the Upper, Middle and Lower Vaal river catchment management areas. A number of dams store water for human consumption, electricity generation and irrigation. These include the Bloemhof, Gariep, and Vanderkloof dams. In the Upper Vaal Water Management Area (WMA), a total of eight dams are found, including the Vaal and the Sterkfontein Dams. The rivers and dams of Free State support economic activities such as agriculture, mining and human consumption and also supply other parts of the country beyond Free State (Free State SDF, 2013). Some of the implications of climate change on water resources in Free State, including groundwater resources and wetlands is presented in Table 4.2 below.

4.1.1.1 Water Pollution

The vast water resources of Free State are affected by pollution, particularly from mining and agricultural activities. Human waste also contributes to pollution of rivers, especially in areas where sanitation systems are not up to date or unavailable. Water pollution due to mining activities affects neighbouring provinces that rely on the same water sources. The projected changes in climate and climate variability will exacerbate the already strained water resources and introduce new challenges as a result of variability and extreme weather events such as droughts and floods, changing rainfall seasons as well as the overall increase in temperatures (DEA, 2013c). The demand for water, for all economic sectors as well as human consumption is expected to increase as a result of increases in temperature. The uncertainty in the projection of rainfall, which is expected to increase or decrease under different climate scenarios will exacerbate the future planning for the management of water resources in the province.

Table 4.2: Some of the implications of climate change on water resources in Free State, including groundwater resources and wetlands (LTAS, 2013)

Scenario	Limpopo/ Olifants/ Inkomati	Pongola-Umzimkulu	Vaal	Orange	Mzimvubu-Tsitsikamma	Breede-Gouritz/ Berg
1: warmer/ wetter	↑ spring and summer	↑ spring	↑ spring and summer	↑ in all seasons	↑ in all seasons	↓ autumn, ↑ winter and spring
2: warmer/drier	↓ summer, spring and autumn	↓ spring and strongly ↓ summer and autumn	↓ summer and spring and strongly ↓ autumn	↓ summer, autumn and spring	↓ in all seasons, strongly ↓ summer and autumn	↓ in all seasons, strongly ↓ in the west
3: hotter/wetter	Strongly ↑ spring and summer	Strongly ↑ spring	↑ spring and summer	↑ in all seasons	Strongly ↑ in all seasons	↓ autumn, ↑ winter and spring
4: hotter/ drier	Strongly ↓ summer, spring and autumn	↓ spring and strongly ↓ summer and autumn	↓ summer and spring and strongly ↓ autumn	↓ summer, autumn and spring	↓ all seasons, strongly ↓ in summer and autumn	↓ all seasons, strongly ↓ in the west

Vulnerability assessments show that the Lower Orange catchment area, which covers the smallest area in the province, will be extremely vulnerable to temperature change. The climate change projections indicate that temperatures in this catchment will increase at twice the national rate with detrimental impacts, particularly on the agricultural sector. The Vaal covers a substantial area in Free State with the catchment being divided into the lower, middle and upper Vaal water management areas.

Table 4.3 highlights the sensitivity, exposure and adaptive capacity as well as the level of vulnerability for the surface water sector to the projected climate variables of the surface water including the rankings. Climatic variables cover current trends and projections that will affect the different aspects of this sector. Climate projections for the Vaal indicate that rainfall will either remain unchanged or increase, while the mean annual temperatures are expected to increase but not radically.

Table 4.3: Vulnerability assessment for Free State surface water sector to the projected climate variables; highlighting exposure, sensitivity, adaptive capacity and vulnerability rankings

Projected Climate Variables	Exposure	Sensitivity	Current Adaptive Capacity	*Vulnerability*
Ranking	**High**	**High**	**High**	***High***
• **Average Temperature**	Between 31.2°C-31.9°C.	• Increased evaporation rates and water losses especially from the Lower Orange catchment. • Decline in water availability and quality • Increased spread of invasive species which favour higher temperatures and consume more water. • Drying of wetlands will affect water quantity and quality as well as loss of ecosystem services. • Increased water demand by plants, animal and humans will reduce water availability.	Strengths • The presence of water boards and water service providers for the management and distribution of water resources in the province. • Drought relief programmes targeting farmers are being conducted by national government and the province. • Budget allocated for water infrastructure through the Urban Settlement Development Grant (USDG). • Local municipality structures that are responsible for service delivery in place. • FS water quality forum – produce monthly report for municipalities. • Water Sector Authorities for the management of water resources. • Alien invasive species removal project is currently underway in the province. • Drought response projects in the province include: ○ Surface water resource management (operation of Caledon and Orange River System optimised). ○ Water conservation and water demand management (War on Leaks) ○ Re-use of water (Mangaung Metropolitan Municipality). ○ Eradication of invasive alien plants/catchment care (WfW). ○ Eradication of illegal water use (Enforcement in the Caledon and Orange River System).	• The vulnerability of surface water resources is regarded as **high**. The demand for water, for all economic sectors as well as human consumption is expected to increase as a result of increases in temperature. The uncertainty in the projection of rainfall, which is expected to increase or decrease under different climate scenarios will exacerbate the future planning for the management of water resources in the province.
• **Changes in rainfall**	• **Under high mitigation** +25.07mm / -112.2mm. • **Under low mitigation** + 35mm / - 65.9mm.	• Decrease in rainfall and increase in extreme weather events such as dry spells and very hot days can lead to increased demand for irrigation and for livestock. • Decrease in rainfall and consequently water availability can result in increased cost of water. • Increased rainfall enhances the threat of groundwater pollution from acid mine drainage and economic activities such as agriculture and from human settlements.		

• **Extreme events per year** (e.g. floods, dry spells, high fire danger days, heat waves, droughts)	• Very hot days to increase to between 121.1-142.15 per year. • Heat wave events to increase to between 28.6-31.4 events/year. • High fire danger days to increase to between 202.4- 219.1 days. • The increase of extreme rainfall events is less than 1. • Dry spell days to increase to between 105-112.1 days.	• Decrease in rainfall and increase in extreme weather events such as dry spells and very hot days can lead to increased demand for irrigation and for livestock.	○ Development of surface water resources, investigation of raising dam walls. ○ Transfer of water (LHWP Ph2, investigation of emergency transfer from Sterkfontein to Fika Patso). ○ Household rainwater harvesting (provision of tanks in selected areas). ○ Early warning monitoring of water services. **Challenges** • Pollution and degradation of the Vaal River from mining activities, irrigation, agriculture, power generation and sewage effluents. • High demand for energy generation • Several municipalities in the province experience water shortages. • Maintenance of bulk water infrastructure to be strengthened. • Failure to notify residents of impending water shortages and possible contamination.	

4.1.2 Groundwater

Each of the water catchments in the province contributes to groundwater recharge. Groundwater resources play a crucial role in the province with a myriad of uses from human consumption, especially domestic supply in rural and small towns where bulk water is not financially sustainable or inadequate (DETEA, 2009). Groundwater is also used as a source of water for livestock. Another crucial use of groundwater is the dewatering of dolomite segments in the mining sector especially in areas where gold ore underlies dolomite.

It is important to note that an increase in groundwater abstraction will reduce surface spring water flow and availability given the direct link between dolomite aquifers and surface water. The reduction in the spring flow may possibly result in the formation of sinkholes. In addition, groundwater resources in the province are facing issues of contamination from mining and agricultural activities.

Table 4.4 presents a vulnerability assessment of groundwater resources in Free State, covering exposure, sensitivity of these resources to the projected climate variables; as well as the adaptive capacity and the resultant vulnerability rankings.

Water is one of the cross sectoral sectors that will have wide ranging impacts on all the social and economic as well as biological systems in the province. The worst affected sectors in the province will be agriculture as well as subsistence livelihoods, and sectors such as mining, which is highly dependent on water. The projected rainfall variability will only exacerbate the already dire water situation in the province.

The recent drought, which had resulted in low dam levels, had increased pressure on groundwater, with more towns in the province depending on it. The resource is not enough to supply the farms in surrounding towns. This has resulted in over-exploitation and drying of some of the boreholes in the province (FS DARD, 2012).

Table 4.4: Vulnerability assessment for Free State groundwater sector to projected climate variables; highlighting exposure, sensitivity, adaptive capacity and vulnerability rankings

Projected Climate Variable	Exposure	Sensitivity	Current Adaptation Options	*Vulnerability*
Ranking	**High**	**High**	**Medium**	***High***
Average Temperature	• Between 31.2°C - 31.9°C.	The projected increase in temperature will result in the following: • Increase evaporation rates from groundwater. • Decreased availability of groundwater and poor groundwater quality. • Increased demand for water for human consumption and from plants will put pressure on groundwater resources.	**Strengths** • At national level the National Groundwater Strategy (2016) is being finalised to enhance the use and protection of groundwater resources in SA. • At national level there is an Integrated Water Management Strategy. • Other legislation which include National Water Act, water Act. • Optimisation of the water monitoring network (rivers, boreholes, water quality). • Reconciliation strategies for the sector have been developed. • Availability of infrastructure grants for upgrade and maintenance. • River Health Programme. • Community cohesion programmes initiatives to cope with water shortages resulting from droughts such as schools providing water to communities. • Managing and use of groundwater resources - drilling and equipping additional boreholes as part of the drought response plan. **Challenges** • Groundwater previously not very well managed in the province. • Over-exploitation of groundwater resources in rural areas and small towns. • Pollution of groundwater from mining, agriculture, human waste.	• The vulnerability of groundwater resources is regarded as **high**. While groundwater resources have not been well managed in the past, the recent legislation as well as the inclusion of groundwater resources in the drought response plan and other initiatives at provincial levels reduces vulnerability. • However the recent drought has resulted in the over exploitation of the resource with boreholes drying up and an increase in the number of towns solely dependent on groundwater. This makes it highly vulnerable.
Annual Average Rainfall	• **Under high mitigation** +25.07mm / -112.2mm. • **Under low mitigation** + 35mm / -65.9mm.	The projected decrease in rainfall will result in the following impacts on the groundwater resources in the province: • Decreased groundwater flow and storage. • Decrease in water availability that may result in increased cost of water • Less rainfall impacts on groundwater recharge. • Impacts on groundwater recharge, storage as well as groundwater quality. • Increased use of groundwater during droughts and dry spells. • Pollution of groundwater sources by organic matter, pesticides and heavy metals especially where recharge aquifers are present as a result of intense storms.		
Extreme events per year (e.g. floods, dry spells, high fire danger days, heat waves, droughts)	• Very hot days to increase to between 121.1- 142.15 per year. • Heat wave events to increase to between 28.6-31.4 events/year.	• Increases in extreme weather events such as dry spells, very hot days and high fire danger days can lead to increased demand for irrigation with groundwater as well as for human consumption.		

	• High fire danger days to increase to between 202.4-219.1 days. • The increase of extreme rainfall events is less than 1. • Dry spell days to increase to between 105- 112.1 days.	• Increased rainfall from flooding will enhance the threat of groundwater pollution from acid mine drainage and economic activities such as mining and human waste.	• Human and financial resources constraints. • Procurement policies red tape.	

The water sectors, both surface and ground are categorised as having high vulnerability to climate change based on high exposure and high sensitivity, and despite the current high adaptive capacity, attributed in part to the current drought response plan that is in operation in the province. While the projected decreases in rainfall and increases in temperature will serve to affect water availability and quality, adaptation options that seek to increase water storage will assist with improved water availability. However, given the importance and the anticipated increased demand of water for agriculture, mining as well as human well-being, water continues to be a critical resource for the development of the province and a priority for adaptation.

4.1.3 Prioritisation of Adaptation options in the water sector

- Water conservation and water demand management (War on Leaks)
- Surface water resource management (Optimised the operation of the Caledon and Orange River System)
- Managing and use of groundwater resources (drilling and equipping additional boreholes)
- Re-use of water (Mangaung Metropolitan Municipality)
- Eradication of invading alien plants/catchment care (WfW)
- Eradication of illegal water use (Enforcement in the Caledon and Orange River System)
- Development of surface water resources, investigation of raising dam walls
- Transfer of water (LHWP Phase 2, investigation of the emergency transfer Sterkfontein to Fika Patso)
- Rainwater harvesting (provision of tanks in selected areas)
- Early warning monitoring of water services (Monday/Wednesday and Friday)

4.2 Agriculture

The Free State agricultural sector is the economic backbone of the province and similarly to the national agricultural sector, is made up of crop and animal production, horticulture, dairy farming, game farming, aquaculture, fruit production and agro-processing. It is estimated that at least 14.5% of South Africa's commercial farming is conducted in this province, which is approximately 90% of the economy of the province. Agriculture is essential to the well-being of Free State, both as the provider of food and as an employer. Major crops are maize, soy beans, wheat, sorghum, sunflowers, potatoes, groundnuts and wool. The main vegetable is asparagus, both the green and white varieties. Agricultural produce from Free State such as horticultural and floricultural products are exported to markets in Europe. Box 2 below highlights some of the important facts and figures regarding the contribution of the agriculture sector to both the Free State and South African economies. Table 6 below highlights the areas in the province where some of the agricultural activities are taking place.

A myriad of climate and non-climatic factors affect agriculture in Free State Province but this section will focus only on the climatic factors. Rainfall variability presents a fundamental risk to agriculture, in particular in the intermediate areas that are affected by different seasonality and the varying amounts of rainfall. These areas are sensitive and vulnerable to changes in climate. Temperature is another critical factor for agriculture, affecting a wide range of agricultural processes and is expected to increase with global warming (DEA, 2013a). The projected increases in temperature and water availability are expected to impact negatively on crop yields, including maize, sorghum, wheat and soya beans, all of which are important to Free State, with decreases in yield of up to 25% for maize and wheat predicted but with a possible increase of 10% under unconstrained emission scenarios (DEA, 2013a). The changes in climate will bring about a myriad of additional challenges for the agriculture sector in terms of production, agro-processing and farm

labour as evidenced by the current drought. This drought has been as a result of the lowest rainfall received in the province in the last 112 years.

The current drought brought to the fore the seriousness of the dependency of agriculture on rainfall and water availability for irrigation and as a result there was a drastic reduction in the production of field crops across the province. The failure of crop production has resulted in unemployment as farmers have been forced to lay off people.This situation has been compounded by the lack of access to credit for commercial farmers. In addition, due to low dam levels, not all farmers had access to water for irrigation in the last season (FS DARD, 2012).

Climate change will also have some positive impacts on the agriculture sector. Increases in temperature may result in the expansion of areas suitable for crops such as sorghum. These changes may also increase the growing period for some crops resulting in increased yields. Changes in temperature may also positively affect over-wintering of livestock, thereby reducing the cost of de-wintering. Livestock farming is a big industry in Free State Province. Box 2 provides a summary of facts and figures on the agriculture sector in Free State Province (Complied by the CSIR, 2016).

Free State Agriculture - Facts and figures

- The Free State province has 7,515 farming units, the highest in the country.
- The Free State accounts for 26.4% of South Africa's field crops and 15.9% of all its animals.
- The Free State is responsible for 15% of South Africa's gross agricultural income.
- The agriculture sector contributes approximately 7% to the provincial gross domestic product.
- 90% of the province is agricultural land, with 32% of 11.6-million hectares classified as arable and 60% suitable for pasture.
- The Free State produces of the nation's sorghum (53%), sunflowers (45%), potatoes (33%), groundnuts (32%), dry beans (26%), wool (24%) and almost all of its cherries (90%).
- The Free State produces about 100,000 tons of vegetables and 40,000 tons of fruit each year
- The Free State produces deciduous fruits such as apples, berries, cherries, peaches, plums and apricots.
- Red meat and dairy are other important products
- Game hunting is a fast-growing industry.

Box 2: Overview of the agriculture sectors in Free State Province (*Complied by the CSIR, 2016*).

Table 4.5 below provides an overview of the vulnerability of the agricultural sector to the projected changes in climatic variables for Free State (www.freestate.org.za). Tables 4.6 and 4.7 provide an outline of the vulnerability assessment for the crop and horticulture sectors respectively in the province, covering exposure to projected climatic variables, sensitivity (the extent of the impact), adaptive capacity (systems in place to respond to the impact/change), as well as vulnerability rankings.

Table 4.5: Districts in Free State Province where agricultural activities are conducted and the type of agriculture (Complied by the CSIR, 2016)

Region	Main Agricultural Activities
Mangaung	This region has grass plains and mountains to the east and commercial livestock farming at Mantsopa and Naledi is the main form of farming, while the eastern areas produce potatoes and sunflowers
Xhariep	The southern parts of the province are mostly dry areas where sheep farming is the most prominent. Irrigation schemes, such as the one at Jacobsdal, allow for the production of grapes, with Landzicht and Wilreza Cellars being two of the main wine producers. Potatoes and walnuts are also farmed in this region. Wheat is also a major crop in the district.
Lejweleputswa	Maize and wheat are the main products of this region and also known as the mealie (maize) capital of South Africa. This region is known for its diversity in farming activities as wheat, sunflowers, nuts, vegetables and dairy are produced as well as commercial livestock farming.
Thabo Mofutsanyane	Major crops produced in this region include maize, wheat, potatoes and sunflowers. Approximately 90% of South Africa's cherries are produced in this region. Also to be found are two major asparagus factories where both white and green asparagus are produced. Other crops grown in the smaller parts of the region include soya, sorghum and apples.
Fezile Dabi	This northern region is at the heart of wheat and maize production in the province as the Vaal Dam provides extensive water supply throughout the region. Furthermore, sunflower, tobacco, sorghum, peanut and cattle are also farmed.

Table 4.6: Vulnerability assessment for crops to the projected climate variables (current trends and projected) in Free State covering exposure, sensitivity, adaptive capacity as well as vulnerability rankings

Projected Climate Variable	Exposure	Sensitivity	Current Adaptive Capacity	*Vulnerability*
Ranking	**High**	**High**	**Medium**	***High***
Average Temperature	Increase in temperature between 31.2°C- 31.9°C	Increased evaporation and evapotranspiration rates and increased demand for water for irrigation leading to decline in agricultural productivity affecting livelihoods depended on farming, the provincial gross domestic product, and South Africa's gross agricultural income. • High temperatures damage seedlings, delay flowering and lead to flower abortion for soya beans • Potatoes are vulnerable to high temperatures which affect tuber quality and yield by causing heat sprouting and internal necrosis	**Strengths** • Progress has been made at national level on cultivars that are heat resistant, drought tolerate and use water efficiently (e.g. potatoes, soya beans, maize and sweet potatoes). • The new agricultural Integrated Growth and Development Policy (IGDP) and Agricultural Policy Action Plan (APAP) serve as a response, for sector growth and development through commodities with high growth potential, food security and contribution to the GDP. **Challenges** • Water shortages affecting the sector e.g. Ficksburg • Water pollution from agriculture and mining • Over extraction of groundwater resources • Increase access to land for the previously disadvantaged and provide resources support and maintain productivity. • Skills development and support for emerging farmers • Transfer of technology to farming communities. • The cost of cultivars that are heat and disease resistance are too high for most farmers. • Extension services that could assist farmers, especially small holder, do not have the capacity, the financial resources, poor infrastructure and	• The crop production sector of agriculture is **highly** vulnerable to climate change. Despite the research on more drought and disease tolerant cultivars, the cost of these cultivars are beyond the reach of many farmers. This has been worsened by the lack of access to financial credit being currently experienced in the country. • The current drought has served to exacerbate the dire situation faced by the horticulture sector.
Rainfall	**Under high mitigation** + 25.07mm/ - 112.2mm. **Under low mitigation** + 35mm / -65.9mm.	• Decrease in water available for irrigation. • Decline in productivity for grain crops and fruits which benefit from both summer (maize) and winter rainfall (wheat and barley) • Gains for drought resistant crops such as sorghum by as much as 30%. • Reduced productivity for subsistence and rain-fed agriculture. • Increases in pests and diseases affecting some crops.		
Extreme weather events (e.g. floods, dry spells, heat waves, droughts, frost)	• Very hot days to increase to between 121.1- 142.15 days • Heat wave events to increase to between 28.6- 31.4 events/year • High fire danger days to increase to between 202.4- 219.1 days • The increase of extreme rainfall events is less than 1	• The onset, cessation and duration of frost will affect crop yields from maize which require frost free conditions. • Frost can damage wheat, especially after the formation of ears in spring resulting in low yield. • However, just as in any other ecosystem, the winter favours certain species in the Free State Botanical Garden. Trees in fruit in winter include the buffalo thorn (*Ziziphus mucronata)* and the parasite *Viscum rotundifolium.* At this time they are		

	• Dry spell days to increase to between 105- 112.1 days	both laden with bunches of bright orange fruits, which attract many birds (www.sanbi.org). • Increased health risk for farm workers due to increased heat waves and very hot days affecting their productivity. • Floods can result in soil erosion and loss of fertile soil. • Droughts and dry spells can also affect flowering and pod formation stages for soya beans (e.g. in Fezile Dabi and Thabo Mofutsanyane).	weak institutional structures to make them effective.	

Table 4.7: Vulnerability assessment for the horticulture sector to the projected climate variables (current trends and projected) in the Free State covering exposure, sensitivity, adaptive capacity as well as vulnerability rankings

Projected Climate Variable	**Exposure**	**Sensitivity**	**Current Adaptive Capacity**	***Vulnerability***
Ranking	**High**	**High**	**Medium**	***High***
Average Temperature	Increase in temperature between 31.2°C- 31.9°C.	• Increases in temperature will result in increases in evaporation and evapotranspiration rates and this will increase the demand for water by plants. • There will be and increased demand for water for irrigation. • Horticulture is a labour intensive activity. Decline in agricultural productivity for horticulture produce maybe experienced some areas of the province. This will impact the livelihoods depended on farming as well as the contribution of horticulture to the provincial gross domestic product for the province and the country. • Increases in temperatures will negatively affect heat and chill units essential for the production of good quality apples and pears. • Changes in chill unites will affect the production of peaches, apricots and	**Strengths** • Research into more suitable cultivars that are heat and disease tolerant is under way at both national and provincial level (e.g. viticulture). • Research and application of water use efficiency in the irrigation of produce. **Challenges** • The sector currently faces issues of Water availability. • The quality of water in the province is affected by pollution from agriculture and mining. • There is over exploitation of groundwater resources. • There is no adequate skills development and support for emerging farmers as well as	• The horticulture sector is **highly** vulnerable to changes in climate, in particular the variability of rainfall. As witnessed from the current drought, the lack of rainfall has severely affected irrigation which supports horticulture in the province. • The current adaptive capacity is not comprehensive and affordable enough for all farmers.

		cherries which have more stringent chilling requirements. • More investment will be needed for cooling equipment for storage and transportation of deciduous fruits, cherries and grapes.	transfer of essential technology to farming communities. • The cost of cultivars too high for most farmers in the industry therefore more financial support in needed.	
Rainfall	**Under high mitigation** + 25.07mm/ - 112.2mm **Under low mitigation** + 35mm / -65.9mm.	• There will be a possible decrease in water available for irrigation on which horticulture depends upon. • The possible increase in pests and diseases will affect fruits such as cherries, berries and plums.		
Extreme weather events (e.g. floods, dry spells, heat waves, droughts, frost)	• Very hot days to increase to between 121.1- 142.15 days. • Heat wave events to increase to between 28.6- 31.4 events/year. • High fire danger days to increase to between 202.4- 219.1 days. • The increase of extreme rainfall events is less than 1. • Dry spell days to increase to between 105- 112.1 days.	• Frost can cause damage to floral and leaf buds in temperature sensitive produce such as peaches, apricots and cherries. • Heat wave days and very hot days will increase the health risk for farm workers. This will affect the productivity of this labour intensive industry. • Floods and wind can result in the loss of fertile soil. • Changes in heat units, chill units affect crop (grains) and fruit production e.g. apples, cherries. • Fires will destroy the vine yards and orchards as well as the infrastructure important for the sector.		

In terms of livestock, the current drought has exposed the lack of preparation by the both the national and provincial government to deal with this extreme event. The lack of stock feed as well as the rise of costs of the available feed resulted in the slaughtering of large herds of animals and a huge loss of the genetic material that has been collected over the years (FS DARD, 2012).

Table 4.8: Vulnerability assessment for the livestock sector in the Free State. Exposure looks at the climatic variables that will affect the sector and the extent of the impact (sensitivity) as well as the systems in place to respond to the impact/change (adaptive capacity)

Projected Climate Variables	Exposure	Sensitivity	Current Adaptation Options	*Vulnerability*
Ranking	**High**	**High**	**Medium**	***High***
Average Temperature	Between 31.2°C- 31.9°C.	• Higher temperatures result in thermal stress for livestock and game affecting their growth, milk production, reproduction, metabolic activity and disease occurrences (e.g. zoonotic tick-borne diseases) (Rust et al., 2015). • Small ruminants such as sheep are more robust and more heat-tolerant than cattle. • Changes in the nutritional value and digestibility of pasture and feed resources. • Decline in carrying capacity of grazing land. • Reduced cost of dewintering of livestock (increase temperature). • Increase in crop suitability areas for specific crops e.g. Sorghum.	**Strengths** • Legal instruments and policies that for the management of agriculture in the country. • A vulnerability assessment conducted by the Department and the Agricultural Research Council with adaptation options for agriculture. • Research on the breeding of more heat and disease resistant breeds with indigenous cows is under way. **Challenges** • Availability of resources to support research. • Research into more adaptable breeds is costly. • Competition for land from other sectors such as energy. • The current drought has exposed weakness in preparedness of the sector for extreme events.	• The livestock sector is **highly** vulnerable to climate change despite all the efforts to adapt which include breeding of heat resistant species. • The availability of water as well as the availability of fodder remains key issues for the sector and these are influenced by the availability of rainfall. • Some of the adaptation option suggested can be costly and some farmers cannot afford.
Annual Average Rainfall	**Under high mitigation** + 25.07mm/ - 112.2mm. **Under low mitigation** + 35mm / -65.9mm.	• Decrease in water available for livestock. • Changes in the range and abundance of disease vectors and pathogens which also affect the quality of fodder.		
Extreme events (e.g. floods, dry spells, heat waves, droughts) Extreme Rainfall events (include thunderstorms and lightning)	Very hot days to increase to between 121.1- 142.15 days. Heat wave events to increase to between 28.6-31.4 events/year. The increase of extreme rainfall events is less than 1. Dry spell days to increase to between 105- 112.1 days.	• Heat wave days and the very hot days to affect livestock productivity. • High fire danger days and heat waves to increase the risk of veld and forest fires. • Loss of livestock due to frosts and cold spells at the end of long, hot dry seasons. • Droughts and dry spells reduce pasture and other feed resources such as grains which affects the price of feedstock. • Changes in dietary patterns of communities that rely on livestock and other small animals such as chickens. • Changes in the range and abundance of disease vectors and the survival of pathogens.		

The agricultural sector in the Free State is highly vulnerable to climate change, given the high exposure, sensitivity and low adaptive capacity. The projected changes in temperature will have a detrimental impact on the production of temperature sensitive crop and animal produce and this coupled with the uncertainly of rainfall will put a strain on agriculture especially the increased demand for irrigation which is expected to increase under all scenarios (Schulze et al., 2009), with the exception of the eastern part of the country. Small holder or subsistence dryland farming is the most vulnerable given the projected increases in the number of dry spell days with possible losses and gains in grains, fruits and livestock.

It is important to note that other climate related factors such as heat and chill units as well as cold snaps will affect the harvest yield of the produce. The impact of climate change on agriculture, which is one of the most important industries in the Free State, has highlighted the importance of temperature and rainfall.

The Free State Department of Agriculture and Rural development has a new Agriculture Integrated Growth and Development Policy (IGDP) and Agriculture Policy Action Plan (APAP) that will assist in the growth and development of the sector, reducing food insecurity and increasing contribution to GDP. The sectors targeted for implementation of the plan include crop production, livestock, dairy, poultry, aquaculture and horticulture. The growth plan will include financial investment and support for emerging farmers as well as women and youth involved in agriculture (FS DARD, 2015).

4.2.1 Prioritisation of Adaptation options in the Agriculture sector

- Improved irrigation technology and its maintenance to minimise water losses from current commercial farming activities and the anticipated increases in drought in the future.
- Implement smart agricultural practises that reduce loss of soil moisture and improve soil organic matter (this will include conservation agriculture)
- Increase investment into the research for short term varieties, and heart and disease resistant cultivars and animal breeds.
- Support community food production to increase food security for poor households through for example agricultural starter pack for vegetable gardens (to improve food security).

4.3 Biodiversity

Healthy, functioning and diverse ecosystems are critical for human wellbeing. Well-functioning biodiversity provides ecosystem goods and services that are essential for human health and food security through the provision of food and fresh water, wood, fibre and fuel. A substantial population directly depend on ecosystems as a livelihood and safety net for food, energy, water and medicinal plants and grazing for livestock especially in rural areas (Murombedzi, 2008). Ecosystems also provide environmental services such as the regulation of climate and protection from floods and storm surges (DEA, 2013b; Driver et al 2011). Biodiversity also serves a social, cultural and recreational role.

4.3.1 Terrestrial ecosystem

Three of the nine biomes in the country are found in the Free State with the largest one being Grassland which occupies 72% of the province, followed by the Nama-Karoo at 22% and savannah at 5.2%. The Azonal vegetation is found in small pockets in the province's south west mainly within the Nama-Karoo biome.

Studies to understand habitats (locations) different species currently live (their climate envelope) are an important tool used in vulnerability assessments to help planners and decision makers understand how plants and animals may respond to a changing climate. Bioclimatic envelopes are characteristic or series of patterns of temperature, and rainfall within which each biome is found, which makes it a suitable habitat for certain species.

The anticpated changes in climate, especially increases in temperature and reductions in rainfall will impact on the bio-climatic envelops in which the different biomes and their inhabitants thrive, espcially in cases where the bio-climatic envelop changes to suit the envelop of a different biome. This is especially relevent for the grassland biome which is currently considered endangered and vulnerable, and has a low protection status, according to the National Biodiversity Assessment (Driver et al, 2011). It is important to point that the capacity of a biome to respond to climate change is dependent on the conditon of the biome, with highly fragmentetd and degraded biomes such as grassland having a reduced capcity to respond or cope with changes.

Ecosystem Services provided by Biomes in the Free State

Grassland biome helps regulate water flow, supports livelihoods through thatching grass and provision of medicinal plants as well as the provision of fodder for livestock. Grasslands cover substantial area, especially in the east of the province.

Savanna biome support services include cultural regulation and climate regulation; it supports livelihoods based on eco-tourism. Added to this the biome plays a key role in carbon sequestration, provision of fodder, medicinal plants and soil retention. The biome is currently found in the western parts of the province.

Nama-Karoo provides services such as fodder for grazing and water provision. The biome covers small areas in the south western areas of the province.

Box 3: Ecosystem services provided by Biomes in the Free State

The predictions of changes in climate based on temperature and rainfall highlight three plausible climate futures which were obtained as a result of climate modelling based on 15 global circulation models that were statistically downscaled for South Africa up to the year 2050 (Driver et al., 2011). These futures are:

- Best case scenario: smallest predicted increases in temperature and changes in rainfall.
- Intermediate scenario: middle of the range (median) predicted increases in temperature increases and changes in rainfall.
- Worst case scenario: greatest predicted increases in temperature and changes in rainfall.

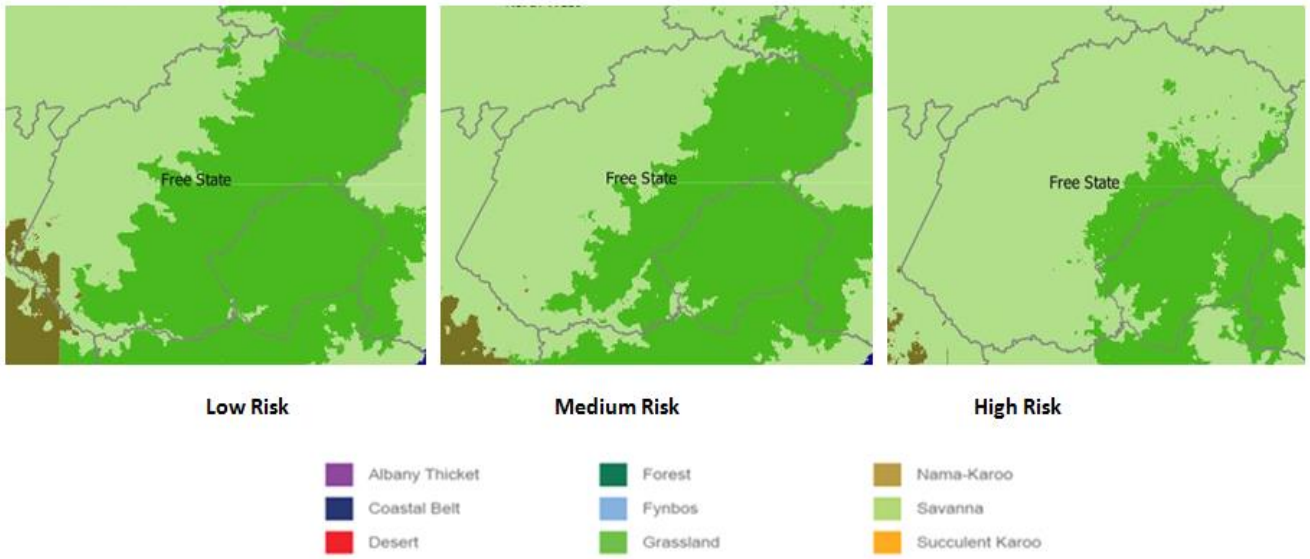


Figure 4.2: Changes in the biomes across the Free State Province with particular attention on the decrease of the grassland and increase in the savannah biomes (DEA, 2014)

4.3.2 Wetland ecosystems

Wetland ecosystems are considered to be the highly threatened with at least 48% of all wetlands classified as critically endangered. Wetlands provide critical ecological functions such as water purification, flood attenuation, drought alleviation, stream flow regulation, erosion control, the recharge of aquifers and water storage (Driver et al., 2011). Wetlands further provide goods and services which have direct socio-economic and cultural value, such as food, water, agriculture and grazing while contributing significantly to tourism, environmental education and, most importantly, to the maintenance of a rich biodiversity.

Wetlands provide habitat for a large variety of animal and plant life (Driver et al., 2011). Table 4.9 provides an outline of the vulnerability assessment for the biodiversity sector (terrestrial and wetlands) in the Free State province, covering exposure to the projected climatic variables, sensitivity (the extent of the impact), adaptive capacity (systems in place to respond to the impact/change), as well as vulnerability rankings.

4.3.2.1 Wetland Ecosystems Status

Free State has a substantial number of wetlands that are classified as critically endangered, endangered and vulnerable classes. The spatial patterns of wetlands and river ecosystems are consistent across all three classes, critically endangered, endangered and vulnerable, and these are located in the grassland biome (Driver et al., 2011). Wetlands under the savanna biome are classified as least threatened while the extent of the wetlands in the Nama-Karoo that are under threat is less than in the grassland biome.

Table 4.9: Vulnerability assessment for the biodiversity sector (terrestrial and wetlands) in Free State province, covering exposure, sensitivity, adaptive capacity as well as vulnerability ranking

Projected Climate Variables	Exposure	Sensitivity	Adaptive Capacity	*Vulnerability*
Ranking	**High**	**High**	**Medium**	***Medium***
Average Temperature	Between 31.2°C-31.9°C.	• Changes to ecosystem function, composition and services essential for human wellbeing and economic activities such as agriculture (e.g. process of pollination in plants). • The bioclimatic envelop for grasslands will be significantly reduced. Grassland is the most threatened biome in the country. • Nama-Karoo is the second most threatened and is likely to look like an arid savanna and maybe replaced by savanna and desert in some areas. • Savanna will possibly expand significantly but this does not necessarily benefit current habitats and species groupings. • Loss of livelihood for households dependent on vulnerable biomes such as Grassland. • Increased evapotranspiration and evaporation. • Invasion of alien vegetation and increased spread of invasive species. • Increases in temperature result in increased evaporation which can result in the drying of the wetlands. • Increases in temperature increase alien invasive species that negatively affect wetlands.	**Strengths** • The province has completed a critical Biodiversity and ecology assessment report, which will help identify priority areas for conservation. • Biodiversity Education Programmes, help to raise awareness of the school learners and the communities. • Groen Sebenza to promote skills development and employment in the biodiversity sector. • University of Free State has a global registry or biodiversity repository. • Conservation areas including national parks and botanical gardens. • Wetlands have been mapped to show their status which is key in their management. **Challenges** • Increased loss and degradation of biodiversity due to economic activities such as mining and agriculture. • Over exploitation of biodiversity for subsistence livelihoods. • Wetlands under threat from development and urbanisation which result in decline in water quality and wetland health.	• The biodiversity sector is classified as having **medium** vulnerability to climate change. The sector has high exposure and sensitivity to projected changes in climate. However, the biomes that are endangered are in protected areas with the exception of some parts of the vast grasslands. • There are plans in place to protect and conserve biodiversity through the establishment of biodiversity protected corridors.
Annual Average Rainfall	**Under high mitigation** + 25.07/ - 112.2mm. **Under low mitigation** + 35mm / -65.9mm.	• Changes in bioclimatic envelopes which have socio economic and environmental impacts. • Habitat degradation and reduced productivity of rangelands.		

		• Increased demand for water • Changes in rainfall affect the quantity and timing of stream flow recharge which also affect wetlands structure and functionality.		
Extreme events (e.g. floods, dry spells, heat waves, droughts) Extreme rainfall event (thunderstorms & lightning)	• Very hot days to increase to between 121.1-142.15. • Heat wave events to increase to between 28.6-31.4 events/year. • High fire danger days to increase to between 202.4-219.1 days. • The increase of extreme rainfall events is less than 1. • Dry spell days to increase to between 105-112.1 days.	• High fire danger days and heat wave days increase fire risk which can destroy biomes. • Intense storms are few but can cause regular and permanent erosion. • Increased droughts, dry spells, very hot days and heat waves increase water stress for biodiversity.		

The biodiversity sector is classified as having medium vulnerability to climate change. While the sector will be exposed to projected changes in climate, the sensitivity of biodiversity is medium due to the biomes that are endangered being in protected areas. Further, there are plans in place to protect and conserve biodiversity for example the establishment of biodiversity protected corridors.

4.3.3 Prioritisation of Biodiversity sector

- Promote initiatives such as eco-tourism
- Raise awareness on and resources for ecosystem based adaptation that includes communities and the different sectors
- Enhance the role of tourist operators to conserve water and energy as well as adopt efficient waste management practices for the industry
- Invest in the much needed transport infrastructure to improve accessibility and mobility which supports tourism

4.4 Tourism

The National Climate Change Response Policy (2011) acknowledges that tourism as one of sectors that is vulnerable to climate change. The impact of climate change on infrastructure and the biodiversity has the potential to impact negatively on tourism, resulting in social and economic impacts in areas that are dependent on tourism as a source of income and employment. Table 4.10 provides an outline of the vulnerability assessment for the tourism sector to the projected climate variables covering exposure to the projected climatic variables, sensitivity (the extent of the impact), adaptive capacity (systems in place to respond to the impact/change), as well as vulnerability rankings.

The Free State has an extensive tourism industry, and is well endowed with the national parks such as the Golden Gate, numerous nature and game reserves, all of which attract a sizable number of tourists every year. The province is also well known for its small towns and festivals. The projections from high temperatures, heat waves and the spread of diseases and pathogens, resulting in direct impacts of climatic factors on human health and thermal discomfort, could negatively affect the numbers of tourists visiting the Free State Province.

Table 4.10: Vulnerability assessment of the tourism sector to the projected climate variables covering exposure, sensitivity, adaptive capacity as well as vulnerability ranking

Projected Climate Variables	Exposure	Sensitivity	Adaptive Capacity	*Vulnerability*
Ranking	**High**	**High**	**Low**	***High***
Average Temperature	• Between 31.2°C- 31.9°C.	• Shift of attractive climatic conditions and biodiversity required for tourism. • Increasing incidence of vector-borne diseases may deter tourists from the province e.g. ticks and malaria for part of the Free State province. • Climate defines the length of the tourism season and influences environmental conditions that attract or deter tourist from visiting the country and the Free State province.	**Strengths** • Draft National Tourism and Climate Change Action plan (2011) in place. • Protected fragile biomes within the national parks and nature conservancies as part of tourism. • Various water conservation efforts in the industry. **Challenges** • Investment into water and energy conservation in the industry (e.g. for golf courses). • Invest in alternative sources of energy. • No climate change plan or strategy for the province.	• The Tourism sector in the province is regarded as being **highly** vulnerable to climate change. The provincial department has no plans or measures in place to address climate change. • Changes in climate will reduce the length of the tourism period thus affecting revenue. • While some conservation effects are in place, the most threatened biomes are located in the province and these are already over-exploited.
Annual Average Rainfall	• Under high mitigation + 25.07mm/ - 112.2mm. • Under low mitigation + 35mm / -65.9mm.	• Loss of biodiversity can result in decline in the number tourists and revenue earned from tourism (also affecting livelihoods depended upon the sector). • Water for irrigation to provide leisure facilities such as golf courses and green areas may become increasingly scarce (GIZ, 2011).		
Extreme events (floods, heat, droughts, etc.)	• Very hot days to increase to between 121.1- 142.15. • Heat wave events to increase to between 28.6- 31.4 events/year. • High fire danger days to increase to between 202.4- 219.1 days. • The increase of extreme rainfall events is less than 1. • Dry spell days to increase to between 105- 112.1 days.	• Flooding of access roads and hotel resorts infrastructure damage. • Increase in operating costs for cooling, irrigation, food and water supply, and insurance costs. • Increased emergency preparedness requirements, which include backup water and power systems and medical supplies. • Increases in fires will endanger tourists.		

The tourism industry at a provincial level is regarded as being highly vulnerable to climate change, given that changes in climate will reduce the length of the tourism period. Further, climate change may change the environmental condition that will either attract or deter visitors from coming to the province. While there plans to develop a national climate strategy for the country, the Department of Tourism at provincial does not have a climate unit and has not included climate changes in its planning. This will hamper any climate adaptation efforts that the sectors might need to initiate in the province.

4.4.1 Prioritisations of Adaptation Options

The following adaptation options have been selected for prioritisation by the team based on the national requirements for adaptation in the tourism industry which need to be applied at provincial level:

- Establish the institutional framework at provincial level to deal with climate change in the tourism sector.
- Coordinate with other keys stakeholders and the national department to develop an adaptation response plan for the sector.
- Raise awareness of stakeholders that are involved in the sector on the impacts of climate change on tourism and potentially on their livelihoods.

4.5 Mining

Mining is the largest economic sector and employer in the Free State Province. A gold reef of over 400 km long, known as Lejweleputswa (formerly known as the Goldfields), stretches through Gauteng and Free State, and the largest gold mining complex is the Free State consolidated Goldfields. The province has twelve gold mines, producing approximately 30% of the country's gold (FDC, 2016). Minerals and mineral by products found in the province include gold, silver, diamonds, uranium, bentonite and bituminous coal (which is converted to petrochemicals). Other minerals found in the province include sand, stone aggregate, granite, gypsum, limestone and salt. These are found in the north-western areas of the province.

Apart from contributing to the Gross Domestic Product (GDP), mining is also a major employer in the province, with international companies such as De Beers, Anglo Gold Ashanti and Sasol found in the province. Table 4.11 below highlights the location of mining activities in the Free State. The mining sector is a major consumer of both water and energy in the province. While mining has contributed immensely to the economy and the development of the Free State, as well as being responsible for the development of most of the settlements in the province, it has also been a major source of pollution of water, air and land. The types of mining practised, such as deep level underground mining and open cast mining have contributed to pollution especially of groundwater sources and this has downstream effects especially for the upper and middle Vaal rivers catchments. This pollution is also affecting the Northern Cape Province which shares water sources with the Free State.

Poor mining practises have also caused a myriad of negative environmental issues such as contamination of land. Mining practises such as open cast mining leave behind large scars on the landscape. This land will need to be rehabilitated for future. Practises such as deep underground mining may result in sink holes in areas where dolomite rocks and severe flooding occurs. Air quality in the province, especially in the Vaal Triangle where most of the mining activities are located is poor and had detrimental effects on human health of both miners and residents of the province.

Table 4.12 provides an outline of the vulnerability assessment for the mining sector to the projected climate variables covering exposure to the projected climatic variables, sensitivity (the extent of the impact), adaptive capacity (systems in place to respond to the impact/change), as well as vulnerability rankings. Biodiversity in the Free State has also been affected by changes in land use and clearing of grasslands for mining activities (FSPSDF, 2012). Loss of biodiversity will compromised the adaptive capacity and response of the province, affected population and sectors to climate change.

Table 4.11: Mining in the Free State (FSPSDF, 2012)

Regions	Main Towns	Products
Lejweleputswa District Municipality	Welkom Virginia Odendaalrus	Primary Gold Mining Also supplying considerable concentrations of silver and uranium.
Fezile Dabi District Municipality	Sasolburg Vanderbijlpark Vereeniging Kroonstad Koppies	Primary Coal Mining Supplying the country's largest deposits to Bentonite. The Bituminous Coal is further converted into Petrochemicals at Sasolburg. Diamond Mining Fezile Dabi is the leading Diamond Mining region in the province, operated by large companies such as Petra Diamonds, Lace Diamonds and De Beers.
Xhariep District Municipality	Jagersfontein Koffiefontein	Diamond Mining Jagersfontein is a world-renowned site for producing some of the world's largest diamonds.

Table 4.12: Vulnerability assessment of the mining sector to the projected climate variables covering exposure, sensitivity, adaptive capacity as well as vulnerability ranking

Projected Climate Variables	Exposure	Sensitivity	Adaptive Capacity	*Vulnerability*
Ranking	**High**	**Medium**	**Low**	***Medium***
Average Temperature	Between 31.2°C- 31.9°C.	• Reduce the efficiency of operation of mining equipment and cooling for water-treatment processes. • Operating thresholds of equipment may be exceeded during episodes of extreme high temperature. • Higher temperatures directly increase the risks of heat stress underground workers.	**Strengths** • Free State Provincial mining working group set up to address some the challenges faced by the mining sector. • Recommendations outlined in the Free State Growth and Development Strategy to support current and future mining opportunities for sustainable mining. **Challenges** • Slowdown in the mining sector affecting its contribution to the country's economy and employment. • Proliferation of illegal mining operations causing damage to the environment. • Water Shortages.	• The vulnerability of the mining sector is regarded as **medium**. While not much research has been done on the impacts of climate change on the sector in the province or at national level, the vulnerability of mining equipment as well as the vulnerability of mine workers is a source of concern and there needs to be plans in place to respond. • The key challenges in the mining sector are non-climate related but will still have impact on the sector. These will be worsened by climate change.
Annual Average Rainfall	**Under high mitigation** + 25.07mm/ - 112.2mm. **Under low mitigation** + 35mm / -65.9mm.	• Less rainfall affects the amount of surface and groundwater available for mining activities. • High/heavy rainfall will result in flash floods that will likely damage the mine infrastructure and roads and impact on accessibility of personnel to the mines; thus impacting on the productivity of the mines and livelihoods.		
Extreme events (e.g. floods, dry spells, heat waves, droughts)	Very hot days to increase to between 121.1- 142.15 days. Heat wave events to increase to between 28.6-31.4 events/year. The increase of extreme rainfall events is less than 1.	• Heat waves increase the use of energy required for cooling. • Intense precipitation events and storms can jeopardize the integrity of surface impoundments, and could necessitate development of additional water storage facilities to contain process solutions and capture rainfall for operational use. • Storms and floods can result in emergency response procedures being compromised. • Droughts may concentrate contaminants that negatively affect the chemistry of surface waters in some areas for example Acid Mine Drainage.		

The mining sector can be regarded as having a medium vulnerability as a result of the vulnerability of mining equipment and mine workers to increases in temperature. While mining and mineral professionals have experience with risk management and managing workplace health and safety (adaptive capacity), there is a need to include and raise awareness on the symptoms that are climate related. The sector is also not dependent on climate but requires water which is vulnerable to the impacts of climate change.

4.5.1 Prioritised adaptation Options for the mining sector are listed below:

- Regularise and enforce active and post mining land rehabilitation.
- Continuous rehabilitation of mining areas land for agricultural and other rural development projects.
- Research into how to address the challenges and opportunities presented by acid mine drainage
- Invest in alternative sources of energy such as solar since mining are a major energy consumer to be introduced.
- Clearly identify water quality and environmental objectives based on downstream environmental values to minimise damage to aquatic and terrestrial ecosystems.
- Develop and adopt strategies for making efficient use of water and increase water conservation at mine sites.
- Adjusting existing risk-identification processes to incorporate additional heat related health risks on miners working underground and surface heat related illnesses.
- Training for mining workers to identify health and safety issues, symptoms, hazards, and preventative measures associated with heat related diseases and heat stress.
- Strengthen plans and procedures to address illegal mining often driven by poverty and unemployment.

4.6 Transport sector

Transport is one of the critical infrastructures in the Free State, given its central location in the country as well as its major agricultural industry and manufacturing all of which are heavily dependent in good road networks. While most roads are in a fair, good and good condition, the province is struggling to maintain the transport infrastructure which is estimated to cost R4.1billion, with an overall budget requirement of R11.4billion for upgrading and maintenance costs for all roads in the province, including the gravel roads. Presently, there are four main transport routes which include the N3 between Durban and Gauteng which is a key freight route, the N1, linking Gauteng to the Western Cape, which is also a key freight route for local produce such as processed foods coal and chemicals, fruit and beverages (Free State Province, 2013). The third major route links the Western Cape and Gauteng via Port Elizabeth and the last on being the Gauteng link to Western Cape through East London a number of goods such as meat, maize and motor vehicles are transported on these roads. Rail is also a key contributor to the transport network in the Free State. There is an anticipated growth in the freight business in the Free State in future, for local and international markets (Free State Province, 2013). Other transport infrastructure in the Free State includes an airport, (the third largest in the country) some air fields and a railway network (Free State Province, 2013).

Table 4.13 provides an outline of the vulnerability assessment for the transport sector to the projected climate variables covering exposure to the projected climatic variables, sensitivity (the extent of the impact), adaptive capacity (systems in place to respond to the impact/change), as well as vulnerability rankings. Climate change, particularly the extreme climate related events such

as floods and very hot days, will result in extensive damage to infrastructure costing the provincial government immense financial resources to repair, maintain and upgrade such infrastructure. The vulnerability of public infrastructure is also exacerbated by increases in population coupled with aging infrastructure as is the case in some of the municipalities in the Free State such as Mangaung Metropolitan Municipality.

The vulnerability of urban settlements in Free State is likely to be enhanced by rapid urbanisation which is currently adding undue pressure on the transport infrastructure. Urban growth is being exacerbated by rural-urban migration trends. In addition, due to the legacy of apartheid; spatial planning in some urban areas is not up to standard, placing historically disadvantaged households on the urban periphery far from economic opportunities.

Table 4.13: Vulnerability assessment of the transport sector to the projected climate variables covering exposure, sensitivity, adaptive capacity as well as vulnerability ranking

Projected Climate Variables	Exposure	Sensitivity	Adaptive Capacity	*Vulnerability*
Ranking	**High**	**High**	**Medium**	***Medium***
Average Temperature	• Between 31.2°C- 31.9°C.	• Higher temperatures can accelerate the ageing of road surfacing bitumen layers. • Buckling of railway tracks.	**Strengths** • Multi-modal transport and logistics hub which also promote economic development in the province. • Budget allocation for maintenance and upgrading of transport infrastructure though it's not adequate. • Upgrading of road across the province e.g. Thaba Nchu. **Challenges** • Growth in freight in the country has increased pressure on province given its central location in the country. • Need gravel roads in some wards e.g. Ward 12, 17. • Need for paving and upgrading of roads and storm water drainage e.g. ward 14, Ward 17. • Road-use behaviour problems e.g. over speeding on major roads. • Inadequate traffic lights and pedestrian warning signs. • Increased maintenance and replacement costs for transport infrastructure.	• The vulnerability of the transport sectors is considered as medium, and despite the impacts of climate change, especially increased temperatures on the road network. • Maintenance and upgrading of the transport network across the province is under way in the province with substantial budgets allocated.
Annual Average Rainfall	• Under high mitigation + 25.07mm/ -112.2mm. • Under low mitigation + 35mm / -65.9mm.	• Low rainfall and droughts can cause damage to road foundations and rail infrastructure.		
Extreme events (e.g. floods, dry spells, heat waves, droughts)	• Very hot days to increase to between 121.1- 142.15 days. • Heat wave events to increase to between 28.6- 31.4 events/year. • High fire danger days to increase to between 202.4- 219.1 days. • The increase of extreme rainfall events is less than 1. • Dry spell days to increase to between 105- 112.1 days.	• Unpaved and gravel roads vulnerable to extreme rainfall and flooding. • Very high temperatures reduce the structural strength of road surface. • Heat waves and increased number of hot days enhance the urban heat island while also increasing heat stress especially for road and rail construction workers, road freight and well as public commuters. • Extreme heat has the potential to affect aircraft lift as hotter is less dense reducing mass flowing the wing to create lift.		

4.6.1 Prioritised Adaptation Options

The following adaptation options for the transport sector are suggested by the team. However, there is a need for investigations into more options as well as further engagement with the sector department. The adaptation options need to be aligned with the provincial development goals and the IDP:

- Budget allocation for the maintenance and up grading of road infrastructure.
- Research into better materials for road construction that is heat resistant and climate smart.
- Maintenance and upgrade of storm water drainage to minimize flooding of roads and streets.
- Enhance disaster management services to be prepared to assist in the event of accidents and chemical spillages (Free State produces a sizable number of chemical that are all transported by road.
- Design standards and planning for roads, rail, and other infrastructure to cope with warming and drainage.

4.7 Energy sector

The energy is one of the key economic industries in the province; especially energy generation. Given the increased demand on energy in the country, the Free State plays its part in the supply of energy, generating power from natural gas, methane, solar and hydro power. Infrastructure sector (particularly electricity) province is vulnerable to various climatic conditions. The FS province houses Gariep hydro power station and transports most of its electricity using transmission lines from coal fired power stations located in Mpumalanga province. Within the FS province, this electricity is stored in substations and distributed to end users (households, industries, etc.) by means of distribution lines. This entire infrastructure is vulnerable to various impacts of climatic conditions such as increased temperatures, heavy rainfall and extreme events (e.g. thunderstorms, lighting, floods, frost etc.).

Eskom, the country's energy provider is involved in major energy projects in the Free State and has been active in rolling out of energy efficient equipment including solar geysers. The province has immense solar harvesting potential and the possibility of manufacturing of solar products such as geysers and panels (Free State Business Report, 2012).

The conceptualised plans such as the solar water geyser manufacturing in Botshabelo to produce 300 000 units per annum and the manufacture of solar modules and solar panels assembly facility have been finalised. Within the Free State, the Xhariep region has the second-best solar radiation index making it opportune to harness the solar power and generate electricity through photovoltaic solar power generation (Free State Business, 2013).

Presently, there are solar park projects in Xhariep district (250MW project) and the Letsatsi solar park located north of Bloemfontein. However there is a need to undertake further research when generating solar energy at a large scale as this requires large areas to be allocated for collection of energy and this may interfere with existing land uses in those areas. Secondly, the energy footprints of energy systems can become incrementally high and have an impact on land, through material exploration, extraction, manufacturing and disposal. Thirdly, the construction of large scale solar facilities requires that land is cleared of all vegetation followed by grading which can result in soil compaction, alteration of drainage channels and increased soil erosion.

Wind power is another renewable energy source being investigated in the Free State province. Preliminary studies and investigation to set up a wind farm in the small town of Springfontein, with a feasibility as well as an Environmental Impact Assessment having been conducted. The wind farm has not been established as yet.

The other option of energy that needs to be investigated is the biogas, derived from human and animal waste, as well as from landfill waste. More research as well as research inessential before these sources of energy can be implemented. Hydro power is generated at the Gariep and Venderkloof dams' power stations with a generation capacity of 360 MW and 240 MW respectively. The option for renewable energy available for the Free State is both dependent on climate change and its impacts, which will also affect the availability of both water for hydro-power and solar radiation for solar energy.

Table 4.14 provides an outline of the vulnerability assessment for the energy sector to the projected climate variables covering exposure to the projected climatic variables, sensitivity (the extent of the impact), adaptive capacity (systems in place to respond to the impact/change), as well as vulnerability rankings.

Table 4.14: Vulnerability assessment of the energy sector to the projected climate variables covering exposure, sensitivity, adaptive capacity as well as vulnerability ranking

Projected Climate Variables	Exposure	Sensitivity	Adaptive Capacity	*Vulnerability*
Ranking	**High**	**High**	**Medium**	***Medium***
Average Temperature	• Between 31.2°C- 31.9 °C	The projected increase in temperature will have the following impacts: • Increased energy demand for cooling for both human and animals, thus putting pressure on the current energy generation capacity. • Sagging and clashing of transmission and distribution line cables that will result in fires and damage to infrastructure. • Increased evaporation from the dams resulting in water shortages for hydro power generation in Gariep, thus affecting generation capacity of this plant. • Benefit the growing solar radiation energy initiatives in the province.	**Strengths** • Investments currently underway in renewable energy and products, e.g. solar water geysers and panels as well as wind energy generation in the province. • Xhariep the second best solar radiation in the country, this presents an opportunity for the province to invest in solar energy generation. **Challenges** • Theft of electrical cables. • Provision and maintenance of high mast lights. • Air pollution from power generation • Increased demand for energy from mining, agriculture and human consumption. • Need to provide electricity to Ward 46.	• The vulnerability of the energy sector is considered **medium**. While there are concerns about water availability to generate hydro-power, the suitability of the province to produce renewable energy (solar) presents immense opportunities for the growth of the sector.
Annual Average Rainfall	• Under high mitigation + 25.07mm/ - 112.2mm. • Under low mitigation + 35mm / -65.9mm.	• Rainfall variability will affect the availability of water for hydro-electricity generation along the Gariep and Venderkloof dams.		
Extreme events (e.g. floods, dry spells, heat waves, droughts, frost/snow)	• Very hot days to increase to between 121.1- 142.15 days. • Heat wave events to increase to between 28.6- 31.4 events/year. • High fire danger days to increase to between 202.4- 219.1 days. • The increase of extreme rainfall events is less than 1. • Dry spell days to increase to between 105- 112.1 days.	• Dry spells will reduce rainfall availability for energy generation. • Flooding may damage energy generation, transmission, distribution and substations and solar energy infrastructure. • Frost/snow builds-up and damage transmission and distribution lines as well as substations; thus impacting on the continuity of electricity supply in the province.		

4.7.1 Prioritisation of the adaptation options for the energy sector

- Continued research and support for renewable energy and research into possible issues of maladaptation.
- Community awareness raising programmes on energy conservation and alternative energy sources.
- Address illegal electricity connections and use smart meters to curb in accurate meter readings.
- Invest in employment opportunities presented by the renewable energy sector.

4.8 Upgrade infrastructure as well as research on constructional materials that are heat resistant. Built Environment and Human Settlements

Cities, towns and settlements are key in the development of South Africa and according to the updated settlement and town typology conducted by the CSIR, BE (2011) these settlements or functional urban areas house more than 70% of the SA population and more than 90% of all economic activity, and thus, the need to understand settlement dynamics within the context of risk and vulnerability for municipalities is clearly essential. The built environment is classified as the structures and infrastructure that is found prevalently in cities, towns and other built up areas. The built environment can also include man-made outdoor environments and provides the basic necessities for human well-being and is closely linked to delivery of basic services, especially in South African cities and urban areas. Some of the infrastructure supporting human settlements such as water, storm water, transport and communications are also vulnerable to climate change.

4.8.1 Urban, Rural and Informal Settlements

Human settlements in the Free State province are undergoing increased pressure to move towards urbanisation. The current drought affecting the agriculture sector as well as the decline in the mining industry has increased the rate of unemployment in the province, resulting in more people migrating to urban areas (FSDARD, 2012). This trend, which results in depopulation of the rural areas through rural-urban migration, will increase pressure on the current basic services and available resources in the urban settlements since there is an anticipated population increase in the urban areas. Basic services, such as housing will become critical, especially the need to curb unplanned development (informal settlements) in the province. Urban settlements also have a large ecological foot print, impacting on the surrounding environment (Free State PSDF, 2013). While migration is a key factor in population dynamics, there is no evidence whether this is influenced by climate change. Other areas such as Mangaung and Maluti a Phofung are former homelands areas and have populations with the highest poverty rates, as well as a history of inequality in terms of access to basic services.

There are five different housing typologies found in the province, with large urban settlements which include Botshabelo, Welkom, Virginia, Thaba Nchu and Bloemfontein. The province has regional towns such as Kroonstad and middle order towns such as Ladybrand and Ficksburg. Small towns are defined by the rural and small farming communities and communal areas are found in Thaba Nchu and Maluti a Phofung.

Free State has its fair share of informal as well as very old settlements which need to be prioritised for basic service delivery. Most of the informal settlements are located in areas that are sensitive and dangerous to live in such as flood lines. For example, the residents of the Dinaweng informal settlement near Mangaung are settled on top of the Bloemwater pipes. This poses a serious danger

to the settlement if the pipes burst, and will result in the settlement being flooded. Moreover, the pipes are old and are need to upgraded (www.bloemfonteincourant.co.za). Most of the informal settlements are found in the Lejweleputswa, Motheo, Fezile Dabi, Xhariep and Thabo Mofutsanyane (DHA, 2012). The nature of construction material used (example) for the informal settlements housing make them highly vulnerable to various climate variability and change related impacts (including extreme weather events).

In terms of rural settlements, rural infrastructure is essential to promote rural development and the empowerment of rural communities. Empowerment of rural communities would include public participation of civil society in decision making. Rural infrastructure will also encourage efficient and sustainable agricultural development especially by providing a link between small-scale farmers and markets; providing employment and reducing poverty in an attempt to curtail rural-urban migration (FSDARD, 2012).

Table 4.15 provides an outline of the vulnerability assessment for the Built Environment and Human settlements sector to the projected climate variables covering exposure to the projected climatic variables, sensitivity (the extent of the impact), adaptive capacity (systems in place to respond to the impact/change), as well as vulnerability rankings. Impacts on built environment results in direct impacts on human health and well-being (especially the unemployed and low income earners), given the areas and spaces these population groups occupy within the built environment. The anticipated impacts will affect the settlements differently, with most rural settlements that depend on small holder and subsistence farming being the most affected.

Table 4.15: Vulnerability assessment of the Built Environment and Human Settlements sector to the projected climate variables covering exposure, sensitivity, adaptive capacity as well as vulnerability ranking

Projected Climate Variables	Exposure	Sensitivity	Adaptive Capacity	*Vulnerability*
Ranking	**High**	**High**	**Medium**	***Medium***
Average Temperature	Between 31.2°C - 31.9°C	The projected increase in temperature will result in the following impacts to this sector: • Declining air quality in cities. • Increased discomfort and demand for energy for cooling. • Water shortages due to decrease in rainfall and evaporation in dams. Deterioration of heat sensitive transport infrastructure e.g. embrittlement and crackling of bitumen on roads.	**Strengths** • Budget has been allocated to eradicate pit and bucket toilets. • Urban settlement development grants to develop and upgrade infrastructure that supports human settlements. • Informal settlements upgrading strategy document in place. • Three registered companies in Welkom dealing with water recycling. Similar efforts are currently underway all over the province. • Low cost housing project is using solar geyser and houses being retrofitted for energy conservation. • Project on rural development being implemented across the province. • Efforts to eradicate the bucket system of sanitation are being implemented across the province. • Provides support to communities living along flood plains. • Disaster Management Centre • Mangaung Metropolitan Municipality Disaster	• The vulnerability of the built environment and human settlements is considered **medium**. • Efforts as well as planning and budgeting have been made available to upgrade informal and old settlements in the province. • Efforts to upgrade and maintain infrastructure are being implemented for the various type of infrastructure that support settlements • It is important to keep a watchful eye on migration and its possible impacts on urban settlements.
Annual Average Rainfall	**Under high mitigation** + 25.07mm/ - 112.2mm. **Under low mitigation** + 35mm / -65.9mm.	• Disruptions to water and electricity supply reducing productivity. Reduced stream flow and groundwater recharge which will consequently lead to an increase in the unit cost of water for settlements.		
Extreme events (e.g. floods, dry spells, heat waves, droughts)	Very hot days to increase to between 121.1- 142.15 days. Heat wave events to increase to between 28.6- 31.4 events/year. High fire danger days to increase to between 202.4-219.1 days. The increase of extreme rainfall events is less than 1. Dry spell days to increase to between 105- 112.1 days.	• Droughts and dry spells increase water demand and affect water quality. • Old settlements and infrastructure vulnerable to extreme rainfall and temperature extremes. • Loss and damage to personal assets due to flooding. • Increased insurance claims for damages which also increase insurance premiums also affecting farmers.		

		• Extreme wet and dry cycles can result in soil movement that make water and sewerage pipes more susceptible to cracking and will require rehabilitation and replacement of affected infrastructure. • Damage to unpaved and poorly tarred roads due to intense storms. • Increased expenditure on repairs to and maintenance of public and private infrastructure such as bridges. Flooding of runways and access roads.	Management Plan in place. • Disaster Management Training and Education Centre of SA (UFS) Early Warning Systems (SAWS). **Challenges** • Illegal and uncovered waste dumping particularly in informal and urban settlements. • Increased pressure on landfill sites and there is little land available for expansion. • Pit and bucket toilets still in use some areas of the province such as Botshabelo, Thaba Nchu and Mangaung. • Impacts of asbestos pollution need to be addressed in the province. • Poor management of landfills resulting in the pollution of water, land and air, as well blockage of storm water drainage systems – that exacerbates flooding in some parts of the province. • Increased pressure on urban areas as a result on rural-urban migration.	

The built environment and human settlements is regarded as having medium vulnerability based on the on-going efforts and allocation of financial resources to improve human settlements, in particular the upgrading of informal settlements as well as the efforts to upgrade water infrastructure and other supporting services for human settlements. The province has reduced the backlogs for the provision of houses and the provision of basic services, even though more still needs to be done.

4.8.2 Prioritisation of adaptation Options for human settlement and built Environment

- Integrated planning across all sectors and alignment with the IDP.
- Continued efforts to provide decent housing as well upgrading of informal settlements and old settlements.
- Accelerate the eradication of the bucket system – to curb issues of water pollution.

4.9 Social Vulnerability and Human Health

Social vulnerability is defined as "the state of individuals, groups, or communities defined in terms of their ability to cope with and adapt to any external stress placed on their livelihoods and well-being". Profiling the social vulnerability of people and communities is essential in order to identify and understand overall vulnerability; especially the ability to cope with and respond to the various impacts of climate change (Van Huysteen, 2013). Profiling spatial and social vulnerability allows planners and decision-makers to effectively develop locally relevant climate change responses for adaptation (Tapsell et al., 2010; Cutter and Finch, 2007). Social factors, although non-climatic, have a key role to play in enhancing vulnerability to climate-related events. It is important to note that different social clusters and population groups have different strengths and needs. Social factors such as social cohesion play a pertinent role in the community's coping capacity.
Climate change related impacts will only serve to exacerbate the already vulnerable population groups. The social drivers of settlement vulnerability include but are not limited to:

- **Access to basic services**: households without access to electricity, water, and sanitation and waste management services are more impacted by climate extremes.
- **Type of dwelling**: Houses that are poorly built, are poorly located, or lack flood and lightning protection, efficient water systems, cool spaces, heat-reflective surfaces or damp-proofing are a source of climate vulnerability. Informal housing (shacks) is particularly vulnerable.
- **Health**: climate resilience is dependent on baseline health, including age. Children and the elderly are more susceptible to illness, heat stress, food insecurity and malnutrition, all of which are projected climate hazards.
- **Economic factors** such as poverty and unemployment link to many of the abovementioned factors and reduce the ability of households to recover from climate shocks. Land tenure status is another important factor: households with insecure tenure such as squatters are less likely or able to invest in adaptation.
- **Demographic factors** such as age and gender. In addition to age-related vulnerabilities to health impacts; asymmetrical power relations may increase the vulnerability of women. Communities with a smaller than average proportion of working-age adults, are particularly vulnerable (DEA, 2013hs).

A social vulnerability index (Appendix 1) has been used in this study to comprehend the extent of social vulnerability in the Free State as well as identify communities that may need support in preparing for and recovering from climate variability and change (including extreme weather events) impacts.

4.9.1 Social Vulnerability

Two methodologies were used to illustrate the vulnerability of communities within the different municipalities in the Free State Province. A Social Vulnerability Index (SVI), which was developed by Le Roux et al (2015) in support of national decision-making in South Africa, was used. This index provides a comparison of vulnerability of Free State municipalities to those in the whole of South Africa (classifying them from the least to the most vulnerable). This index was built for the purpose of developing an appropriate means of measuring social vulnerability across South Africa by performing principal component analysis of 14 unique (South African-specific) variables. Factors used in the SVI were selected based on their potential contribution to human health and well-being. The SVI for the different municipalities may be derived in two ways: 1) in relation to other municipalities within the Free State and 2) in comparison to other municipalities across South Africa. The comparative SVIs for municipalities within the Free State are shown in Figure 4.3.

Population density, poverty level, education, employment status, as well as disability, all influence vulnerability to climate change. While all populations will be affected by climate change, some are more vulnerable than others , such as the elderly and children (due to their physiological development stage), people with pre-existing medical conditions, and populations with special needs populations such as the physically or mentally challenged (WHO, 2013). Vulnerable population groups have decreased ability to cope with climate change and the socio-economic status of such communities is as important as their susceptibility/sensitivity in terms of their coping capacity (WHO, 2013). Issues of social vulnerability, especially population dynamics are critical factors in how affected communities respond to climate change and are equally critical in improving the resilience of communities to climate change.

The social factors such as **employment status, head of household, poverty, type of housing, social cohesion and access to information** contribute to the adaptive capacity of households. The current challenges in the economic development of the province have resulted in increased social vulnerability, with unemployment on the increase as well as increases in poverty.

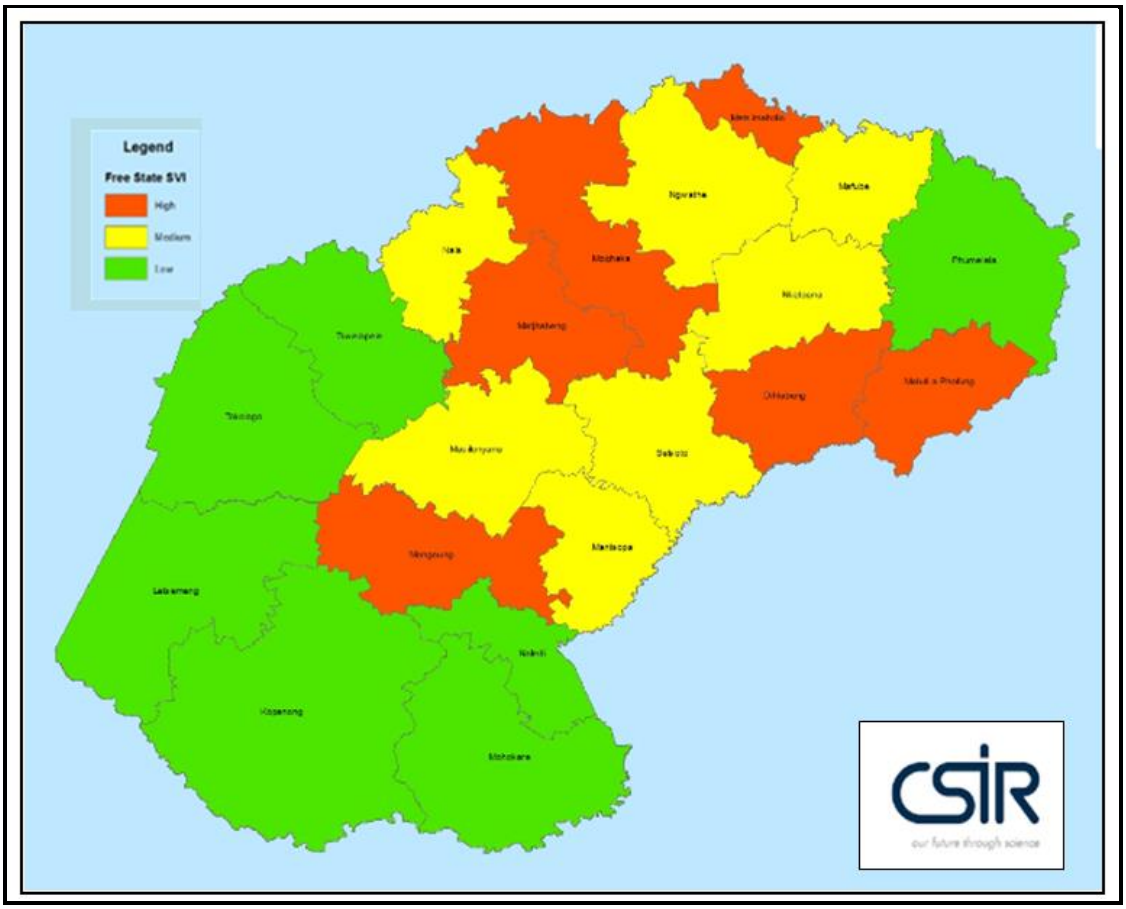


Figure 4.3: Map showing the social vulnerability of the municipalities in the Free State (Compiled by the CSIR, 2016)

The most (**highly**) socially vulnerable municipalities highlighted in the reddish/orange colour are Mangaung, Dihlabeng, Matjhabeng, Maluti a Phofung, Moqhaka, and Metsimaholo. Seven municipalities are classified as having **medium** vulnerability, highlighted in yellow colour, while the rest of the municipalities (eight) located in the mainly commercial agricultural areas are considered to have **low** social vulnerability highlighted in green. This may be attributed to low population in these areas. The main influencing factors for Mangaung include poverty, economic dependency and lack of access to transport. In term of Metsimaholo and Matjhabeng, unemployment proved to be the biggest social issue, In Maluti a Phofung, the issue of household heads is highlighted with single headed and chid headed household showing high scores of vulnerability.

Social vulnerability is a critical factor in the response of the province's population to climate change, and given the vulnerability status of some of the municipalities, extreme weather events will cause a wide range of challenges especially for the poor population in the informal settlements. Projected increases in extreme rainfall events even though they are very slight (Section 3.2) will cause extensive damages to housing and other infrastructure (which is essential for human wellbeing such as clinics and schools).

Extreme temperature variations which are also expected to increase in frequency will result in increased heat stress and together with air pollution will bring about respiratory diseases as well as high levels of human discomfort during both hot and cold months, especially affecting vulnerable populations. Issues of drought will bring about more water-related and communicable diseases as

well as other sanitation challenges in a province that is already experiencing water problems (WSS NC, 2015). Addressing service delivery backlogs will go a long way in strengthening the adaptive capacity of the vulnerable population in the Free State Province. The impacts of climate change on human health resulting from expected increases in the frequency, intensity and duration of extreme weather events are likely to have a major effect on public health (DEA, 2013). Human exposure to climate change may be direct and/or indirect, and will be determined by the character, magnitude and rate of climate variability (WHO, 2003 in DEA, 2013).

4.9.2 Human Health

A key consideration for climate change and human health is the vulnerability of the population to the impacts and the ability to cope and or respond. In this instance vulnerability is defined as the extent to which the population/health target group is prone to the effects of climate change, exposure being the contact between public health system with climate change and the extreme weather events and lastly sensitivity will be defined by the characteristics that inform the response of the system to the effects of climate change and adverse weather events (DEA, 2013h). Adaptive capacity depends on the capacity of the health system to respond to climate change and extreme weather events. The social and bio-physical factors of a population may alter the outcome of the relationship between climate change and human health; these factors include poverty, urbanisation and its associated problems (DEA, 2013h).

Table 4.16 provides an outline of the vulnerability assessment for the Social and Human Health sectors to the projected climate variables (current and future) covering exposure to the projected climatic variables, sensitivity (the extent of the impact), adaptive capacity (systems in place to respond to the impact/change), as well as vulnerability rankings.

Table 4.16: Vulnerability assessment of the Human Health sector to the projected climate variables covering exposure, sensitivity, adaptive capacity as well as vulnerability ranking

Projected Climate Variables	Exposure	Sensitivity	Adaptive Capacity	*Vulnerability*
Ranking	**High**	**High**	**Medium**	***Medium***
Average Temperature	Between 31.2°C- 31.9°C.	• High temperatures increase the extent of areas with conditions conducive to vectors and pathogens. • Increased risk of deaths from cardiovascular and respiratory diseases due to high temperatures and increased pollutants (e.g. among elderly people). • Greater risk of the transmission of vector borne diseases (VBD) and zoonotic diseases (ZD) through pathogen-host interaction.	**Strengths** • Improved human wellbeing as a result of increases access to basic services such as housing, water and sanitation. • Improved blue drop status – for water quality. • Droughts: Programme in place: malnutrition: by providing vitamin A to children less than 4 years old. • Vaccine provision for communicable diseases such as diarrhoea. • Web based outreach team is in place. • A few social development projects that support youth and women have been initiated in the province and these are: • Social entrepreneurship. • Skills development. • Household Profiling. **Challenges** • Sewage spills which pollute rives and posing health risk to communities dependent on the river e.g. Jordan River. • Declining air quality which threatens human health in some part of the province due to processing of petro-chemical e.g. Sasolburg. • Declining air quality to due to industrial and household level burning of fossil fuels. • The province has the second highest percentage of malnutrition in South Africa, which is likely to be exacerbated by climate change. • The location cattle kraals pose a health to humans.	• Human health and social vulnerability are regarded as having medium vulnerability to climate change. Despite the high exposure the provincial government is reducing the backlog in the provision of basic services, including in informal settlements. • There are social development project in place which assists to reduce unemployment and poverty but these are not enough. • More needs to be done in terms of understanding impacts of climate change and human health.
Annual Average Rainfall	**Under high mitigation** + 25.07mm/ - 112.2mm. **Under low mitigation** + 35mm / -65.9mm.	• Enhance food insecurity and malnutrition especially among the poor. • Rainfall variability can compromise hygiene and increase the risk of diarrhoeal disease.		
Extreme events (e.g. floods, dry spells, heat waves, droughts)	Very hot days to increase to between 121.1- 142.15 days. Heat wave events to increase to between 28.6-31.4 events/year. High fire danger days to increase to between 202.4- 219.1 days. The increase of extreme rainfall events is less than 1.	• High fire danger days increase the risk of death and injuries due to fires. • Extreme events such as droughts, thunderstorms and dry spells impact on social and environmental determinants of health such as clean air, safe drinking water, and sufficient food and secure shelter. • Floods can lead to a heightened risk of water-borne diseases and breeding grounds for disease-carrying insects such as mosquitoes. • Floods can also result in drowning and physical injuries, damage to		

	Dry spell days to increase to between 105- 112.1 days.	homes and disruption in the supply of medical and health services. • Very hot days and heat waves increase heat related diseases especially for people who spend more time exposed to the sun e.g. farm workers. • Heat waves and very hot days increase the levels of pollutants in the air such as ozone that exacerbate cardiovascular and respiratory disease. • Dust storms can affect human health and visibility. • Frost increases health risks especially for the poor.		

The table above provides an overview of the vulnerability of the health sectors in terms of its exposure, sensitivity and adaptive capacity. The health sector can be regarded as having medium vulnerability to climate change. Non climatic health problems in the province such as malnutrition, HIV/Aids and non-communicable diseases increase the vulnerability of communities to the impacts of climate change. Diseases such as HIV/AIDS reduce the coping capacity of individuals and households to respond and recover from shocks and stress such as drought or flood. Other health issues especially from exposure of miners to asbestos as well as asbestos roofing affect the population in the province well as putting a strain on the health system.

However, there is still need for more research to better understand the relevance of temperature-health impact relationships and the vulnerability factors applicable to the South African population.

4.9.3 Prioritised adaptation options for the human health sector

- Acceleration of delivery of basic services to improve human wellbeing and reduce vulnerability.
- Improve coordination with disaster management in case of a disaster and need for emergency aid.
- Provision of vitamin A to children less than 4 years old as part of the province programme on malnutrition
- Provide Rota and other vaccines to patients and communities to address communicable diseases such as diarrhoea and malaria.
- More financial and human resources to be allocated.
- Programmes/initiatives to raise awareness on issues of climate change at community level have been initiated in the province.
- Use the green economy initiatives to address climate related issues and employment creation.

4.9.4 Conclusion

This chapter has reviewed the vulnerability of the different economic and social sectors in Free State to climate variability and change. Free State is expected to get warmer and drier, although some projections indicate possible increases in rainfall. Significant changes in extreme weather events such as heat waves, very hot days, high fire danger days and dry spells are projected to increase under both low mitigation and high mitigation scenarios. Projections show an increase in extreme rainfall events, which, despite being slight will still affect the province.

Impacts of the projected climate change variables such as increasing temperatures, rainfall variability and extreme weather events will have devastating consequences for the water resources sector and the agriculture based economy of Free State. The province will experience reduced availability of water, given the dependency of the agriculture sector on irrigation. Other sectors such as tourism, mining, human health, and the built environment will also be affected. In addition, communities and economic sectors whose livelihoods depend on the natural environment are threatened by the loss of biodiversity and the ecosystem services they provide. On the other hand, social vulnerability which is influenced by non-climatic factors will increase the vulnerability of communities in the province. Therefore, there is a need for Free State to address underlying socio-economic factors that exacerbate the inequalities of the past through the provision of basic services, thus increasing the resilience and adaptive capacity of the communities. The process of identifying and understanding these aspects of social vulnerability in the province is a starting point for devising appropriate response plans and adaptation strategies that will assist communities to cope/adapt to the negative impacts of climate variability and change (including extreme events) while contributing to the building of communities that are resilient to these impacts.

5 Adaptation Options and Proposed Interventions

5.1 Adaptation options for key sectors in the Northern Cape

Based on the sector climate risk and vulnerability assessments in Chapter 4, adaptation options suggested by stakeholders for *water resources (surface and ground); agriculture; biodiversity and wetlands; tourism; mining; transport; energy, human settlement and built environment, social vulnerability and human health* sectors to enhance and build on their current adaptive capacity are summarised as follows:

5.1.1 Water Resources Sector

The projected changes in climate will impact on surface and ground water resources *availability, conservation, quality, as well as supply and demand*. Adaptation of these areas will ensure that it includes making sure that there is adequate and quality water supply to meet the demands for the different sectors. Some of the suggested adaptation options for this sector include (*See Annexures for detailed options*):

Surface Water Resources

I. **Reduce water losses through leakages by fixing leaks and reducing the amount of water in pipes during off peak periods, while remaining sensitive to the needs for human health and well-being.** The projected increases in temperature and rainfall coupled with aging and leaking infrastructure will result in water shortages for various sectors and human consumption in the province. Increased evaporation rates and water losses especially from the Lower Orange catchment .catchment. Increased spread of invasive species which favour higher temperature and consume more water. Drying of wetlands will affect water quantity and quality as well as and will result in the loss of ecosystem services. Furthermore, the projected reduced rainfall will affect water availability and quality and worsen the levels of drought that the province is currently experiencing; and variability will affect runoff in the Orange and Vaal catchments. On the other hand, the projected increase in rainfall will contribute to the growth and extent of alien invasive species, as well as bush encroachment in some parts of the province; where the grassland biome will be replaced by the savannah resulting in devastating impacts for livestock grazing and the livelihoods of communities and farmers and as the province's economy. Potential increases in rainfall will be beneficial to socioeconomic activities. Lastly, the projected increases in high fire danger days that will be experienced in the province will result in increased conditions favourable for fires, and will require lots of water to extinguish (put-off). Various initiatives (such as water restrictions; introducing rain water harvesting for agriculture and household use; raising awareness on climate change water conservation and adaptation; restoring and protecting ecosystems such as wetlands that improve stream flow and water quality; etc.) are currently underway in the province to address leaks and reduced dam water levels, and these efforts need to be expanded in the province.

II. **Intensify water *conservation* efforts in all municipalities including increasing investment in water smart technologies and appliances.** The projected increases in temperatures will result in increases in evaporation of dams and rivers coupled with evapotranspiration that will result in the reduction in water availability required to meet the demand for water in the province. The projected increases in rainfall and extreme rainfall events are likely going to cause sedimentation in the Upper Orange River due to the sandy

soil structure. Concerted efforts to conserve water at provincial, district and local municipal levels as well as by key sectors such as human settlements, agriculture and mining, etc. will be required for the province to cope with these impacts.

III. **Improve sanitation systems to minimise groundwater pollution from human settlements, as well conserving, protecting and restoring wetlands to assist in purifying water**. Poor water quality will affect the quantity of water that is available and fit for human consumption. The projected increase in rainfall may result in flooding in some parts of the Vaal catchment and may also affect water quality and exacerbate the risk of acid mine drainage. Furthermore the decline in water quality available for human consumption as a result of pollution from mining, agriculture and human settlements activities is also a serious concern in the province.

IV. **Strengthening of the water supply infrastructure in the province.** To be able to meet the water supply and demand needs of the province, the province is currently investing in programmes aimed at strengthening water infrastructure to ensure effective delivery and access to water, storage and distribution. In addition, the province is upgrading infrastructure to monitor and curb water losses due to leakages as well as improving coordination between sector departments, particularly when developing sector specific adaptation responses and implementing projects. Some of the initiatives include upgrading bulk water supply infrastructure to monitor and curb water losses due to leakages, through introducing effective early warning system for impending extreme events, as well as systems to retain storm water for use for during drier periods (such as rain water harvesting; and upgrading and maintaining storm water drainage infrastructure to avoid flooding during intense rainfall events and damage to infrastructure, etc.). The projected increases in heat waves, very hot days, dry spells and droughts is likely going to result in increased evaporation rates and demand for water in the province.

V. **Invest in initiating and conducting research on climate smart agriculture practices and techniques for irrigation to save water.** The Free State Province is already experiencing water shortages due to drought as a result of the El Niño phenomenon. Implementing climate smart agricultural practices to ensure effective water use will benefit this sector. Examples climate smart agricultural practices that can be implemented include the use of recycled water from sewage treatment works for gardening and urban agriculture; enforcement of the requirement that Department of Water and Sanitation takes into account the impact of climate change on rainfall and run-off when reviewing or granting water use licences and water purchase agreements; and promoting water harvesting in local and farming communities.

VI. **Restore and protect ecosystems such as wetlands that improve stream flow and water quality.** The province has initiated various initiatives such as the removal of alien invasive species aimed at rehabilitating and restoration of wetlands to improve on the ecosystem services that they offer. The province is collaborating with the National Department of Environmental Affairs Working for Water and Wetlands programmes on a few interventions focusing on restoring the natural resources.

Ground Water Resources

VII. **Encourage water conservation and demand management for settlements dependent on groundwater.** The projected reduction on rainfall in province will result in increased evaporation reduced groundwater availability.

VIII. **Encourage artificial recharge (transfer of surplus surface water underground by injecting it into aquifers using boreholes).** The projected decrease in rainfall and increase in extreme weather events such as dry spells and very hot days can lead to increased demand for irrigation with groundwater and may also impact on groundwater recharge resulting in reduced groundwater availability.

IX. **Put measures into place to reduce groundwater pollution from waste water treatment plants, agriculture and mining activities.** The projected increase in temperature and intense storms will result in decreased groundwater quality and pollution of groundwater sources by organic matter, pesticides and heavy metals especially where recharge aquifers.

X. **Optimisation of the water monitoring network.** The province have initiated the monitoring network for rivers, boreholes, water quality to capture quantities, qualities and levels of underground water available for in the province. The increased demand for water for human consumption in small towns where bulk water supply is expensive or inaccessible. These projected decreases in rainfall and water availability may also result in increased cost of water.

5.1.2 Biodiversity and Environment

I. **Monitor trends of how climate variability's and change is impacting on biodiversity and investment in biodiversity off-sets.** The projected changes in temperature will affect the composition and functioning of biomes and the ecosystem services such as pollination by birds and insects as well as breeding cycles of reptiles and amphibians and productivity of medicinal plants and grazing land for subsistence livestock that they provide. Furthermore, changes and shifts in rainfall seasons and patterns will affect the quantity and timing of stream flow recharge which also affects wetland structure and functionality. The province is investing in various initiatives such as the conservation of national parks and botanical gardens, as well as the mapping of wetlands to show their status, which is crucial in their management – to establish a basis for identifying areas to target and channel for conservation and restoration efforts. In addition, the University of the Free State has a global registry or biodiversity repository which will assist with biodiversity conservation.

II. **Capacity building and awareness raising of communities on the importance of biodiversity and ecosystem functions to encourage conservation.** Given the fact that the projected climatic changes will impact negatively on the province; the province is currently exploring implementing various initiatives such as the Biodiversity Education Programme that will help to raise awareness of school learners and communities need to be initiated across the province; as well as participating in DEA's GroenSebenza programme to promote skills development and employment in the biodiversity sector.

III. **Minimising loss of biodiversity through the protection of threatened and vulnerable ecosystems.** The projected decrease in rainfall and changes in seasonality threaten biodiversity and result in changes in bioclimatic envelopes. Projected intense storms can result in loss of top soil that can result in biodiversity losses, and rapid siltation of rivers and

dams. On the other hand, the projected increases in rainfall and temperatures in some parts of the province are likely going to contribute to the growth of alien invasive species and bush encroachment, where grasslands will be replaced by savannah biomes – thus impacting on the livestock grazing and the resultant livelihood of communities and famers in the province. The province is currently participating in the Department of Environmental Affairs' Working for Water, Wetlands and Ecosystems programmes to minimise the impacts of climatic conditions of the natural resources in the province.

IV. **Removal of alien plant species, replacing them with indigenous plants.** Strengthen collaborations with DEA's Working for programmes that focus on the removal of alien invasive species to improve and maintain sustainable of ecosystem services. Collaborate with other key sectors, such as the agricultural to implement climate-smart agricultural strategies that help in the restoration and management of threatened grassland ecosystems while also creating jobs; remove and control invasive alien plants, and replace them indigenous plants.

5.1.3 Agriculture

I. **Assess alternative crops that are more resilient to higher temperatures and lower rainfall conditions.** The projected increase in temperature and decreases in rainfall in some parts of the province will result in increased evaporation and evapotranspiration rates and increased demand for water for irrigation resulting in the decline in agricultural productivity (crop yields), affecting livelihoods dependent on farming, the provincial gross domestic product, and South Africa's gross agricultural income.

II. **Develop as well as invest in a Climate Smart Agriculture programme that will explore applicable and improved irrigation technologies and maintenance to minimise water losses from commercial farming activities.** The projected reductions and rainfall and increased temperatures will result in water shortages as well as reductions in crop yield for this sector. The province is currently implementing various initiatives such as the *introduction of water storage and the provision of incentives to water smart users; develop and promote the use of specific seed or plant varieties in specific locations; as well as switching from crop to livestock (or vice versa) farming measurement of agricultural efficiency from using more to less water resources.* Farmers need to ensure that they use efficient irrigation techniques that consider soil type, crop type, soil water status and weather conditions. The province needs to also conduct research into short season and drought resistant crop cultivars and livestock suitable for the province.

III. **Investigate breeding options for livestock under the projected climatic changes**. The projected increases in temperature and very hot days are likely going to reduce livestock breeding levels as well as disease potential, such as increases the transmission of infections of tick-borne diseases; emergence of new diseases and/or changes in the prevalence of existing diseases; reduced feed intake which reduces the productivity of all forms of livestock; decrease in milk yield and conception rates; as well as decline in reproductive rates and weaning weights. Limited efforts are currently underway in the province to address this impact, and need to be strengthened. In addition, the province need to investment in research on diseases and pests that will potentially affect agriculture, e.g. locusts given the fact that the projected changes in climatic conditions is likely going to enhance conditions that favour increases in pests and diseases affecting some crops and livestock. Furthermore, changes in the timing of rainfall have the potential to enhance the

range and abundance of disease vectors and pathogens that may affect livestock and the quality of fodder.

IV. **Conduct capacity building, awareness and training for all farmers to communicate the projected climatic changes as well as their likely impacts on the sector and possible adaptation options; to build resilience of this sector.** The province initiated various initiative aimed at empowering farmers on the adoption and use of various climate smart practices to cope with the negative impacts of climate change. For instance, the Free State Department of Agriculture and Rural development has a new Agriculture Integrated Growth and Development Policy (IGDP) and Agriculture Policy Action Plan (APAP) that will assist in the growth and development of the sector, reducing food insecurity and increasing contribution to GDP. The sectors targeted for implementation of the plan include crop production, livestock, dairy, poultry, aquaculture and horticulture. The growth plan will include financial investment and support for emerging farmers as well as women and the youth involved in agriculture (FS DARD, 2015).

V. **Strengthen governance and institutional arrangements issues in the province to support initiative aimed at building resilience in the agricultural sector.** Lobbying for political and the farming community to partner to implement climate smart related projects, regulations and policies within the province is being strengthened at the provincial and local municipality levels, to ensure buy-in by all relevant stakeholders. In addition, the province needs to also improve and institutional arrangements such as human resources, budgets and support in the implementation of existing and propped adaptation options for this sector. Furthermore the province needs to also explore and take advantage of global funding opportunities on climate change (e.g. Global Climate Fund, Adaptation Fund, Global Environment Facility, etc.).

VI. **Practice conservation agriculture which uses an integrated approach to harvest field, roof and road rain water runoff to complement irrigation especially at small scales.** Practice sustainable and efficient application of nitrogen fertilisers or switch to organic farming. Build shaded areas to reduce exposure of dairy cows to heat stress that may result from the projected increase in the annual number of very hot days in the province that is likely going to reduce the quantities of milk provided by dairy cows.

5.1.4 Mining

I. **Develop and adopt strategies for efficient water use and increase water conservation by the Free State mines.** Given the fact that the mining sector is one of the major water users in the province; the projected higher temperatures and low rainfall scenarios in some parts of the province will result in the evaporation of dams and water shortages for this sector. This will reduce the efficiency of operation of mining equipment and water available for operational processes. This will results in reducing the productivity of the mines that will impact on the yields and turn over for this sector.

II. **Conduct research focusing on how to address the challenges and opportunities presented by the projected climatic conditions to the mining sector, to be able to introduce sector specific adaptation measures.** The projected increases in temperatures and very hot day is likely going to impact on the materials used to construct mining equipment (iron and steel) and human health of employees working at the mine. High temperatures can also reduce efficiency of the mining equipment and increase the

need for cooling for water-treatment processes. In addition, operating thresholds of equipment may be exceeded during episodes of extreme high temperature, causing delays.

III. **Invest in capacity building, awareness and training of the mine management and employees to capacitate them to understand the likely impact of the projected climatic condition on the mine, their health and livelihoods.** Identify health and safety issues, symptoms, hazards, and preventative measures associated with the projected climatic conditions such as heat related health conditions and the associated heat stress resulting from these conditions. Develop and adopt strategies for making efficient use of water and increase water conservation (for instance through recycling of used water, rain and storm water harvesting, etc.) at the mine sites.

IV. **Undertake yearly progressive rehabilitation to address soil erosion and pollution that can be exacerbated by the projected increase in extreme rainfall events that may result in flooding and soil erosion.**

5.1.5 Tourism

I. Upgrade and maintain the transport infrastructure to improve accessibility and mobility that supports economic activities such as tourism. The projected increases in extreme weather events such as heavy rainfall events and storms in some parts of the province may cause damages to the tourism infrastructure flooding of access roads and damage to hotel and resort infrastructure. This will lead to increase in operating costs for cooling, irrigation, food and water supply, and insurance costs, thus impacting on the incomes and livelihoods of this sector and its employees.

II. **Early warning systems for impending disasters that could destroy tourism infrastructure, as well as enhancing emergency preparedness requirements (such as backup water and power systems, medical supplies, etc.).** The projected increases in the annual number of fire day's events that will pose threats to the tourism infrastructure especially for resorts that use thatched roofing. The Free State Province working in collaboration with the South Africa Weather Service is currently providing early warning systems for the province (Francis Mosetlhe – FS SAWS, 2015, Personal Communication).

III. **Raise awareness and increase resources into the maintenance, management, conservation, and restoration of ecosystems important for tourism (ecosystem based adaptation), communities and other sectors.** The biodiversity tourism sector of the province is vulnerable to the projected climatic changes. The projected reductions in rainfall and increasing temperatures can result in loss of biodiversity (particularly at the flora hotspots parts of the province) resulting in the decline in the number of tourists visiting the province and revenue generated from this sector. This will impact the income of this sector and the livelihoods of people that are dependent on the sector.

IV. **Invest in capacity building, awareness and training of people in the hospitality industry.** Conduct workshops and awareness campaigns to communicate information on the potential impacts that the projected climatic conditions will have on this sector, as well as empowering this sector on the various adaptation options and opportunities that may result from these impacts.

5.1.6 Transport

I. **Continued investment in multi-modal transport and logistics hub which will promote economic development in freight sectors in the province.** Increase the budget allocation for maintenance and upgrading of transport infrastructure which is currently inadequate. The projected higher temperatures can accelerate the ageing of road surfacing bitumen layers, as well as weakening the structural strength of road surface.

II. **There is continued need to upgrade gravel roads to improve roads across the province.** Unpaved and gravel roads will be vulnerable to projected increases in extreme rainfall and flooding events. The province needs to invest in paving and upgrading roads and storm water drainage systems across the province to harvest rain water that can be used during drought conditions.

III. **Capacity building and raise awareness on the likely impacts and opportunities that the projected climatic conditions are likely going to have on this sector.** The province needs to educate management and employees of this sector in the potential impacts that can be experienced from the projected provincial climatic conditions such as the impacts of extreme heat on workers and the entire transport infrastructure.

5.1.7 Energy

I. **Enhance investments in alternative energy supply sources such as renewable energy technologies (e.g. solar, wind, hydro power etc.) and products such as solar water geysers and panels, etc. in the province.** The projected increase in temperature and extreme weather events (severe thunderstorms, snow, etc.) will compromise the supply of electricity in the province; by damaging the infrastructure and also causing sagging and clashing of transmission and distribution line cables - and this may result in fires that can damage electricity infrastructure in the province. Furthermore, the projected flooding may also damage energy generation, transmission, distribution and substation infrastructure. This will compromise the security of supply of electricity in the province and will have negative impacts on the incomes of households and businesses operating in the province. The Free State province is currently implementing various initiatives such that focus on the roll-out of solar and hydro power generation. However, the scale at which these initiatives are being implemented can be improved to cover the entire province.

II. **Increase the power generation capacity to meet the demand for energy from mining, agriculture and human consumption. This could include upgrading essential infrastructure for the storage and distribution of power in the country.** Increase in temperature will result in increased energy demand for cooling for both human and animals, thus putting pressure on the current energy generation and supply capacity of the existing infrastructure. Furthermore, frost/snow builds up and damages transmission and distribution lines as well as substations; thus impacting on the continuity of electricity supply in the province.

5.1.8 Human Settlements and the Built Environment

I. **Upgrading, maintenance and replacement of old water and sanitation infrastructure.** The projected decrease in rainfall and increase in temperature will result in impacts such as water shortages and evaporation of water stored in dams; reduced stream flow and groundwater recharge which will consequently lead to an increase in the unit cost of water for settlements. Extreme events such as floods will cause extensive damage to the built environment infrastructure (i.e. water, transport, energy and communication).

II. **Intensify existing awareness campaigns on water conservation, climate change impacts on human settlements in the province; as well as in communities and schools on waste management and recycling.** Training of community volunteers to assist in the event of disasters, which also provides them with skills that they can use to look for jobs. Old human settlements are vulnerable to extreme rainfall events such as flooding of homes that can lead to loss and damage to personal assets.

III. **Provision of fairly good basic services is across the province but needs to the accelerated.** The projected decline in rainfall and dry spells affect water availability and quality especially for majority of communities who rely on groundwater. In addition, the projected rainfall variability and dry spells affect stream flow and groundwater recharge which will consequently lead to an increase in the unit cost of water from dams/boreholes, and this cost will be passed through the water value chain resulting in higher water tariffs for users. On the other the projected increases in extreme weather events such as flooding and thunderstorm will damage households and personal assets in some parts of the province. The province is currently investing in upgrading the storm water drainage systems infrastructure to channel excessive rainwater properly. The town planning system includes making sure that human settlements are not located along the flood plains.

IV. **Build capacity of government officials so that they can integrate climate change into planning and decision making.** On-going capacity building, awareness and training need to be undertaken to capacitate officials on how to address and ensure mainstreaming of climate change issues; particularly the projected changes in climatic conditions in human settlements planning and developmental plans.

5.1.9 Social Vulnerability and Human Health

I. **Increase public awareness on communicable and non-communicable diseases associated with climate change.** The projected high temperature increase is likely going to result in various human health impacts such as heat stress, the development of conditions conducive to vectors and pathogens as well as increased risk of deaths from cardiovascular and respiratory diseases due to increased atmospheric pollutants (especially among children and elderly people). The Free State Provincial Department of Health is currently rolling our community engagement and primary health care initiatives aimed at assisting vulnerable community groups to adapt to these impacts; using the National Climate change response strategy for the human health sector The Department is currently intensifying various programmes such as providing vaccines for communicable diseases such as diarrhoea; insulating houses to protect communities against heat waves and very hot and cold days (Mokgatlhe, 2015, *Personal Communication*).

II. **Develop early warning and effective disaster risk management systems that utilise weather forecasts to alert communities to the potential health risks of extreme weather events and the pollution levels.** The projected climatic conditions particularly increases in the number of extreme rainfall events will severely affect vulnerable communities by increasing condition that will enhance the spread of various diseases, particularly in isolated rural communities in the province; as well as causing a wide-spread destruction of assets resulting in remote rural communities being cut off from essential services. The Province's Social Development Department – Disaster Management Office is currently collaborating with the South African Weather Service to provide early warning systems and seasonal forecasts to communities in the province.

III. **Invest in community outreach programmes to educate communities on health risks of increasing temperature and other climatic variables.** Increase public awareness on communicable and non-communicable diseases associated with climate change.

5.2 Institutional structure

The province needs to identify and put into place structures and working groups to facilitate the implementation of this climate change response strategy in the province. These institutional structures need to have specific roles and responsibilities outlined in order to achieve set goals on climate change adaptation. This should be done at various levels and with different role players and can include:

- An institutional structure responsible for planning, prioritising, implementation, as well as monitoring and evaluating the province's response activities
- Keeping a database of current climate change adaptation response activities undertaken by different stakeholders and their objectives and anticipated outcomes
- Partnerships with other stakeholders who have vested interests in climate change response locally and internationally.
- Establishing partnerships with specialists and researchers in the field of climate change to stay abreast of new science and technology.

The province needs to have an understanding of climate change adaptation so that they can mainstream climate change into their strategic and corporate processes and actions to achieve the ultimate goal of sustainable development.

5.3 Partnerships for integrated response

Climate change response requires collaboration between stakeholders to avoid duplication of efforts and wastage of resources. Partnerships also allow for stakeholders to share resources and lessons learnt so as to maximise the effectiveness of climate change adaptation activities. DESTEA would need to lead some of these activities while in some instances it would have to facilitate and support other role players who can be in the private or civic sector. Possible partners in the FS province include:

- Government stakeholders from neighbouring local and district municipalities, provincial government, as well as national government.
- University of Free State as well as other tertiary institutions.
- Funding institutions, research institutions and project implementers in South Africa and internationally.
- Private companies.

- Non-governmental and community based organisations.

5.4 Resource and finance mobilisation

Climate change response is expensive and in many developing countries such as South Africa the need is high and direct government funding is limited by other pressing development needs such as the provision of basic services. There is a need for funders at different spatial scales to shift current and projected "business-as-usual" investments, and mobilise resources at the scale required. However for DESTEA to access this funding (on behalf of the entire province), it needs to have an understanding of the province's climate response needs and the institutions that can be approached for funding. DESTEA also needs to have a solid business case that can be financed through grants, concessionary finance, risk insurance, specialised environmental funds and new capital market innovations, for example green and climate bonds (Western Cape Government, 2014:40). The province will also need to create an enabling environment so that these resources can be utilised effectively without succumbing to institutional barriers.

The province needs to continuously seek and maintain the financial resources for climate change adaptation over a long term as the benefits of these activities are realised over time. DESTEA needs to promote partnerships between multiple stakeholders (e.g. industry, civil society, and local government and research institutions in the climate response projects so as to promote sharing of resources as well as skills and capacity building. In addition, to the South Africa National Government budgeting processes and allocations; there are various financing mechanisms and partnership opportunities that can be targeted and accessed by the Free State Province to secure funding for the implementation of the proposed adaptation responses outlined in this strategy. Some of these funding mechanisms (national and international) include the following (*but not limited to*):

- Global Environment Fund (GEF)
- Global Climate Fund (GCF)
- Special Climate Change Fund (SCCF)
- Adaptation Fund (AF)
- Green Fund
- Natural Resources Management (NRM) and Expanded Public Works Programmes (EPWP)
- Environmental Protection and Infrastructure Programme (EPIP)
- Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) support programme

- **Global Environment Fund**

The Green Climate Fund (GCF) was adopted as a financial mechanism of the UN Framework Convention on Climate Change (UNFCCC) in 2011. This fund aims to make an ambitious contribution to attaining the mitigation and adaptation goals of the international community, and it is expected to become the main multilateral financing mechanism to support climate action in developing countries over time.The GEF's Small Grants programme (SGP) is a programme that specifically invests in the development of underprivileged communities impacted by the effects of environmental degradation. The work that has been done by the GEF SGP supported projects has contributed significantly to the environmental conservation by local communities, particularly on biodiversity conservation and climate change mitigation, which has had the added benefit of

contributing global environmental benefits.

In South Africa, the focal point of the SGP is the Department of Environmental Affairs, which is responsible for the general oversight of the programme and is the custodian of GEF Funds. The Fund is managed by the Development of Bank of South Africa (DBSA) on behalf of Department of Environmental Affairs and provides funding to low carbon, resource efficient and climate resilient projects. This fund is available to all non-governmental organizations and community based organisations working towards the achievement of environmental sustainability for local and global benefit. Each successful applicant is eligible to financial support of up to USD$ 50 000 per project. *Source: http://www.climatefundsupdate.org/data/the-funds-v2*

- **Green Climate Fund**

The Green Climate Fund (GCF) was adopted as a financial mechanism of the UN Framework Convention on Climate Change (UNFCCC) at the end of 2011. This fund aims to make an ambitious contribution to attaining the mitigation and adaptation goals of the international community, and it is expected to become the main multilateral financing mechanism to support climate action in developing countries over time. The board of the GCF met for the first time in August 2012 and its modalities will be agreed throughout 2012 with a goal of making the fund operational by early 2014. In South Africa, this fund is managed by the Development of Bank of South Africa (DBSA) on behalf of Department of Environmental Affairs and provides funding to low carbon, resource efficient and climate resilient projects.
Source: http://www.climatefundsupdate.org/data/the-funds-v2.

- **Special Climate Fund**

The Special Climate Change Fund (SCCF) was created in 2001 to address the specific needs of developing countries under the UNFCCC. It covers the incremental costs of interventions to address climate change relative to a development baseline. Adaptation to climate change is the top priority of the SCCF, although it can also support technology transfer and its associated capacity building activities. This fund is intended to catalyse and leverage additional finance from bilateral and multilateral sources. *Source: http://www.climatefundsupdate.org/data/the-funds-v2.*

- **Adaptation Fund**

The Adaptation Fund is a financial instrument under the UNFCCC and its Kyoto Protocol (KP) and has been established to finance concrete adaptation projects and programmes in developing country Parties to the KP, in an effort to reduce the adverse effects of climate change facing communities, countries and sectors. This fund was established by the Parties to the Kyoto Protocol of the United Nations Framework Convention on Climate Change to finance concrete adaptation projects and programmes in developing countries that are parties to the Kyoto Protocol (KP). The fund is financed by 2% of the Certified Emission Reduction issued for projects of the Clean Development Mechanism and from other funding sources. The board operationalised the Direct Access Modality, which allows recipient countries to have direct access to its funds through National Implementing Entities (NIE), to ensure that projects are driven by country needs and priorities. As of March 2016, 23 NIEs have been approved by the AF Board. The South African National Biodiversity Institute (SANBI) serves as the accredited National Implementing Entity (NIE) to the Adaptation Fund in South Africa. *Source:* http://www.sanbi.org/news/south-africa%E2%80%99s-first-adaptation-fund-projects-approved

- **Green Fund**

The Green Fund is a national fund that seeks to support green initiatives to assist South Africa's transition to a low carbon, resource efficient and climate resilient development path while delivering

high impact economic, environmental and social benefits. The Fund is managed by the Development of Bank of South Africa (DBSA) on behalf of Department of Environmental Affairs. *Source:* http://www.sagreenfund.org.za

- **Natural Resources Management (NRM) and Expanded Public Works Programmes (EPWP)**

The NRM and EPWP programmes were initiated by DEA in 1994. They are aimed at addressing unemployment through inclusive economic growth and working with communities to identify local work opportunities that will also directly benefit the wider communities. The programmes are centred on environmental rehabilitation, environmental protection, and socio-economic development for local communities.
Source: https://www.environment.gov.za/projectsprogrammes#workingfor

- **Environmental Protection and Infrastructure Programme (EPIP)**

The EPIP has been implemented by DEA since 1999. Since then the programme has evolved and grown from a budget of R75 million in 2000 to more than R750 million. Over the years the programme has successfully developed projects through Working for the Coast, Greening and Open Space Management, People and Parks, Working on Waste, Working for Land, Working for Wetlands, Working for Wildlife, and Youth Environmental Services.
Source: https://www.environment.gov.za/branches/environmental_programmes

- **Gesellschaft für Internationale Zusammenarbeit (GIZ) support programme**

GIZ is German funded development cooperation, supporting the German Ministry for the Development, Environment and Climate Change. GIZ has been working on a number of climate support programmes in South Africa focused on the development and implementation of environmental policies. The programme has supported development of sectoral GHG reduction targets for South Africa as well as the LTAS. In collaboration with DEA, it is supported development of Climate Adaptation Response Strategies for the Free State Province.
Source: https://www.giz.de/en/worldwide/312.html

5.5 Programme- based approach

Sector departments are responsible for undertaking programmes to integrate adaptation activities for their sectors. This should be done in consultation with other sector departments and not in isolation, as some of these activities overlap. For example, promoting investment in community food production and urban gardens requires partnership between the agriculture and social and community development sectors.

5.6 Role players and continuous capacity building

Climate change adaptation is a multilevel governance challenge because its impacts cut across different government levels, sectors and social groups (Bauer and Steurer, 2014). Responding to these impacts also requires collaboration between these different groups. The Disaster Management Act (Act no 57 of 2002) makes provision for “an integrated and coordinated disaster management policy that focuses on preventing or reducing the risk of disasters, mitigating the severity of disasters, emergency preparedness, rapid and effective response to disasters and post disaster recovery” at various levels of government. Climate change has an impact on every sector

and department in the Free State province. Adaptation efforts are only effective if there is real commitment to collaborate from stakeholders both within and external to the province. This requires effective communication and coordination among the different role-players. In doing so, it will be important for departments to understand their respective roles and how they interface with that of other stakeholders. Assessing the linkages between stakeholders (Table 5.4) is important as it will help to identify synergies between them and ways in which strategies can be aligned and implemented across institutional boundaries.

Table 5.1: Stakeholders that can contribute to climate change response and their roles

Stakeholder	Role
Community based organisations	• Awareness raising in communities, • Develop adaptation projects to improve livelihoods and food security • Enhance communities' adaptive capacity
Small, Medium and Micro-sized Enterprises (SMMEs)	• Contribute to adaptation through green economy projects and creating green jobs
Community Policing Forum	• Assist with disaster management
Civil Society	• Assist with adaptation implementation projects at local level. • Identify members of the community who need special assistance
Schools; Early childhood development centres; School governing bodies, Tertiary institutions	• Raise awareness among children. • Tertiary institutions can conduct research to understand as well as find solutions for local climate change and development challenges
Disabled groups	• Develop climate change information to cater for disabled persons' needs
Faith based groups	• Climate change awareness raising within the community
Business forums	• Provide resources to support climate change response projects and improve livelihoods • Apply low carbon measures and resource efficiency in operations • Raise climate change awareness amongst employees; • Improve working conditions of employees who are required to work in harsh climatic conditions
Political leaders	• Awareness raising and support for implementation of climate response projects
Community	• Engage in climate response projects such as energy saving, water conservation and recycling of waste • Volunteers for disaster response

Capacity Building and Stakeholder engagement workshops were undertaken to facilitate knowledge transfer, build capacity, identify vulnerabilities and risks, determine the level of adaptive capacity, and identify opportunities to adapt, prioritise adaptation options and/or projects, gather input and get feedback from Free State stakeholders. Workshops were conducted on 20 January 2016 and 23 February 2016 in Mangaung (Bloemfontein), and on 30 June 2016 (see Figure 5.2 below) in Welkom, respectively. Workshops were attended by stakeholders from various key

economic sectors and departments within the province. Therefore, in the implementation of this response strategy, it is important\ for DESTEA to continuously engage stakeholders in capacity building for purposes of knowledge transfer, exchange of information, buy-in and ownership.

Figure 5.2: Capacity Building and Stakeholder Engagement workshop held in Welkom on 30 June 2016

6 Conclusion

Free State already experiences some of the highest daily temperatures, with the highest temperatures recorded in the northern parts of the province. Climate change projections present a robust signal that temperatures will increase, along with the number and frequency of very hot days, heat wave days, and fire danger days. These increases in temperature will result in an increasing aridity overall, regardless of rainfall received. Projected temperature increases are smaller under high mitigation scenarios, and larger under low mitigation scenarios. Temperatures are projected to rise by 1.6 °C and 2.3 °C under high and low mitigation scenarios respectively over the province for the period 2020-2050 relative to the baseline period (1971-2000).

Some model ensembles project drying, while others project wetting; and these results are highly spatially variable and highly seasonal. Projected changes in rainfall and related extreme events exhibit more uncertainty than projected temperature changes. However, the ways in which rainfall interacts with rising temperatures, as well as the projected increase in the number of dry spell days; will contribute to an overall drying trend in Free State. Projected changes in climate variables will expose a variety of key sectors (such as water, agriculture, biodiversity, human health and settlements) in the province to various climate related risks. A risk and vulnerability assessment was undertaken to understand the level of risks to which the sectors are exposed. The impacts of the projected changes in rainfall and temperature highlighted key vulnerability issues that will affect the economic development of the province due to reduced availability of water. In the province, rainfall variability and droughts increase the vulnerability of social and economic sectors such as tourism, mining, human health and agriculture. Communities and economic sectors whose livelihoods depend on biodiversity are especially vulnerable to the projected trends, thus impacting on the ecosystem services that they provide.

On the other hand, social vulnerability of communities is influenced by factors such population density, poverty levels, education, employment status, access to information and disability. Socio-economic conditions and inefficient institutional arrangements often limit the capacity to prevent or mitigate climate change impacts and extreme events. These non-climatic factors enhance the vulnerability of regions and therefore an assessment was undertaken of the underlying social and economic factors that influence vulnerability, together with processes that shape the consequences of climate change, to identify the conditions that enhance or reduce vulnerability to adverse outcomes. This assessment focused on addressing inequalities of the past as well as the provision of basic services to communities, as this will go a long way to reducing the social vulnerability of the province.

The process of identifying the location and nature of the respective vulnerability aspects in Free State is a starting point for devising appropriate response plans that will combat climate variability and change impacts in the province while, at the same time contributing to building of communities' resilience to climate change. To enhance its adaptive capacity, Free State has been proactive in developing institutional structures, policies and other legal documents that link to the National Climate Change Response Policy and the National Development Plan, in order to implement climate change adaptation responses in the province. The province has several programmes and projects currently underway that are aimed at building the resilience of key economic sectors such as water, agriculture, biodiversity and disaster management. However, the province still experiences challenges that compromise its adaptive capacity, including lack of both human and financial resources and skills at various departments to address climate variability and change, such as water management and environmental management, political interference in water provision and management, and limited coordination of efforts between and within sectors to

respond to climate change. As a way forward a Climate Change Response Action Plan for the response options need to be developed by DEA in consultation with DESTEA and representatives from the identified vulnerable sectors within the province. This action plan will assist the province address the issues of climate variability and the long term climate change risks to ensure effective implementation of the prioritised adaptation options that were proposed by the sectors during stakeholder engagement and capacity building processes.

7 Recommendations

This strategy has been developed through consultation with external stakeholders to ensure that it is a Free State-wide strategy, and encourages the level of buy-in and partnerships required to transition Free State into a climate resilient province. Since successful implementation requires cross-sectoral action, all sectors are encouraged to develop plans to implement the sections of the strategy that are relevant to their sectors. These sectoral plans should identify key performance indicators for key implementing agencies. In addition, formal linkages should be established with relevant provincial and national departments to ensure that local climate change responses are aligned with provincial and national efforts. Partnerships will be formed with neighbouring municipalities to co-ordinate a regionally appropriate response to climate change (Draft Durban Climate Change Strategy, 2014). The following are recommendations for the Implementation of the response strategy:

Table 7.1: Recommendations for the implementation of the strategy

Action	Responsibility
Establish an inter-sectoral forum to promote partnerships between the sectors, support existing work in responding to climate change and to oversee the implementation of the strategy.	DESTEA
Develop implementation plans for each of the sectors. The implementation plans should detail the steps involved in implementing the strategy	All sectors
Identification of funding opportunities for the implementation of the key priorities in each sector	All sectors, DEA could also assist in identifying sources of funding and facilitate transactions
Promote alignment of the strategy with sectoral policies and plans	DESTEA and all sectors
Promote alignment of the strategy with the Integrated Development Plans (IDPs)	DESTEA and various district and local municipalities (facilitated by with SALGA)
Revision of the Strategy to incorporate latest developments (such as new interventions related to policy and plans, new innovations, etc). Reviews of the strategy should be published and participation of the public in the review process should be promoted.	DESTEA
Continuous capacity building workshops	DESTEA
Monitoring and Evaluation. DEA in collaboration with DESTEA should establish a system for monitoring the implementation of the strategy. Key indicators of performance should be identified (and agreed upon with sectoral departments / municipality and any other stakeholders) and revised annually.	DEA in collaboration with DESTEA

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9 IMPLEMENTATION PLAN FOR THE FS CLIMATE CHANGE RESPONSE STRATEGY

Table A1: GENERAL AND CROSS-CUTTING MEASURES: PROPOSED FRAMEWORK FOR IMPLEMENTATION

GOAL: HARMONIZED AND COORDINATED CLIMATE CHANGE STRATEGIES, PROGRAMMES AND ACTIONS						
Objective	**Sub-objective**	**Target/Actions**	**Indicators**	**Time frames**	**Responsible/Lead Agency**	**Partners**
Establish a provincial framework for harmonised and coordinated response to climate change.	Enhance institutional cooperation and networking amongst provincial departments and stakeholder.	Establish a provincial climate change coordination structure/committee to lead and coordinate all the climate change adaptation activities across the province.	Provincial committee on Climate change established.	Short-term (1-2 years).	DESTEA.	Sector Departments. Municipalities (district and local). Private Sector. Civil society and communities.
		Coordinate an annual provincial climate change summit to facilitate knowledge management, information sharing and networking amongst key stakeholders.	Provincial climate change summit convened.	Short-term and on-going.	Free State Climate Change Steering Committee.	
	Promote mainstreaming of climate change considerations into provincial and municipal policies, strategies and developmental plans.	Identify priority provincial and sectoral adaptation actions and outline roles of all stakeholders.	Identify, prioritise and document key adaptation areas and measures.	Short term and on-going.	DESTEA.	Provincial & local government. Private Sector.
		Ensure that climate change adaptation is taken into account when developing new or reviewing existing provincial and municipal policies, strategies and development plans (e.g. SDFs, SDPs, IDPs, and provincial departmental plans).	Number and list of provincial policies, strategies and development plans that evidently recognise and respond to climate change threats and vulnerabilities.	Short term to medium term (3-5 years).	DESTEA and the Free State Climate Change Steering Committee.	
	Ensure periodic and on-going monitoring and evaluation, review and update of the provincial response strategy.	Report annually to all sectors and all stakeholders on progress towards meeting the adaptation indicators outlined in this implementation plan.	Progress report.	Annually.		Provincial & local government municipalities Sectoral Departments. Private Sector.
		Assess the effectiveness of existing adaptation techniques,	Assessment report.	Medium term.		Civil society and community.

		including barriers to implementation.				
		Undertake review of policies and institutions with a view to ensure consideration of adaptation issues.	Revised strategy published.	Medium term and on-going.		
Build climate change response capacity through institutional strengthening, technology transfer, capacity building, resource mobilisation and partnerships, and stakeholder engagement.	Enhance climate change resource mobilisation and institutional arrangements for implementation of climate change response actions.	Create an enabling environment for accessing resources for implementation of climate change response actions from private public partnerships.	Institutional arrangements in place to aid effective implementation of the proposed strategies at all sectors within provincial and local government offices. Increased allocation of resources to climate change response.	Short-medium term.		
	Develop and implement capacity building and empowerment programs at all sectors and levels of society.	Promote education, awareness raising, training, information dissemination, knowledge management and social empowerment on climate change through engaging all stakeholders.	Number of stakeholders engaged in capacity building activities. Number of capacity building and awareness workshops convened with all stakeholders.	Short term and on-going.		
	Strengthen climate change knowledge generation through research, monitoring, predictions and projections.	Promote and support climate change research and adaptation training at research and academic institutions.	Number of research activities/programs supported.	Short term and on-going.		
		Coordinate and oversee the implementation of climate change adaptation projects, programmes and research activities in the Free State province	Short term and on-going.	Short term and on-going.		

Table A2: Vulnerabilities of the surface water resources for Free State, covering adaptation options, proposed interventions and key implementation partners

Surface water resources	Vulnerability	Adaptation options	Proposed interventions/activities	Key implementing partners
• Availability • Includes making sure that there is adequate water supply to meet the demands of the different sectors.	• Increased evaporation rates and water losses especially from the Lower Orange catchment. • Increased spread of invasive species which favour higher temperature and consume more water. • Drying of wetlands will affect water quantity and quality as well as loss of ecosystem services. • Reduced rainfall affects water availability and quality. • Rainfall variability will affect runoff in the Orange and Vaal catchment. • Changes in rainfall affect the growth and extent of alien invasive species. • Potential increases in rainfall are beneficial to socioeconomic activities. • Increase in high fire danger days will result in increased fires which will require more water resources to fight the fires.	• Reduce water loss through leakages by reducing the amount of water in pipes during off peak periods, while remaining sensitive to needs for human health and well-being. • Increase water storage infrastructure by building more dams and storage areas on farms and for households for continued access to water during drought periods. • Employ water saving irrigation techniques to reduce wastage of water in commercial agriculture farms. • Reuse and recycle grey water for use in gardening and urban agriculture. • Impose water restriction for some activities especially during drier periods. • Review the process of granting water use licences and water purchase agreements to take into account reduced water availability as a result climate change.	• Building on the work done in LTAS, there is a need to conduct a detailed analysis and modelling of rainfall/run-off projections. • Water resource management and protection to include enforcement of the Water Use Licence Authorisation (WULA) as well as disaster management for floods. • Invest in research on affordable climate smart agriculture to reduce water use in commercial agriculture. This is essential given the extent of commercial agriculture in the province. • Intensify on-going activities to raise awareness at provincial, district and local level. • Water governance for the sector to include awareness, improved communication with stakeholders, investment into research and development and to engage with regional partners. • Enforcement of legislation relating to surface water conservation and management. • Promote water conservation and management across all water dependent sectors. • Promote the use of green roofs and pavements to collect rain water.	• Provincial offices of DWS (leading). • DESTEA for support and guidance. • District and local municipalities. • Intensive water users in FS such as agriculture, mining, etc.). • Department of Police, Roads Infrastructure. • Free State Community. • Research to be undertaken by the province and academic bodies and research institutes such as UKZN, UFS, WRC, CSIR, etc.
• Conservation • Concerted efforts at district, municipal and local levels to conserve water. • Water conservation efforts in all sectors,	• Sedimentation in the Upper Orange River due to the sandy soil structure which is vulnerable to extreme rainfall events. •	• Introducing rain water harvesting for agriculture and household use. • Raise awareness on climate change water conservation and adaptation. • Implement a variety of conservation practices to reduce	• Increase the adaptive capacity of institutions responsible for surface water resources including the national, provincial, district and local municipalities.	

including human settlements, agriculture and mining.		soil erosion and sedimentation of rivers. • Restore and protect ecosystems such as wetlands that improve stream flow and water quality. • Intensify water conservation efforts in all municipalities including increasing investment in water smart technologies and appliances.	• Initiate a province wide Working for Rivers programme on a catchment by catchment basis. • Intensify Working for Wetlands programmes to cover more wetlands in FS. • Enforce water restrictions from non-essential activities during drier periods and droughts.	
• Quality • Water quality will affect the quantity of water that is available and fit for human consumption.	• Decline in water quality that is fit for human consumption as a result of pollution from mining, agriculture and human settlements. • Decline in rainfall can result in accumulation of salts leading to higher salinity. • Potential increase in rainfall can exacerbate the risk of acid mine drainage. • Flooding in some parts of the Vaal catchment, which affects water quality. •	• Put measures into place to reduce water pollution from wastewater treatment plants, agriculture and other activities such as mining. • Improve sanitation systems to minimise groundwater pollution from human settlements. • Conserve, protect and restore wetlands, which will assist in purifying water.	• Early warning systems to inform different user groups of impending climate extremes that affect surface water quality and quantity. • Protect and restore riparian vegetation so as to protect integrity of river banks and retain biological buffers against flooding. • Invest in new technologies to reduce water hardness and improve water quality e.g. the use of plastic instead of metal (pipes) and proper water treatment. • Improve systems to monitor and regulate water quality.	
• Supply and demand infrastructure – to ensure that infrastructure is able to meet demands for delivery and access to water storage and distribution.	• Increased water demand by plants, animals and humans will reduce water availability. • Increased demand for and cost of water, which will also have an impact on water use for mining, agriculture, human settlements and health. • Increased evaporation rates and demand for water due to heat waves, very hot days, dry spells and droughts.	• Upgrade bulk water supply infrastructure to monitor and curb water losses due to leakages. • Retain storm water for use for during drier periods through rain water harvesting. • Effective early warning system for impending extreme events. • Upgrade and maintain storm water drainage infrastructure to avoid flooding during intense rainfall events and reduce damage to infrastructure.	• Water management to include detailed vulnerability assessments of the sector, planning and strategies which include water conservation and demand management. • Increase in investment and resources for water related projects and infrastructure, technology and research. • Continue to invest in research to mitigate acid mine drainage and other pollutants.	

Table A3: Vulnerabilities of the Groundwater resources for Free State, covering adaptation options, proposed interventions and key implementation partners

Groundwater Resources	Vulnerability	Adaptation options	Proposed interventions / activities	Key implementing partners
• Availability •	• The projected increase in temperature will result in the following: • Increased evaporation reduces groundwater availability. • The projected decrease in rainfall will result in the following impacts to the groundwater resources in the province: • Decreased groundwater which will affect water flow and storage. • Decrease in water availability that may result in increased cost of water. • Less rainfall will impact on groundwater recharge resulting in reduced groundwater availability •	• Encourage water conservation and demand management for settlements dependent on groundwater. • Encourage artificial recharge (transfer of surplus surface water underground by injecting it into aquifers via boreholes).	• Increase the adaptive capacity of institutions responsible for groundwater resources. • Enforcement of legislation relating to groundwater conservation and management. • Expand current initiatives in artificial recharge of aquifers. • Put effective measures into place to monitor and regulate groundwater use and quality.	• DEA and DESTEA supported by DWS. • Provincial disaster management to assist in improving current disaster management practices in place. • Department of Police, Roads, Transport and Infrastructure. • Water users (e.g. agriculture, mining, community, etc.).
• Quality	• The projected increase in temperature will result in decreased groundwater quality. • Pollution of groundwater sources by organic matter, pesticides and heavy metals especially where recharge aquifers are present as a result of intense storms. • Impacts on groundwater recharge and storage will	• Put measures into place to reduce groundwater pollution from waste water treatment plants, agriculture and other activities such as mining. •	• Invest more resources into research and reuse of groundwater polluted by mining (acid mine drainage) and agriculture (fertilisers). • Early warning systems to inform different user groups of impending climate extremes that affect groundwater quality and quantity. •	

	also affect groundwater quality. • Increased rainfall from flooding will enhance the threat of groundwater pollution from acid mine drainage and economic activities such as mining and human waste. •			
• Supply and demand	• Increases in temperature will result in: • Increased demand for water for human consumption and from plants will put pressure on groundwater resources. • Increased use of groundwater during droughts and dry spells will increase demand • Increases in extreme weather events such as dry spells, very hot days and high fire danger days can lead to increased demand on groundwater for irrigation as well as human consumption.	• Upgrading of bulk water storage and distribution infrastructure and water management technologies to monitor water use and curb losses due to leakages. • Infrastructure development, operations and maintenance to increase water supply, improve infrastructure safety and implement flood protection measures.	• Ensure effective systems are in place to regulate and monitor groundwater for the different sectors, e.g. mining and agriculture. • Develop a provincial implementation plan for National Groundwater Resource Management Strategy (2016) • Capacitate and increase resources for water resources including groundwater management institutions that are already in place (municipalities, water boards, water user associations).	•

Table A4: Vulnerabilities of the Agriculture sector in Free State, proposed adaptation options, proposed interventions and key implementing partners

Agricultural Sectors	Vulnerability	Adaptation options	Proposed intervention activities	Key implementing partners
Crop production	• The increases in temperature will result in: • Increased evaporation and evapotranspiration rates and increased demand for water for irrigation. • Decline in agricultural productivity affecting livelihoods dependent on farming, the provincial gross domestic product, and South Africa's gross agricultural income. • High temperatures damage seedlings, delay flowering and lead to flower abortion for soya beans. • Potatoes are vulnerable to high temperatures which affect tuber quality and yield by causing heat sprouting and internal necrosis. • Decreases in rainfall will result in: • Decrease in water available for irrigation. • Decline in productivity for grain crops and fruits which benefit from both summer (maize) and winter rainfall (wheat and barley). • Reduced productivity for subsistence and rain-fed agriculture. • Increases in pests and diseases affecting some crops. • The impact of extreme events such as droughts and floods will result in: • The onset, cessation and duration of frost will affect crop yields from maize which require frost free conditions.	• Assess alternative crops that are more resilient to higher temperatures and lower rainfall. • Farmers need to ensure that they use efficient irrigation techniques that consider soil type, crop type, soil water status and weather conditions. • Research into short season and drought resistant crop cultivars suitable for the province. • Improved irrigation technology and its maintenance to minimise water losses from commercial farming activities. • Regulate the use of groundwater for irrigation • Implement smart agriculture practices that reduce loss of soil moisture and improve soil organic matter. • Increase production of drought resistant crops such as sorghum, which is expected to gain by as much as 30%. • Practice conservation agriculture which uses an integrated approach to harvest field, roof and road rain water runoff to complement irrigation especially at small scales. • Sustainable and efficient application of nitrogen fertiliser and manure to reduce water pollution. • Support of smallholder farmers to improve market access • Increased investment in developing the agriculture sector to increase its contribution to GDP,	• The proposed adaptation interventions are derived from the IGDP and APAP which target the following sectors:- • Grain production; • Red meat value chain; • Poultry value chain; • Dairy value chain; • Aquaculture; • Fruit and vegetable value chain. • • There is a need to address infrastructure backlogs that hamper development of emerging black farmers and reduce competitiveness of the sector. • It is essential to improve the competitiveness of local produce for international markets • Inadequate human resources and skills base for effective and efficient support, research and delivery systems especially in DARD. • Exploitative and unsustainable use of natural resources has led to degradation and is connected to the poverty trap of many previously disadvantaged people • Address issues faced by emerging farmers and previously excluded sectors of society, including: • Production limitations • Access to credit • Human capacity • Market access	• DESTEA. • Free State DARD. • National Department of Agriculture and Fisheries and Forestry (DAFF). • Crop Famers (commercial, small scale and subsistence). • Supporting Research institutions include: ARC, CSIR, UCT, UKZN, etc.

	• Frost can damage wheat, especially after formation of ears in spring, resulting in low yield. • Increased health risk for farm workers due to increased heat waves and very hot days affecting their productivity. • Floods can result in soil erosion and loss of fertile soil. • Droughts and dry spells can also affect flowering and pod formation stages for soya beans (e.g. in Fezile Dabi and Thabo Mofutsanyane).	employment and income, as well as meet increased demand for food • Implement the IGDP and APAP.	• Transfer of technology to small scale or rural farming communities • Stimulation and support of agribusinesses and agro-processing • Enhance the adaptive capacity of farmers to climate change • Capacitate extension services so that emerging farmers are given much needed support • Introduce more agriculture training programmes that support youth and women.	
Horticultural crops	• Increases in temperature will result in:- • Increases in evaporation and evapotranspiration rates will increase the demand for water for irrigation. • Horticulture is a labour intensive activity. Extreme heat could impact workers, resulting in a decline in agricultural productivity for horticulture produce. This will impact livelihoods dependent on farming as well as the contribution of horticulture to the provincial GDP. • Increases in temperature will negatively affect heat and chill units essential for the production of good quality apples, pears, peaches, apricots and cherries which have stringent chilling requirements • There will be a possible decrease in water available for irrigation, on which horticulture depends upon. • Possible increase in pests and diseases will affect fruits such as cherries, berries and plums.	• There is need to stimulate and support agri-business and agro-processing. • There is need to increase dam storage capacity for irrigation, either by building more dams or re-evaluation of current dam capacity. • Reward, recognition as well as training and capacity building of staff that supports the agricultural sector. • Support community food production to increase food security for poor households through for example starter packs for vegetable gardens. • Efficient use and application of nitrogen fertilizer and manure to reduce pollution of water resources. • Investment in affordable plant breeding and cultivars that are more resilient to climate change. • Expand current efforts on implementation of climate-smart technologies for high value crops and grains. •	• Ensure the cooperation between institutions that is necessary to ensure the full development and utilisation of human and other resources for development. • Invest in the improvement of access to markets for small scale farmers, including improving transport infrastructure, providing more information on supplies and prices, and addressing issues of storage and the lack of extension services and basic business and management skills. Farmers will also need access to more arable land. • Skills development as well as integration of emerging farmers into appropriate institutional support structures. • Introduce and promote agro-ecology forms of crop production and land management to conserve resources, produce healthy food, and protect biodiversity.	• DESTEA • DARD • DAFF • Horticulture famers and associations (commercial, small scale and subsistence) • Supporting research institutions include: ARC, CSIR, UCT, UKZN, etc. .

	• Frost can cause damage to floral and leaf buds in temperature sensitive produce such as peaches, apricots and cherries. • Floods and wind can result in loss of fertile soil • Fires will destroy vineyards and orchards as well as infrastructure important for the sector. • Increases in pests and diseases affecting fruits and other crops.			
Pasture and Rangelands	• Impacts on pasture crops – rangelands and planted pastures. • As a result of the current drought there was not enough fodder which resulted in farmers slaughtering most of their livestock. • There are potential threats to the nutritional value of the fodder resulting in poor quality meat and fibre.	• Encourage integrated agro-forestry systems that combine crops, grazing lands and trees in ecologically sustainable ways. • Investigate the use of ecosystem based adaptation to ensure preservation of the productive value of grazing land. •	• More investment is needed in research on the impacts of climate change on rangelands and the grasses used for fodder. • The province needs to be better prepared for extreme events such as droughts.	
Livestock (including dairy, including the rangelands)	• Impacts on animal production - livestock sector • Increases the transmission of infections of zoonotic tick-borne diseases. • Reduced feed intake which reduces the productivity of all forms of livestock. • Decrease in milk yield and conception rates. • Decline in reproductive rates and weaning weights. • Small ruminants such as goats and sheep are more robust and heat-tolerant than cattle. •	• Need for research on environmentally friendly methods of dealing with pests and diseases that will affect agriculture and game farms. • Practice organic precise farming at small scale levels. • There are efforts underway to investigate breeding options for livestock using indigenous cattle breeds. • Put measures into place to reduce heat stress such as provision of shaded areas for dairy cows. • Need for research on environmentally friendly methods of dealing with pests and diseases that will affect agriculture and game farms.	• There is investment in research and development in animal breeding and research on more resilient animal breeds such as indigenous breeds. • There is need to investigate how to preserve livestock genetic material in cases of drought. •	• DESTEA. • DARD. • DAFF. • Livestock farmers and associations (commercial, small scale and subsistence). • Supporting research, institutions include: ARC, CSIR, UCT, UKZN, etc.

Impacts on farm labour – human discomfort index.	• Extreme temperature will affect productivity of farm workers.	• Investigation of potential solutions to lost labour productivity in the agricultural sector as a result of high temperatures, heat waves and heat stress. • Reduce exposure of farm worker to harsh weather conditions.	• There is a need to explore shifting working hours to start earlier and end later, with a longer break during peak heat times in the day.	
Other factors that will affect agriculture and be worsened by climate change.	• The use of cultivars is costly and not all farmers can afford it. • Mismanagement that has resulted in significant land degradation.	• Promote the growth of farm workers and tenants to enhance their livelihoods and ensure full participation in agriculture • There is a need to improve risk management capacities for key role players • Take advantage of global funding opportunities that support climate change projects e.g. Green Climate Fund. • There is a need to include women and youth in the agriculture sector.	• Promote coordination between private and public sector to support both commercial and small scale agriculture. • Coordination and support of effective collaboration between public and private sector to support agriculture. • Increased funding and capacity building of role players in the sector.	

Table A5: Vulnerabilities of the Biodiversity sector in Free State, proposed adaptation options, proposed interventions and key implementing partners

Biodiversity and Wetlands	Vulnerability	Adaptation options	Proposed Interventions activities	Key Implementing Partners
Ecosystem function and services	• Climatic changes will result in loss of the Grassland biome. This results in loss of livelihoods for households dependent on Grasslands. • Increased evapotranspiration and evaporation will increase water demand by plants. • Increase in temperature results in increased evaporation which can result in the drying of wetlands. • Increase in temperature increases growth of alien invasive species that negatively affect natural vegetation and wetlands. • Changes in climate will result in habitat degradation and reduced productivity of rangelands which is a Grassland ecosystem function. • Changes in rainfall affect the quantity and timing of stream flow recharge which also affects wetlands structure and functionality. • Intense storms are few but can cause regular and permanent erosion which leads to degradation and loss of ecosystem function.	• Biodiversity Education Programmes that will help to raise awareness of school learners and communities need to be initiated across the province. • GroenSebenza to promote skills development and employment in the biodiversity sector. • University of Free State has a global registry or biodiversity repository which will assist with biodiversity conservation. • Conservation areas including national parks and botanical gardens. • Wetlands have been mapped to show their status; and this is which is important in their management since it provides a basis for identifying areas to target for conservation and restoration. • Raise awareness of communities on the importance of biodiversity and ecosystem functions to encourage conservation.	• Collaboration with key sectors affecting biodiversity to develop strategies that help in the restoration and management of ecosystems. • Invest in research on ecosystem based adaptation and how it can be used across the province in key sectors. • Investment in research to identify and understand the impacts on the environment, flora and fauna from concentrated solar power in areas in and around solar farms. • Invest in protection of urban ecosystems to support their ability to deliver functions such as stream flow regulation, flood control, water provision, and biodiversity protection.	• The lead implementing partners will be DESTEA with support from other key national departments such as DEA and provincial offices of DWS as well as district and local municipalities. • Other partners will include: • SANBI. • SANParks. • Environmental NGOs such as WWF and Conservation South Africa (for implementation of programmes on conversation) • WESSA for capacity building.
Ecosystem composition	• Changes to ecosystem function, composition and services essential for human wellbeing and economic activities such as agriculture (e.g. process of pollination in plants). • Invasion of alien vegetation and increased spread of invasive species. • High fire danger days and heat wave days increase fire risk which can destroy biomes.	• The province has completed a critical biodiversity and ecology assessment report, which will help identify priority areas for conservation. • Wetland rehabilitation and management of priority wetlands • Removal of alien plants and replacing them with indigenous plants.	• Programmes to minimise loss of biodiversity through the protection of threatened and vulnerable ecosystems and ecological infrastructure need to be prioritised. • Initiate programmes such as bio-monitoring to monitor the quality and diversity of species, especially in high risk areas.	• The lead implementing partners will be DESTEA with support from other key national departments such DEA (e.g. Working for programmes) • and provincial offices of DWS • Other partners will include:

	• Increased droughts, dry spells, very hot days and heat waves increase water stress for biodiversity. • Increased loss and degradation of biodiversity due to economic activities such as mining and agriculture.			• SANBI • SANParks • Environmental NGOs such as WWF and Conservation South Africa (for the implementation of programmes on conversation).
Extent of bioclimatic envelopes	• The bioclimatic envelop for grasslands will be significantly reduced. Grassland is the most threatened biome in the country. • Nama Karoo is the second most threatened and is likely to become more like an arid Savanna, and may be replaced by Savanna and Desert in some areas. • Savanna will possibly expand significantly but this does not necessarily benefit current habitats and species groupings. • Changes in bioclimatic envelopes which have socio economic and environmental impacts.	• Effective management of the negative environmental impacts from economic activities such as agriculture and mining. • Increase the extent of wetlands rehabilitation under the Working for Wetlands projects.	• Integrate biome adaptation plans across all key sector departments including water, health, agriculture and tourism. • Coordinate with communities to implement multi-benefit and affordable biodiversity conservation projects • Integrate indigenous knowledge systems for specific biomes in the conservation efforts and engage with local communities to initiative conservation programmes	• The lead implementing partners will be DESTEA with support from other key national departments such DEA and DWS. • Other partners will include: • SANBI • SANParks • NGOs such as WWF and Conservation South Africa for implementation of programmes on conversation • SAEON for research and bio-monitoring of ecosystems • CBOs for design and implementation of programmes at community level and for access to traditional knowledge on ecosystems • DEA Working for programs

Table A6: Vulnerabilities of the Tourism sector in Free State, proposed adaptation options, proposed interventions and key implementing partners

Tourism	Vulnerability	Adaptation options	Proposed interventions activities	Key implementing partners
Infrastructure	• Flooding of access roads and damage to hotel and resort infrastructure. • Increase in operating costs for cooling, irrigation, food and water supply, and insurance costs. • Increases in fires will pose a danger to infrastructure especially for resorts that use thatch.	• Upgrade and maintain the transport infrastructure to improve accessibility and mobility that supports economic activities such as tourism. • Early warning of impending disasters that could destroy tourism infrastructure. • Increased emergency preparedness requirements, which include backup water and power systems and medical supplies.	• There is urgent need for the Department of Tourism in the province to set up a unit dealing with climate change. • The province needs to develop its own climate change strategy for the sector. This is currently only at national level. • Respond effectively to concerns about GHG emissions generated by flying to and from South Africa.	• The leading implementation partner in the province will be the FS Department of Roads and Public Works and Tourism with support from DESTEA, National Department of Tourism and SANParks. • Other partners may include: • The hospitality industry including tour operators, game park owners, etc. • CBOs. • Banks and financial institutions.
Biodiversity based tourism	• Loss of biodiversity can result in decline in the number tourists and revenue earned from tourism (also affecting livelihoods dependent on the sector). • Water for irrigation to provide leisure facilities such as golf courses and green areas may become increasingly scarce (GIZ, 2011). • Climate defines the length of the tourism season and influences environmental conditions that attract or deter tourists from visiting Free State province. • Changes in rainfall and temperature can result in loss of biodiversity and may cause a decline in the number of tourists and revenue earned from tourism (also affecting livelihoods dependent on the sector).	• Raise awareness of and invest in resources for ecosystem based adaptation that includes communities and the different sectors involved in tourism. • Engage with other stakeholders and communities to boost biodiversity conservation and restoration relevant for tourism • Enhance the role of tourism operators to conserve water and energy as well as adopt efficient waste management practices	• More research is needed to improve understanding of the vulnerabilities of tourism to the physical impacts of climate change in order to build resilience and adaptive capacity of the industry. • Conduct a study on the feasibility of implementing a Carbon Offset Programme for the tourism industry for the province. • Develop and distribute a Tourism and Climate Change brochure for industry at provincial level • Create and update a database of tourism and climate change initiatives to monitor and report on the implementation of Tourism and Climate Change initiatives.	• The leading implementation partner in the province will be Department of Roads and Public Works and Tourism with support from DESTEA, National Department of Tourism and SANParks. Other institutions may include: • SANBI for information and research on biodiversity • Academic institutions for research on impacts of climate change on biodiversity • Research Institutes such as CSIR global change and biodiversity groups. •

Human health and human comfort in the tourism sector.	• Shift of attractive climatic conditions required for tourism e.g. increased temperature and extreme heat will deter visitors. • Increasing incidence of vector-borne diseases may deter tourists from the province e.g. ticks and malaria for parts of Free State. • Increases in fires and floods potentially directly endanger tourists.	• Early warning of impending disasters that could disrupt tourism activities. • Preparedness of the health system in the province to deal with vector borne diseases. • Raise awareness of the potential impacts of climate change on human health in the sector.	• Conduct more research on issues of climate change and human health including disease pathogens. • Design a Visitor/Tourist Climate Change Awareness Programme for the province • Develop a Tourism Industry Implementation Protocol on Climate Change.	• • The leading implementing partner will be FS Department of Health supported by DESTEA. • • Other partners will include: • SANParks • The hospitality industry, including tour operators • Research institutions such as Medical Research Council. • •

Table A7: Vulnerabilities of the Mining sector in Free State, proposed adaptation options, proposed interventions and key implementing partners

Mining Resources	Vulnerability	Adaptation options	Proposed interventions / activities	Key implementing partners
• Infrastructure	• Higher temperatures will reduce the efficiency of operation of mining equipment and cooling for water-treatment processes. • Operating thresholds of equipment may be exceeded during episodes of extreme high temperature. • Heat waves increase the use of energy required for cooling. • Increased water demand for mining activities.	• Develop and adopt strategies for efficient water use and increase water conservation at mine sites at both national and provincial level. • Invest in alternative renewable sources of energy. • Investment in research on sustainable and renewable energy options. •	• Invest in research in materials that can be used to manufacture mining equipment that can withstand high temperatures. • Invest and conduct more research into how to address the challenges and opportunities presented by acid mine drainage. •	• The leading implementing partners will be DMR and DST. • Academic institutions specialising in mining engineering, e.g. Mintek, CSIR mining department, University of Witwatersrand geosciences department. • Mining companies to invest in research initiatives focusing on the impacts of extreme events on the sector. • Mining bodies, e.g. Council for Geosciences, Chamber of Mines.
• Labour • Surface Water • Groundwater	• Heat waves and higher temperatures will increase the use of energy for cooling and water for mining operations. • Extreme rainfall that results in flooding can cause soil movement and instability resulting in sink holes Droughts may concentrate contaminants that negatively affect the chemistry of surface water in some areas. • Less rainfall and/or increasing aridity affects the amount of surface water and groundwater available for mining activities.	• Initiatives to stabilise mining environments, especially underground mining (at national level). • Efforts to reduce groundwater pollution and address acid mine drainage are being carried out by mining companies and national government. These need to be adopted at provincial level. • Undertake yearly progressive rehabilitation to address soil erosion and pollution. • Adjust existing risk-identification processes to incorporate additional heat related health risks on miners working underground and surface heat related illnesses. • Clearly identify water quality and environmental objectives based on downstream environmental values to minimise damage to aquatic and terrestrial ecosystems.	• More research on stabilising mining environments is essential • Integrated environmental management to minimise damage to the environment. • Skills development and re-skilling of employees in the mining sector to improve resilience of communities whose livelihoods are dependent on mining. • Develop and adopt strategies for making efficient use of water and increase water conservation at mine sites. • Recycling and reuse of water.	• Provincial disaster management to assist in improving current disaster management practices in place.

	• Storms and floods can result in emergency response procedures being compromised. • Higher temperatures directly increase the risks of heat stress for underground workers, presenting a health risk.	• As part of mining operations, the mining industry has very strict guidelines and procedures to ensure safety of miners. These can be improved to include disaster responses for extreme events. • Improve ventilation in mines especially for underground mining. • Undertake yearly progressive rehabilitation to reduce rainfall runoff.	• Investment in mining safety operations is essential in preparation of increases in extreme events. • Invest in better mining methods to improve the condition of miners underground and in other forms of mining and reduce the exposure of miners to extreme heat and temperature.	• Mining companies. • Provincial disaster management.
• Non-climate issues affecting mining that will be exacerbated by climate change	• Environmental degradation and contamination of soil, water and air as a result of poor mining practices.	• There is a need for accountability across the board in the industry. • Regularise mining activities to address issues of illegal mining, often engaged in by those affected by poverty and unemployment. • Continuous rehabilitation of mining land for agricultural and other rural development projects.	• Regularise and enforce post mining land rehabilitation of land for agricultural and other rural development projects. • Invest resources to address black markets for precious stones which drive illegal mining activities. Illegal mining has detrimental environmental impacts which affect the surrounding areas.	

Table A8: Vulnerabilities of the Transport sector in Free State, proposed adaptation options, proposed interventions and key implementing partners

Transport	Vulnerability	Adaptation options	Proposed interventions activities	Key implementing partners
Infrastructure	• Higher temperatures can accelerate the ageing of road surfacing bitumen layers. • Very high temperatures reduce the structural strength of road surface. • Unpaved and gravel roads are vulnerable to extreme rainfall and flooding. • Extreme heat has the potential to affect aircraft lift as hotter air is less dense and reduces mass flowing under the wing to create lift. • Buckling of railway tracks. • Low rainfall and droughts can cause damage to road foundations and rail infrastructure.	• Continued investment in multi-modal transport and logistics hub which will promote economic development in freight sectors in the province. • Increase the budget allocation for maintenance and upgrading of transport infrastructure which is currently inadequate. • There is continued need to upgrade gravel roads to improve roads across the province e.g. Thaba Nchu. • Need for paving and upgrading of roads and storm water drainage across the province – this will assist with gathering of rain water. • Upgrading of roads that are vulnerable to gully erosion and flooding.	• Investment in research on more durable materials to be used for road construction. • It is essential to increase the budget for the increased maintenance and replacement costs for transport infrastructure. • Maintenance and upgrade of storm water drainage to minimise flooding. • Enhance disaster management services to be prepared to assist in the event of accidents and chemical spillages.	• DESTEA. • FS Department of Transport. • FS Department of Police, Roads, Transport and Infrastructure. • Transnet.
Road construction workers	• Heat waves and increased number of hot days enhance the urban heat island while also increasing heat stress especially for road and rail construction workers, as well as commuters using public transport.	• Raise awareness of the dangers of extreme heat on workers for the rail and road sector.	• Investigate changing the work hours of workers so that they are not exposed to dangerously high temperatures during the day.	

Table A9: Vulnerabilities of the Energy sector in Free State, proposed adaptation options, proposed interventions and key implementing partners

Energy	Vulnerability	Adaptation options	Proposed interventions activities	Key implementing partners
Infrastructure	• The increase in temperature will result in sagging and clashing of transmission and distribution line cables that will result in fires and damage to infrastructure. • Flooding may damage energy generation, transmission, distribution and substation infrastructure.	• Benefit from the growing solar energy initiatives in the province e.g. some solar farms have already been established in the province. • Need more investment to boost initiatives in renewable energy and energy products, e.g. solar water geysers and panels as well as wind energy generation in the province. • There is a need to improve and enforce security measures to curb the theft of cables and other energy infrastructure • Provision and maintenance of high mast lights to be implemented across the province	• Take advantage of the solar generation capacity at Xhariep which is the second best solar radiation in the country. This presents an opportunity for the province to invest in solar energy generation. • Need to invest in mitigation measures to reduce air pollution from power generation activities • Address illegal electricity connections and use smart meters to prevent inaccurate meter readings • Continued support for renewable energy and research into possible issues of maladaptation	• National Department of Energy • CENTLEC • Eskom • Renewable Energy Power Producers. • FS Department of Human Settlements and Built Environment
Energy Demand and Supply	• Increase in temperature will result in increased energy demand for cooling for both human and animals, thus putting pressure on the current energy generation capacity. • Frost/snow builds up and damages transmission and distribution lines as well as substations; thus impacting on the continuity of electricity supply in the province.	• Increase the power generation capacity to meet the demand for energy from mining, agriculture and human consumption. This could include upgrading essential infrastructure for the storage and distribution of power in the country • Community awareness raising programmes on energy conservation and alternative energy sources • Retrofitting buildings to save energy	• Provision of electricity in areas where there is currently no power • Improve material used for solar panels and solar water geysers • Need to increase efficient appliance programmes to reduce the use of energy (kettles and light bulbs)	• CENTLEC • Eskom •
Energy Generation Capacity	• Increased evaporation from dams resulting in water shortages for hydro power generation at Gariep, thus affecting generation capacity of this plant. • Rainfall variability will affect the availability of water for hydro-electricity generation along the Gariep and Venderkloof dams • Dry spells will reduce rainfall availability for energy generation.	• Increase power generation from a range of renewable energy sources such as solar and wind	• Improve community safety by installing and maintaining high mast lights and street lights – this will increase demand for power • Support the use of renewable energy technologies in households and small businesses to promote localised energy generation	• DESTEA • Eskom • Renewable Energy Power Producers

Table A10: Vulnerabilities of the Human Settlement and Built Environment sector in Free State, proposed adaptation options, proposed interventions and key implementing partners

Human Settlements and Built and Environment	Vulnerability	Adaptation options	Proposed interventions activities	Key implementing partners
Water and Sanitation	• The projected increase in temperature will result in the following impacts to this sector: • Water shortages due to decrease in rainfall and evaporation in dams. • Reduced stream flow and groundwater recharge which will consequently lead to an increase in the unit cost of water for settlements. • Droughts and dry spells increase water demand and affect water quality. • Extreme wet and dry cycles can result in soil movement that make water and sewerage pipes more susceptible to cracking and will require rehabilitation and replacement of affected infrastructure. • Rainfall variability and dry spells will affect availability of groundwater. This may increase the cost of water for the consumers. • Poor state of bulk water infrastructure in old settlements including sanitation, water services, and sewage treatment plants.	• Upgrading and maintenance of bulk water storage and distribution, sanitation, and storm water infrastructure. • Intensify the on-going awareness campaigns on water conservation and climate change impacts on human settlements in the province. • There is a need for continued coordination on waste management with key stakeholders • Raising of awareness in communities and schools on waste management and the recycling of waste. • There is a need for strict regulation and selection of future sites for landfills and waste disposal recycling sites to minimise land and water pollution.	• Climate change response needs to be integrated into local level spatial planning tools such as Spatial Planning and Land-use Management Act (SPLUMA) and the Lets Respond Toolkit. • Provide sanitation systems in areas where they do not exist and upgrade sanitation systems in old settlements to curtail pollution of both surface water and groundwater sources. • Allocate adequate budget for maintenance of waste management infrastructure at landfills and within the city e.g. bins and trucks. • Investigate generation of energy from waste.	• Leading implementing department will be DWS, supported by DESTEA. • Key government sector departments within the province, e.g. human settlements. • Key water users in the province (e.g. agriculture, mining, etc.).
Settlements – rural and urban	• Informal settlements • Informal settlements located in many urban areas such as Mangaung have backlogs with basic service delivery. • Old settlements in areas such as Thaba Nchu are vulnerable to	• Upgrading and maintenance of roads and storm water drainage infrastructure to reduce flooding. • Improve quality of low cost housing to ensure that they are insulated for temperature regulation and retrofitted for energy saving.	• Monitoring of hazard trends (location, frequency and magnitude) in order to develop appropriate response measures. • Improve coordination between sector departments particularly	• Leading implementing department will be DHS, supported by DESTEA. • Key government sector departments within the province, e.g. human settlements,

	extreme rainfall events which will cause destruction of property and personal assets. • Rural settlements • Old settlements and infrastructure vulnerable to extreme rainfall and temperature extremes. • Loss and damage of personal assets due to flooding. • Increased insurance claims for damage which also increases insurance premiums, also affecting farmers.	• Training of community volunteers to assist in the event of disasters especially in old and informal settlements. • Control new developments and encourage mixed land use which will assist in the reduction of commuter travel distance to places of employment. • Support access to heat resistant, insulating, and safe building materials for informal settlements. • Promote urban agriculture in formal and informal settlements to reduce food insecurity and heat stress.	when developing sector specific adaptation responses. • There is a need for integrated land use planning to limit unplanned urban growth which usually results in informal settlements and poor access to basic services. • There is a need to invest in improved technologies for better housing especially in informal and urban areas where heat stress will be an issue.	infrastructure / built environment and local municipalities. • Free State Disaster Management Department. • Community based organisations.
Infrastructure to support human settlements	• Damage to unpaved and poorly tarred roads due to intense storms. • Deterioration of heat sensitive transport infrastructure e.g. embrittlement and cracking of bitumen on roads. • Increased discomfort as a result of increases in temperature resulting in demand for energy for cooling. • Extreme events such as floods will cause extensive damage to water, transport, energy and communication infrastructure, including runways. • Extreme events will cause disruptions to water and electricity supply which will result in reduced productivity.	• Increased expenditure on repairs to and maintenance of public and private infrastructure such as bridges. • Build capacity of government officials so that they can integrate climate change into planning and decision making.	• Review of SDFs and IDPs to include climate change impacts – as well as use of tools such as Lets Respond Toolkit and SPLUMA. • Urban greening to address biodiversity & heat stress/human health. • Regulation of prices for waste collection and recycled waste because it is a lucrative and viable livelihood activity. • Increase public private partnerships to develop and implement community development and adaptation projects.	• Leading implementing department will be DHS, supported by DESTEA. • Key government sector departments within the province, e.g. human settlements, infrastructure and built environment and local municipalities. • UFS Disaster Management unit.

Table A11: Vulnerabilities of the Social and Human health sector in Free State, proposed adaptation options, proposed interventions and key implementing partners

Social and Human Health	Vulnerability	Adaptation options	Proposed interventions activities	Key implementing partners
Human Health **Temperature /rainfall Impacts.**	• High temperatures increase the extent of areas with conditions conducive to vectors and pathogens. • Increased risk of deaths from cardiovascular and respiratory diseases due to high temperatures and increased pollutants (e.g. among elderly people). • Greater risk of the transmission of vector borne diseases (VBD) and zoonotic diseases (ZD) through pathogen-host interaction. • Enhanced food insecurity and malnutrition especially among the poor. • Rainfall variability can compromise hygiene and increase the risk of diarrhoeal disease.	• Increase public awareness on communicable and non-communicable diseases associated with climate change. • The existing efforts to provide basic services such as housing, water and sanitation will improve human health and well-being. • Continue with programmes to improve water provision and water quality - as well as improve the blue drop status for water quality. • Continued investment in the on-going droughts programmes including provision of vitamin A to children less than 4 years old to curb malnutrition • Intensify programmes to provide vaccines for communicable diseases such as diarrhoea. • Insulate house to protect communities against heat waves and very hot and cold days.	• Research and technologies to improve food preservation and storage thereby improving food security especially in rural areas. • Expand the few projects that are in place that will build the capacity of youths and women, including: • Social entrepreneurship. • Skills development. • Household profiling. • Increase public awareness on communicable and non-communicable diseases associated with climate change. • Enforce compliance with air quality legislation. • • •	• National Department of Health (particularly findings from the study on the impacts of climate change on human health) • FS Department of Health. • FS Disaster Management Department. • DESTEA (providing guidance and support). • SAWS. • CBOs. • Other partners could be DWS, UFS, SAEON, etc.
Human Health Extreme Events	• High fire danger days increase the risk of death and injuries due to fires. • Extreme events such as droughts, thunderstorms and dry spells impact on social and environmental determinants of	• Continued upgrading and maintenance of sanitation systems to curb seepage of sewage into water sources and the spread of diseases especially when there are flooding events.	• Increase resources allocated to emergency services such as the police, health and fire brigade to increase efficiency in responding to disasters. • Support economic development projects that	

	health such as clean air, safe drinking water, and sufficient food and secure shelter. • Floods can lead to a heightened risk of water-borne diseases and breeding grounds for disease-carrying insects such as mosquitoes. • Floods can result in drowning and physical injuries, damage to homes and disruption in the supply of medical and health services. • Very hot days and heat waves increase heat related diseases especially for people who spend more time exposed to the sun e.g. farm workers. • Heat waves and very hot days increase the levels of pollutants in the air such as ozone that exacerbate cardiovascular and respiratory disease. • Dust storms can affect human health and visibility. • Frost increases health risks especially for the poor.	• There is a need to keep health records and monitor health data for humans and animals to identify trends and changes in disease prevalence • Provision and upgrading of water services, roads, housing and storm water systems. •	involve youth and women to create jobs and reduce poverty. • Promote and expand the Working for Fire Programmes – to assist with emergency response as well as create employment and reduce poverty. • Engage with key stakeholders such as war veterans and CBOs to initiate and implement climate response/proofing projects. • Build and rehabilitate sporting and social amenities. •	