Garden Route District Climate Change Adaptation Response Implementation Plan

2024

Developed as a collaborative initiative by the Garden Route District Municipality, the Department of Environment, Forestry and Fisheries (Local Government Climate Change Support Program), and the below stakeholders:

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1. Executive Summary

Historically, the Western Cape Province has been the most disaster prone province in the country (WCG DMC, 2021). The province frequently experiences drought, fire and flood events with significant adverse impacts (Pasquini, Cowling, and Ziervogel, 2013). Increased temperatures in the future are certain for the Western Cape (Western Cape Government, 2015), but rainfall projections are less certain, with some projections revealing increased rainfall, whilst others predict decreased rainfall in the future.

The following climate change impacts have already been observed in the Garden Route District: increased average temperatures; shifts in seasonality; increased frequency of veld fires; increased magnitude and frequency of storm events accompanied by strong winds; more frequent and severe storm surges and flood events; and increases in rainfall variability as well as the number of dry days.

In addition, sea level rise and associated hazards are a major concern for coastal areas within the district. Sea level rise impacts are likely to include inter alia coastal erosion, flooding, disturbance of estuarine systems, destruction of infrastructure and salt water contamination of fresh water bodies (WCG DMC, 2021).

It is for this reason that the Garden Route District Municipality recognises climate change as a threat to the environment, its residents, and to future development. Therefore, measures should be implemented to reduce or eliminate carbon emissions or enhance greenhouse gas sinks (mitigation) (Böckmann, 2015). However, due to lag times in the climate and biophysical systems, the positive impacts of past and current mitigation will only be noticeable in the next 25 years (Jiri, 2016). In the meanwhile, adaptation is regarded as inevitable and a necessary response to the changes that are projected to take place in the District. The Garden Route District Municipality has therefore prioritised the development of a Climate Change Adaptation Plan developed in 2014. This Garden Route District Climate Change Strategy builds on the original Adaptation Plan by providing more detail at a sector level on key Climate Change Vulnerabilities and Responses.

The Climate Change Adaption Strategy was developed with the assistance of the Local Government Climate Change Support (LGCCS) Programme (http://www.letsrespondtoolkit.org/); in partnership with the Western Cape Climate Change Municipal Support Programme. The LGCCS is led by the Department of Environmental Affairs and is part of the International Climate Initiative (IKI) and is supported by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH on behalf of The Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB).

Through the LGCCS Programme, a Climate Change Vulnerability Assessment Toolkit was developed to assist municipalities to identify and prioritise climate change indicators to facilitate the assessment of adaptive capacity. Indicators are a range of potential impacts which have been developed using the Long Term Adaptation Scenario (LTAS) reports (DEA, 2013g).

The LGCCS Toolkit was applied to the Garden Route District to assist with the development of its Climate Change Response Plan. The Vulnerability Assessment methodology included a Garden Route District workshop, which was held with key environmental stakeholders of the seven Category-B Municipalities in the district, where the focus was specifically on the identification and review of key climate change vulnerabilities for the area. The process included the identification of context specific climate change indicators, assessing exposure, sensitivity and adaptive capacity. Participants also developed priority climate change responses (please refer to the Garden Route District Climate Change Needs and Response Assessment document for the detailed vulnerability assessment methodology used). The vulnerability assessment outlined the key climate change vulnerabilities, as well as the responses to address these vulnerabilities for the Garden Route District Municipality.

A summary of the key vulnerability indicators is provided in the table below (DEAb, 2017).

Table 1: Key Vulnerability indicators for Garden Route District Municipality.

No	Sector	Name Indicator Title	Exposure Answer	Sensitivity Answer	Adaptive Capacity Answer
10	Agriculture	Increased risks to livestock	Yes	High	Low
13	Biodiversity and Environment	Increased impacts on threatened ecosystems	Yes	High	Low
14	Biodiversity and Environment	Increased impacts on environment due to land-use change	Yes	High	Low
15	Biodiversity and Environment	Loss of Priority Wetlands and River ecosystems	Yes	High	Low
19	Coastal and Marine	Loss of land due to sea level rise	Yes	High	Low
20	Coastal and Marine	Increased damage to property from sea level rise	Yes	High	Low
30	Human Settlements, Infrastructure and Disaster Management	Increased impacts on traditional and informal dwellings	Yes	High	Low
32	Human Settlements, Infrastructure and Disaster Management	Increased migration to urban and peri-urban areas	Yes	High	Low
33	Human Settlements, Infrastructure and Disaster Management	Increased risk of wildfires	Yes	High	Low
36	Water	Decreased water quality in ecosystem due to floods and droughts	Yes	High	Low
40	Air Quality	Increase in Air Pollution	Yes	High	Low
41	Air Quality	Increase in odour complaints	Yes	High	Low
42	Air Quality	Increase in Brown haze	Yes	High	Low

Based on the vulnerability assessment, the following indicators were identified as high priority climate change vulnerabilities for the municipality. These were shortlisted by answering “yes” to exposure, “high” to sensitivity and “low” to adaptive capacity. Indicators are grouped into the following themes:

- Agriculture
- Biodiversity and Environment
- Coastal and Marine
- Human Health
- Disaster Management, Infrastructure and Human Settlements
- Water

The major climatic hazards in the Garden Route district as identified by the Vulnerability Assessment include: droughts, floods and veld fires. Climate change is also expected to incrementally increase the frequency and severity of these hazards. Additionally, financial losses in the district, due to these climate hazards, has already been high, and will increase going into the future.

It is therefore crucial to conserve our water resources, wetlands, marine and coastal environment, and our rich biodiversity. Land-use and settlement plans should be updated to take disaster risk management criteria into account, and by increasing public awareness regarding water conservation, droughts, fires and floods. This is particularly pertinent given the recent devastating fires in and around the Garden Route as well as the severe ongoing drought in the Garden Route district.

As an outcome of the Vulnerability Assessment, various Sector Plans were also developed as part of this Strategy (please refer to Chapter 6 to view these Plans). This Garden Route District Climate Change Adaptation Response Implementation Plan was developed for use by the Garden Route District Municipality, which includes all the Category-B local Municipalities within its borders, as a climate change implementation guidance document, and can be adopted by the Councils of the Local Municipalities, as well as being incorporated within their Integrated Development Plans and Spatial Development Frameworks. It can also serve as a guidance document to any other key climate change stakeholders within the district who are responding to climate change.

1 Climate Change Introduction

1.1 Document Outline

This document outlines key climate change vulnerabilities and responses to address these vulnerabilities for the Garden Route District. The main chapters within this document are as follows:

- Introduction
- Provincial Climate Change Context
- Garden Route District Municipality
- Major Climate Change Impacts of Extreme Concern within the Garden Route District
- Garden Route District Climate Change Vulnerability Assessment
- Sector Response Plans
- Climate Change Objectives and Projects
- Concluding Remarks

1.2 Climate Change Defined

Climate change is a natural phenomenon that takes place over geological time. However, over the past few decades the rate of climate change has been more rapid and the magnitude of global warming has increased dramatically (Warburton and Schulze, 2006; Warburton, 2012). This change has been attributed to increased anthropogenic greenhouse gas emissions (Koske and Ochieng, 2013). For example, the burning of coal to generate electricity, the burning of petrol in cars, some chemical processes in industries, and many farming activities all contribute to the increased concentration of greenhouse gasses in the atmosphere. Climate change adaptation can be defined as: "*The adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploit beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation*" (IPCC TAR, 2001).

Moser and Ekstrom‟s (2010) definition of adaptation is also useful:
"*Adaptation involves changes in social-ecological systems in response to actual and expected impacts of climate change in the context of interacting non-climatic changes. Adaptation strategies and actions can range from short-term coping to longer-term, deeper transformations, aim to meet more than climate change goals alone, and may or may not succeed in moderating harm or exploiting beneficial opportunities*."

This definition recognizes that adaptation to climate change takes place in a complex context where climate variability and change is only one of many stressors that require response. It also acknowledges that some adaptive responses help deal with current variability and others may be more transformative and sustainable; yet there is no defined separation between the two and they can, and in fact in many circumstances should, be linked.

Climate change is not just an increase in average global temperatures but changes in regional climate characteristics such as rainfall, relative humidity and severe weather extremes (Davis, 2011). Climate change can manifest as a shock or a stress (Ziervogel and Calder, 2003). Shocks are defined as discrete, extreme events (rapid onset) such as floods, while gradual change (slow onset) such as long-term climate variability is classified as a stress (Ziervogel and Calder, 2003). The negative impacts of climate change "*are already felt in many areas, including in relation to, inter alia, agriculture, and food security; biodiversity and ecosystems; water resources; human health; human settlements and migration patterns; and energy, transport and industry*" (United Nations Women Watch, 2009:1).

Projections for the Western Cape show that under a 'middle-of-the-road' greenhouse gas emissions scenario, where good global mitigation of greenhouse gas (GHG) emissions (also referred to as 'carbon' emissions) takes place, we can expect a 1.5ºC increase by 2100, on top of the 1.5ºC increase we've seen since 1850 (WC DEA&DP, 2023). Differential impacts will, however, be felt in different regions. For example, in the interior average temperatures may rise by up to 6ºC by the year 2100, which could accelerate migration to coastal areas that are subject to increased risk from rising sea levels (at least 60 cm) and more intense storms. Infrastructure along the coast will come under increasing threat as sea levels continue to rise (WC DEA&DP, 2023).

The more extreme climate patterns will make day-to-day activities increasingly difficult, especially those taking place outdoors or dependent on a secure supply of water. Certain agricultural activities will become increasingly marginal or inviable, whilst the temperatures and other associated climate change impacts will affect our attractiveness as a tourist destination. Damages from increasingly frequent wildfires will escalate, and our water resources will remain under severe pressure. The costs of carbon emissions, in particular, will impact our global competitiveness if we are unprepared (WC DEA&DP, 2023).

1.3 Climate Change Legislative Context in South Africa

Climate change is a relatively new area of policy development in South Africa. As policies and structures are developed, it is necessary to ensure that they are evidence-based, coordinated and coherent.

1.3.1 Alignment with the New Draft South African Climate Change Act (Bill), 2022

The new Draft South African Climate Change Act (Bill), 2022 requires that all organs of state align their policies with the Act. They must also give effect to the objectives and principles of the Act. This new Act will be binding to all organs of state. The Garden Route District Municipality therefore took the opportunity to pre-empt the review of its current Garden Route Climate Change Strategy to be aligned with, and to ready, the document in anticipation of the date when the new Act comes into operation by proclamation in the Gazette.

The draft Climate Change Act (Bill), 2022 also requires the Mayor of a District Municipality to develop two documents which must both be reviewed every 5 years, and to be published in the Gazette:

1. A climate change needs and response assessment, and;

2. A climate change response implementation plan.

In order to prepare the current Garden Route District Climate Change Strategy document, and ready ourselves for the requirements of the new Act, the Garden Route District Municipality revised its Garden Route Climate Change Strategy to comply with the requirements of the new Act, resulting in the title change of the current document as follows:

- Garden Route District Municipality Climate Change Response Implementation Plan, 2024

The Climate Change Response Implementation Plan contains the response measures or programmes relating to both adaptation and mitigation, as per the requirements of the Act.

The GRDM also developed a second document which contains a Climate Change Vulnerability Assessment and other info as per the requirements of the new Act., and which informs the content of the Climate Change Response Implementation Plan. The title of this second document is:

- Garden Route District Municipality Climate Change Needs and Response Assessment, 2024.

As per the draft Climate Change Act (Bill), 2022, the following climate change objects and principles is of importance in achieving, promoting and the protection of a sustainable environment:

- **Objects of the South African Climate Change Act (Bill), 2022**

  The objects of the Act are to—
  (a) provide for a coordinated and integrated response by the economy and society to climate change and its impacts in accordance with the principles of cooperative governance;
  (b) provide for the effective management of inevitable climate change impacts by enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change, with a view to building social, economic and environmental resilience and an adequate national adaptation response in the context of the global climate change response;
  (c) make a fair contribution to the global effort to stabilise greenhouse gas concentrations in the atmosphere at a level that avoids dangerous anthropogenic interference with the climate system;
  (d) to ensure a just transition towards a low carbon economy and society considering national circumstances;
  (e) give effect to the Republic's international commitments and obligations in relation to climate change; and
  (f) protect and preserve the planet for the benefit of present and future generations of humankind.

- **Principles of the South African Climate Change Act (Bill), 2022**

The interpretation and application of the Act must be guided by—
(a) the national environmental management principles set out in section 2 of the National Environmental Management Act where applicable in this Act;
(b) the principle that the climate system should be protected for the benefit of present and future generations of humankind;
(c) the principle that acknowledges international equity and each country's common but differentiated responsibilities and respective capabilities, in light of different national circumstances;
(d) a contribution to a just transition towards low-carbon, climate-resilient and ecologically sustainable economies and societies which contribute to the creation of decent work for all, social inclusion and the eradication of poverty;
(e) the need for integrated management, in the context of climate change, which requires climate change considerations to be integrated into the making of decisions which may have a significant effect on the Republic's ability to mitigate or which exacerbate its vulnerability to climate change;
(f) the need for decision-making to consider the special needs and circumstances of localities and people that are particularly vulnerable to the adverse effects of climate change, including vulnerable workers and groups such as women, especially poor and rural women, children, especially infants and child-headed families, the aged, the poor, the sick and persons with disabilities;
(g) the need for a risk-averse and cautious approach to be adopted, which takes into account the limits of current knowledge about causes and effects of climate change and the consequences of decisions and actions in relation thereto;
(h) the need for climate change mitigation and adaptation responses to be informed by evolving climate change scientific knowledge and decisions which should be based on the best available science, evidence and information;
(i) an effective climate change response which requires preventative measures to mitigate the causes of climate change and to strengthen resilience through the adoption of adaptation measures;
(j) the costs of responding to the adverse impacts of climate change and of mitigation which must be paid for by those responsible for causing the adverse impacts;
(k) an integrated climate change response which requires the enhancement of public awareness of climate change causes and impacts and the promotion of participation and action at all levels; and
(l) a recognition that a robust and sustainable economy and a healthy society depends on the services that well-functioning ecosystems provide, and that enhancing the sustainability of the economic, social and ecological services is an integral component of an effective and efficient climate change response.

1.3.2 The National Environmental Management Act 107 of 1998

This Garden Route District Municipality Climate Change Response Implementation Plan is Guided by the principles in the National Environmental Management Act (NEMA), 107 of 1998 as set out in section 2 of the Act, which are as follows:

- **Principles of the National Environmental Management Act 107 of 1998**

Environmental management must place people and their needs at the forefront of its concern, and serve their physical, psychological, developmental, cultural and social interests equitably. Development must be socially, environmentally and economically sustainable.

(a) Sustainable development requires the consideration of all relevant factors including the following:

- That the disturbance of ecosystems and loss of biological diversity are avoided, or, where they cannot be altogether avoided, are minimised and remedied;
- that pollution and degradation of the environment are avoided, or, where they cannot be altogether avoided, are minimised and remedied;
- that the disturbance of landscapes and sites that constitute the nation's cultural heritage is avoided, or where it cannot be altogether avoided, is minimised and remedied;
- that waste is avoided, or where it cannot be altogether avoided, minimised and re-used or recycled where possible and otherwise disposed of in a responsible manner;
- that the use and exploitation of non-renewable natural resources is responsible and equitable, and takes into account the consequences of the depletion of the resource;
- that the development, use and exploitation of renewable resources and the ecosystems of which they are part do not exceed the level beyond which their integrity is jeopardised;
- that a risk-averse and cautious approach is applied, which takes into account the limits of current knowledge about the consequences of decisions and actions; and
- that negative impacts on the environment and on people's environmental rights be anticipated and prevented, and where they cannot be altogether prevented, are minimised and remedied.

(b) Environmental management must be integrated, acknowledging that all elements of the environment are linked and interrelated, and it must take into account the effects of decisions on all aspects of the environment and all people in the environment by pursuing the selection of the best practicable environmental option. :

(c) Environmental justice must be pursued so that adverse environmental impacts shall not be distributed in such a manner as to unfairly discriminate against any person, particularly vulnerable and disadvantaged persons.

(d) Equitable access to environmental resources, benefits and services to meet basic human needs and ensure human well-being must be pursued and special measures may be taken to ensure access thereto by categories of persons disadvantaged by unfair discrimination.

(e) Responsibility for the environmental health and safety consequences of a policy, programme, project, product, process, service or activity exists throughout its life cycle.

(f) The participation of all interested and affected parties in environmental governance must be promoted, and all people must have the opportunity to develop the understanding, skills and capacity necessary for achieving equitable and effective participation, and participation by vulnerable and disadvantaged persons must be ensured.

(g) Decisions must take into account the interests, needs and values of all interested and affected parties, and this includes recognising all forms of knowledge, including traditional and ordinary knowledge.

(h) Community wellbeing and empowerment must be promoted through environmental education, the raising of environmental awareness, the sharing of knowledge and experience and other appropriate means.

(i) The social, economic and environmental impacts of activities, including disadvantages and benefits, must be considered, assessed and evaluated, and decisions must be appropriate in the light of such consideration and assessment.

(j) The right of workers to refuse work that is harmful to human health or the environment and to be informed of dangers must be respected and protected.

(k) Decisions must be taken in an open and transparent manner, and access to information must be provided in accordance with the law.

(l) There must be intergovernmental co-ordination and harmonisation of policies, legislation and actions relating to the environment.

(m) Actual or potential conflicts of interest between organs of state should be resolved through conflict resolution procedures.

(n) Global and international responsibilities relating to the environment must be discharged in the national interest.

(o) The environment is held in public trust for the people, the beneficial use of environmental resources must serve the public interest and the environment must be protected as the people's common heritage.

(p) The costs of remedying pollution, environmental degradation and consequent adverse health effects and of preventing, controlling or minimising further pollution, environmental damage or adverse health effects must be paid for by those responsible for harming the environment.

(q) The vital role of women and youth in environmental management and development must be recognised and their full participation therein must be promoted.

(r) Sensitive, vulnerable, highly dynamic or stressed ecosystems, such as coastal shores, estuaries, wetlands, and similar systems require specific attention in management and planning procedures, especially where they are subject to significant human resource usage and development pressure.

1.3.3 The Disaster Management Act (57 of 2002), as amended

Disaster risk management (DRM) in South Africa is regulated by the Disaster Management Act (No. 57 of 2002) as amended (DMA). South Africa took an essential step towards strengthening its DRR capabilities on 15 January 2003, with the promulgation of the DMA, which provides for:

- An integrated and coordinated DRM 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;

- The establishment of national, provincial and municipal Disaster Management Centres (DMC);
- Powers of National, Provincial and Municipal undertakings in implementing DRM;
- Funding of post disaster, recovery and rehabilitation;
- DRM volunteers; and
- Matters relating to these issues.

The DMA thus provides the legal context for concerted action related to disasters and disaster risks in South Africa. It complements and adds value to existing related legislation in many sectors. It also recognises the multi-disciplinary and multi-sectoral character of efforts to improve management of disaster risks, as well as potential and actual disaster situations. In addition, it underlines the need for wide-ranging partnerships between government, the private sector, civil society, and particularly those communities most at-risk.

However, the implementation of the DMA has posed significant challenges, particularly at the level of local municipalities. As a result, the Disaster Management Amendment Act No. 16 of 2015 was promulgated, with the purpose of tackling these challenges by maximising the effect of disaster management legislation to communities, especially those most at risk. The amendments also included the inclusion of adaptation to climate change and the development of early warning mechanisms. The amendments are as follows:

- Clarification of policy focus on rehabilitation and functioning of DMCs;
- Alignment of the functions of the National Disaster Management Advisory Forum to accommodate the South African National Platform for DRR;
- Providing for the South African National Defence Force (SANDF) and South African Police Service (SAPS) to assist disaster management structures;
- Providing for an extended reporting system by organs of state on information regarding events leading to declarations of disasters, expenditure on response and recovery, actions pertaining to risk reduction and particular problems experienced in dealing with disasters;
- Strengthening of reporting on implementation of policy and legislation relating to DRR and management of allocated funding to municipal and provincial intergovernmental forums established in terms of the Intergovernmental Relations Act of 2005;
- Expanding the contents of disaster management plans (DMP) to include conducting DRAs for functional areas, mapping of risk, areas and communities vulnerable to disasters;
- To provide measures to reduce the risk of disaster through adaptation to climate change and developing of early warning mechanisms;
- Providing for regulations on disaster management, education and training matters; and
- Substitution and insertion of certain definitions.

The Garden Route District Municipality's Disaster Management Centre, in conjunction with the Western Cape Provincial Disaster Management Centre, have conducted a DRA for its municipal area, identifying and mapping risks, areas, ecosystems, communities and households that are exposed or vulnerable to physical and human-induced threats, as part of its Garden Route Disaster Risk Assessment document of 2021.

1.3.4 The Western Cape Climate Change Response Strategy: Vision 2050

The Western Cape Climate Change Response Strategy: Vision 2050 responds to the global climate change emergency amidst the dramatic global events since 2020-21. It describes a climate future that the Western Cape province will strive towards. It incorporates the latest science and the overwhelming evidence supporting the need for a green and low-carbon economic recovery. Whilst recognising the progress made since the release of its predecessor in 2014, the updated strategy aims to address an urgent 2030 deadline, ultimately planning a trajectory for strategic outcomes in 2050 (WC DEA&DP, 2023).

The Strategy is envisaged as a transversal strategy providing policy direction in response to climate-related risks and potential opportunities, through either creating or leveraging systemic innovative response programmes that tackle the region's vulnerability to droughts, heat and floods and take advantage of opportunities that will enable climate resilient development which fosters economic growth that is low-carbon and further creates an advanced Green Economy (WC DEA&DP, 2023).

1.3.5 Other International and National Climate Change Policies and Structures

This section introduces international and national climate change policies and structures, which are listed below:

- The United Nations Framework Convention on Climate Change (UNFCCC). This international treaty provides guidance on setting agreements pertaining to the reduction of greenhouse gas emissions;
- The Paris Agreement, came into effect on 4 November 2016. This is the first agreement all countries have committed to and stipulates that all countries must reduce carbon emissions to limit global temperature increase to 1.5 degrees Celsius above pre-industrial levels;
- South Africa's Nationally Determined Contributions came into effect after the Paris Agreement was signed. South Africa is therefore required to report on mitigation and adaptation efforts. Concerning mitigation, South Africa is to reduce emissions by a range between 398 and 614 million metric tons of carbon equivalent by 2025 and 2030. There are several instruments to ensure reduction in carbon emissions including car tax and company carbon budgets among other instruments. With reference to adaptation a National Adaptation Plan is currently being developed, and climate change is to be incorporated in all policy frameworks, institutional capacity is to be enhanced, vulnerability and adaptation monitoring systems are to be in place, vulnerability assessment and adaptation needs framework are to be developed and there needs to be communication of past investments in adaptation for education and awareness;
- The National Climate Change Response White Paper (NCCRWP) was adopted in 2011 and presents the South African Government's vision for an effective climate

change response in the long-term, to transition to a climate-resilient and lower-carbon economy and society;

- The National Development Plan, focuses on eliminating poverty and reducing inequality by 2030 and creating an environmentally sustainable country through mitigation and adaptation efforts;
- Long Term Mitigation Scenarios, outline different scenarios of mitigation action for South Africa;
- Long Term Adaptation Scenarios, consist of two phases. Phase one, was the identification of climate change trends and projections as well as impacts and responses for the main sectors. Phase two focussed on integrating issues such as climate information and early warning systems, disaster risk reduction, human settlements and food security.

1.4 Climate Change Impacts in South Africa

South Africa's temperature is expected to increase to 1.2o C by 2020, 2.4o C by 2050 and 4.2o C by 2080 (Kruger and Shongwe, 2004). Contrary to the global increase in rainfall, South Africa's rainfall is expected to decrease by 5.4% by 2020, 6.3% by 2050 and 9.5% by 2080 (Kruger and Shongwe, 2004). The frequency and intensity of climate extremes, inter alia, droughts, floods, storms and wild fires will increase (Davis, 2011; Böckmann, 2015). Climate change evidence indicates the changes in frequency and intensity of flood and prolonged drought events at small scales (Meyiwa *et al*., 2014). Furthermore, the sea level will continue rising and ocean acidification will get worse (Böckmann, 2015). There are however uncertainties associated with climate projections because they are based on the potential rates of resource use in the future, and associated greenhouse gas emissions (Nicholson-Cole, 2005).

To assist with assessing the potential impacts from climate change, the country has been divided into six hydrological zones (Figure 1). These hydrological zones not only reflect water management areas but have been grouped according to common climatic and hydrological characteristics (DEA, 2013a). Based on a range of data and projections, four possible climate scenarios have been identified for South Africa:

- Warmer/wetter (with greater frequency in extreme rainfall events);
- Warmer/drier (with an increase in frequency of drought and somewhat increased frequency of extreme rainfall events);
- Hotter/wetter (with substantially greater frequency of extreme rainfall events), and;
- Hotter/drier (with a substantial increase in the frequency of drought events and greater frequency of extreme rainfall events).

Projections on rainfall have also been developed for each of the hydrological zones (Department of Environmental Affairs, 2013a). The following four climate change scenarios have been described for the Breede-Gouritz-Berg Hydrological Zone (the dominant zone in the Western Cape) in the Department of Environmental Affairs' Long Term Adaptation Scenarios Reports. These are:

- Warmer wetter scenario - Decreased rain in autumn & increased in winter & spring;
- Hotter drier scenario - Decreased rain in all seasons & strongly decreased in west;
- Hotter wetter scenario - Decreased rain in autumn & increased in winter & spring;

- Warmer drier scenario - Decreased rain in all seasons & strongly decreased in west.

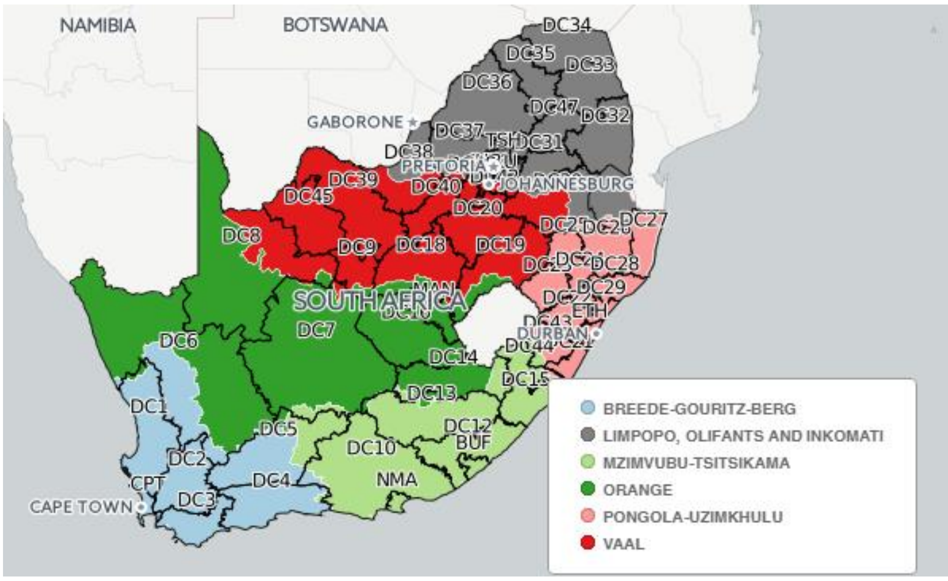

Figure 1: The hydrological zones of South Africa (Department of Environmental Affairs, 2013a).

According to Schulze (2016), globally, the effects of climate change resulting from steady increases in carbon dioxide (CO2) emissions into the atmosphere can no longer be denied or ignored, with 2015 having been the planet's warmest year on record (Figure 2). Since the 1860s, and up to the end of 2015, 14 of the 15 hottest years on record had been in this century.

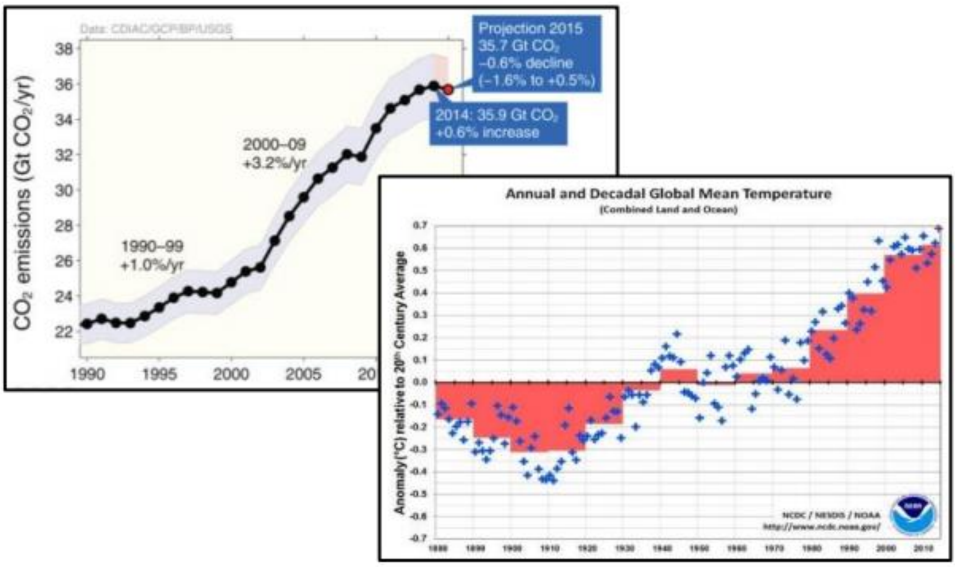

Figure 2: Annual CO2 emissions (in Gigatons) into the atmosphere (top) and annual (red pluses) as well as decadal (red bars) global temperature differences relative to the 20th century average (bottom), showing 2015 to be the hottest year on record (USGS, 2016; NOAA, 2016; Schulze (2016).

While not as steady as the global temperature trend, South Africa's temperature is also showing an overall upward trend in temperature (Figure 3) (SAWS, 2015).

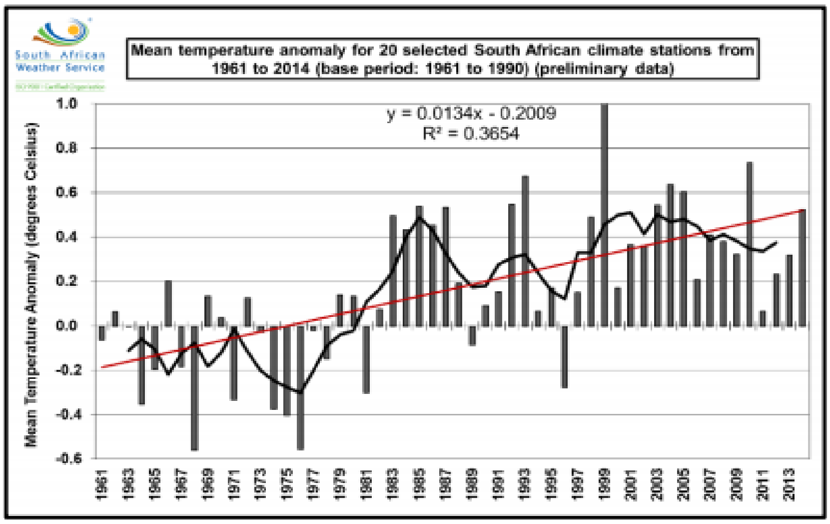

Figure 3: Annual mean temperature anomalies (base period 1961-1990) of 20 climate stations in South Africa for the period 1961-2014, with the red line indicating the linear trend and the black line the 5-year moving average (SAWS, 2015).

An increase in Greenhouse Gas (GHG) emitting activities in South Africa have significantly increased the atmosphere's absorption of the earth's outgoing infrared radiation, thereby enhancing the existing greenhouse effect, and then re-radiating part of it back to earth, resulting in the rising trend in global temperatures shown in Figure 4. Climate change thus refers to the changes of climate which are attributed directly or indirectly to human activities that alter the composition of the global atmosphere. This change in climate is superimposed onto natural climate variability which is experienced world-wide, but which is particularly severe over South Africa (IPCC, 2007; NOAA, 2015).

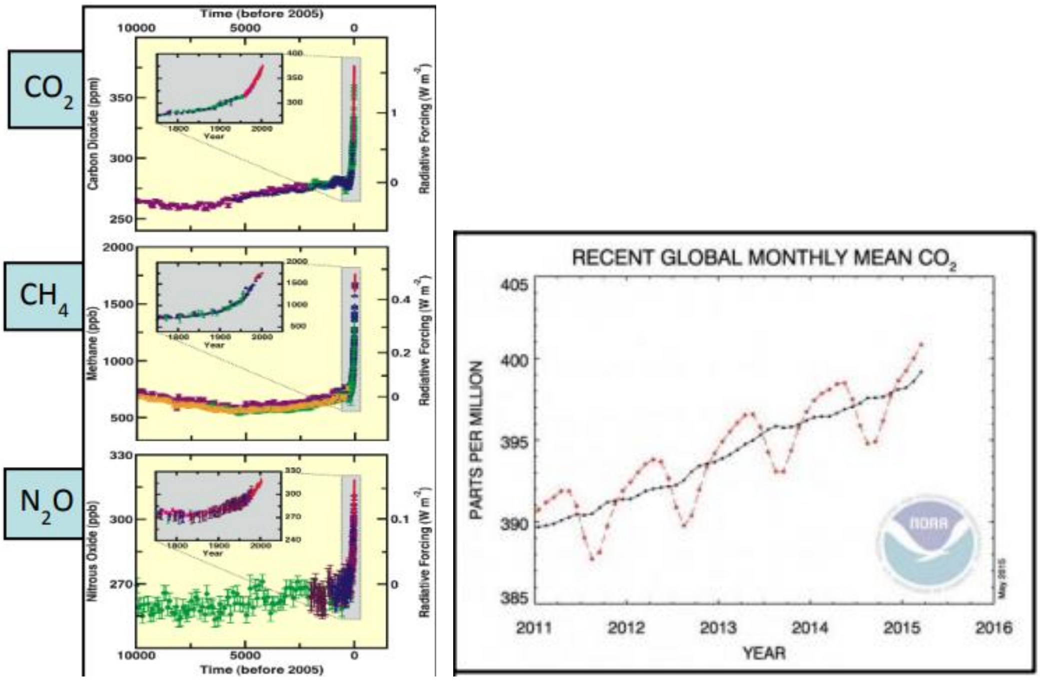

Figure 4: Increases in GHG emissions in the recent past (left), with more detail on recent global monthly mean CO2 concentrations in the atmosphere (IPCC, 2007; NOAA, 2015).

A 1.5ºC increase in temperature refers to an increase of the Earth's average temperature and not of an individual location. In fact, there are many regions across the world where warming has already surpassed 1.5ºC above pre-industrial levels. The Earth heats up differentially, generally with the strongest warming in the Arctic during its cool. season and in the Tropics during its warm season. Warming also tends to be higher over land in the interior of continents, compared to oceans and coastal areas.

Climate change has altered terrestrial, freshwater and ocean ecosystems across the globe, and further increases in global average temperatures will lead to more severe climate-related impacts such as temperature extremes, drought, declining human health, amongst others. Although efforts to limit the global temperature increase to 1.5ºC does not mean that these impacts will not happen; it will reduce the magnitude of the impact, making it easier for biodiversity and societal frameworks to adapt (WC DEA&DP, 2023).

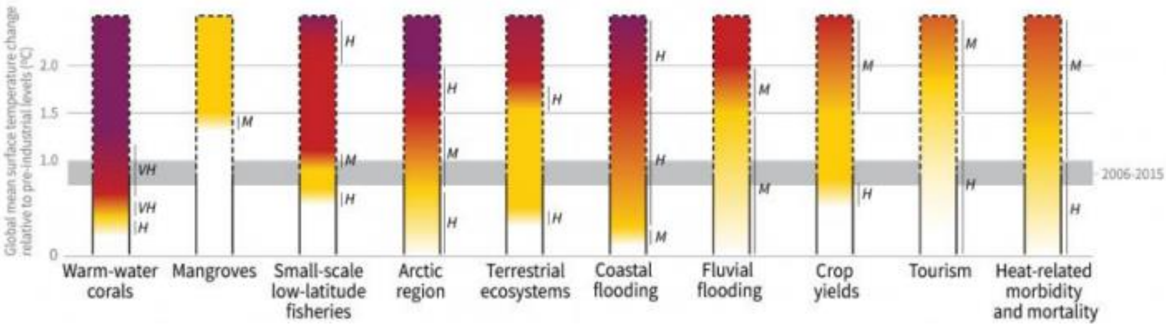

Figure 5: Climate change impacts and risks for selected systems as temperatures rise – white indicates no impacts, and purple shows very high risk of severe and/or irreversible impacts. The grey band denotes global temperatures for 2006-2015 (source: www.ipcc.ch/sr15; WC DEA&DP, 2023).

Human activities have already increased the global average temperature by 1.1ºC and committed us to a further increase every decade. This means that global warming will reach 1.5ºC by 2030 (IPCC, 2021; WC DEA&DP, 2023). Africa, under the current climate, experiences one to three heatwaves per year. This could more than double at 1.5ºC warming.

From a food security perspective, every degree of global temperature rise could reduce global yields of wheat by 6%, rice by 3.2% and maize by 7.4%. This would put many African regions such as the African Sahel and Southern Africa at high risk of food insecurity. An increase in temperature beyond 1,5ºC will make it very challenging for the continent to establish any viable climate resilient development pathways (IPCC, 2022; WC DEA&DP, 2023). Limiting future global temperature increase to 1.5ºC as opposed to 2ºC could mean that approximately 420 million fewer people are exposed to extreme heatwaves, and a reduced exposure to severe drought for 61 million people in urban areas.

90% of all disasters globally are now climate related, and the latest science points to the attribution of climate change being a driver behind many extreme weather events (National Academies of Sciences, 2016; WC DEA&DP, 2023). We need to formally recognise the economic costs and risks of climate related disasters as ones that we are witnessing will increase in magnitude and frequency. In response to the climate change driven drought of 2015-2019, the cumulative totals of the impact of the drought are still being calculated on an ongoing basis. Drought impacts cost R14 billion in the agriculture sector alone. In addition, a single severe storm, and Knysna fires in June 2017 caused R4 – 6 billion losses in damage; the avian influenza outbreak (associated with the drought) caused losses of R800 million to the poultry sector.

Over 30 000 seasonal jobs in agriculture were lost. The responses in reactive disaster funding have been but a fraction of the economic cost: R1 billion in 2017; and close to another half a billion rand was requested from national disaster management funds in 2018 (WC DEA&DP; WC DMC, 2023). The situation is a clear indicator of the economic cost of failure to adapt to climate change. Proactive planning and adaptive measures rather than reactive measures are likely to be less costly.

2 Provincial Climate Change Context

The Western Cape has a well-developed climate change policy environment. In 2005, the Western Cape government carried out a study titled the "Status Quo, Vulnerability and Adaptation Assessment of the Physical and Socio-economic Effects of Climate Change in the Western Cape" and in the same year, the Western Cape government signed the Montreal Accord to protect the Ozone layer (Western Cape Government Department of Environmental Affairs and Development Planning, 2008). The Western Cape Climate Change Response Strategy and Action Plan was then developed in 2008 (Western Cape Government Department of Environmental Affairs and Development Planning, 2008; Coastal & Environmental Services, 2011). The Climate Change Response Strategy and Action Plan placed a lot of emphasis on adaptation to allow for developmental prioritises (Coastal & Environmental Services, 2011). The Climate Change Strategy was then updated in 2014 to align with the National Climate Change Response Policy and is geared to strategically direct and mainstream climate change actions and related issues throughout relevant Provincial transversal agendas (Western Cape Government: Environmental Affairs and Development Planning, 2014).

The province experiences drought and flood events with significant adverse impacts (Pasquini, Cowling, and Ziervogel, 2013). Historically the province has been the most disaster prone in the country (Western Cape Government, 2015). Increased temperatures in the future are certain for the Western Cape (Western Cape Government, 2015). Rainfall projections are less certain, some projections reveal increased while others reveal decreased rainfall in the future, decreased rainfall has the most adverse impacts in comparison to increased rainfall (Western Cape Government, 2015).

Concerning wildfire, the frequency and intensity is expected to increase with climate change (Pasquini, Cowling, and Ziervogel, 2013). The frequency and intensity of extreme events is expected to increase as well (Department of Environmental Affairs and Development Planning, Western Cape, 2008).

The Table 2 below is a summary of the key climate change impacts in the province as outlined in the Climate Change Response Strategy and Action Plan for the Western Cape (2014).

Table 2: Climate change impacts for the Western Cape Province (Climate Change Response Strategy and Action Plan for the Western Cape (DEA&DP, 2014).

Change to climate variable	Vulnerability Details
Higher mean temperatures	• Increased evaporation and decreased water balance; • Increase wild fire danger (frequency and intensity).
Higher maximum temperatures, more hot days and more heat waves	• Heat stress on humans and livestock; • Increased incidence of heat-related illnesses; • Increased incidence of death and serious illness, particularly in older age groups; • Increased heat stress in livestock and wildlife; • Decreased crop yields and rangeland productivity; • Extended range and activity of some pests and disease vectors; • Increased threat to infrastructure exceeding design specifications relating to temperature (e.g. traffic lights, road surfaces, electrical equipment, etc.); • Increased electric cooling demand increasing pressure on already stretched energy supply reliability; • Exacerbation of urban heat island effect.
Higher minimum temperatures, fewer cold days and frost days	• Decreased risk of damage to some crops and increased risk to others such as deciduous fruits that rely on cooling period in autumn; • Reduced heating energy demand; • Extended range and activity of some pests and disease vectors; • Reduced risk of cold-related deaths and illnesses.
General drying trend in western part of the country	• Decreased average runoff, stream flow; • Decreased water resources and potential increases in cost of water resources; • Decreased water quality; • Decrease in shoulder season length threatening the • Western Cape fruit crops; • Increased fire danger (drying factor); • Impacts on rivers and wetland ecosystems.

Change to climate variable	Vulnerability Details
Intensification of rainfall events	• Increased flooding; • Increased challenge to stormwater systems in urban settlements; • Increased soil erosion; • Increased river bank erosion and demands for protection structures; • Increased pressure of disaster relief systems; • Increased risk to human lives and health; • Negative impact on agriculture such as lower productivity levels and loss of harvest.
Increased mean sea level and associated storm surges	• Salt water intrusion into ground water and coastal wetlands; • Increased storm surges leading to coastal flooding, coastal erosion and damage to coastal infrastructure; • Increased impact on estuaries and associated impacts on fish and other marine species.

The provincial climate change strategy also lists a number of priority responses in each of the key sectors. These are summarised in Table 3 below:

Table 3: Priority Climate Change Adaptation Responses for the Western Cape Province

Adaptation Category	Adaptation Responses
Water Security and Efficiency	• Invasive alien vegetation clearing; • Prioritisation, valuation, mapping, protection, and restoration of ecological infrastructure in catchments; • Effective utilisation of irrigation water; • Resource nexus decision support; • Develop ecosystem goods and services (EGS) investment opportunities.
Biodiversity and Ecosystem Goods and Services	• Prioritisation, valuation, mapping, protection, and restoration of ecological infrastructure; • Landscape initiatives/biodiversity corridors and identification of requirements for climate change adaptation corridors; • Biodiversity stewardship; • Mainstreaming of conservation planning into decision making.
Coastal and Estuary Management	• Establishment of coastal hazard overlay zones and setback lines; • Research best practice regarding responding to repeated coastal inundation in high risk areas; • Protecting and rehabilitating existing dune fields as coastal buffers / ecological infrastructure; • Monitor possible linkages between climate change and fisheries industry; • Ensure Estuary Management Plans take cognisance of climate change.
Food Security	• Farming practices that are in harmony with nature, i.e. 'conservation farming'; • Climate smart agriculture; • Agricultural water technologies that reduce consumption and increase efficiency; • Research on climate resilient and alternative crops and livestock applicable

Adaptation Category	Adaptation Responses
	to the Western Cape; • Addressing climate vulnerability through the Municipal Support Programme; • Assessing food security in the context of the resource nexus.
Managing the effects of increased temperature on human lives	• Societal adaptation to human health impacts from temperature increases associated with climate change.
Healthy Communities	• Monitoring health trends in relation to climate trends; • Research linkages between human health and climate change in the WC context. These include: Air quality, Water quality, Food security, Heat stress, Disease vectors

3 The Garden Route District Municipality

Garden Route District Municipality is one of five district municipalities within the Western Cape Province. The district is situated on the south-western portion of the province and comprises of the following seven local municipalities: Bitou, George, Hessequa, Kannaland, Knysna, Mossel Bay, and Oudtshoorn Local Municipality. George local municipality is home to a great proportion of the district's population and Kannaland local municipality is home to the least proportion of the district's population. The district is the largest and most rural district in the Western Cape Province (Garden Route District Municipality, 2017b).

The Garden Route District is a place of exceptional natural beauty which offers a range of environmental goods and services that, to a large extent, underpin the economic activity in the area. This "sense of place" has resulted in the district being collectively termed "The Garden Route" and is a major tourism draw card. However the same things that form part of this tourism draw card, such as the lovely beaches, estuaries and rivers, pose a serious disaster risk to the area, particularly in the face of a changing climate. Over the past decade the district has been hit annually by climate related extreme events, resulting in a string of massive floods, coastal inundation, fires, and water crisis and drought.

3.1 Garden Route District Climate Overview

The historical climate monthly averages for the Garden Route District area have been calculated using the nearest weather data station to the Municipality, which is the measuring station at George. The graph below (Figure 5), shows that average temperatures peak in January and February, while rainfall is fairly consistent throughout the year, indicating that the Garden Route District area is a year-round rainfall area (Climate System Analysis Group, 2017b). The lowest average monthly rainfall historically occurs in June, which averages less than 38 mm (Climate System Analysis Group 2017b).

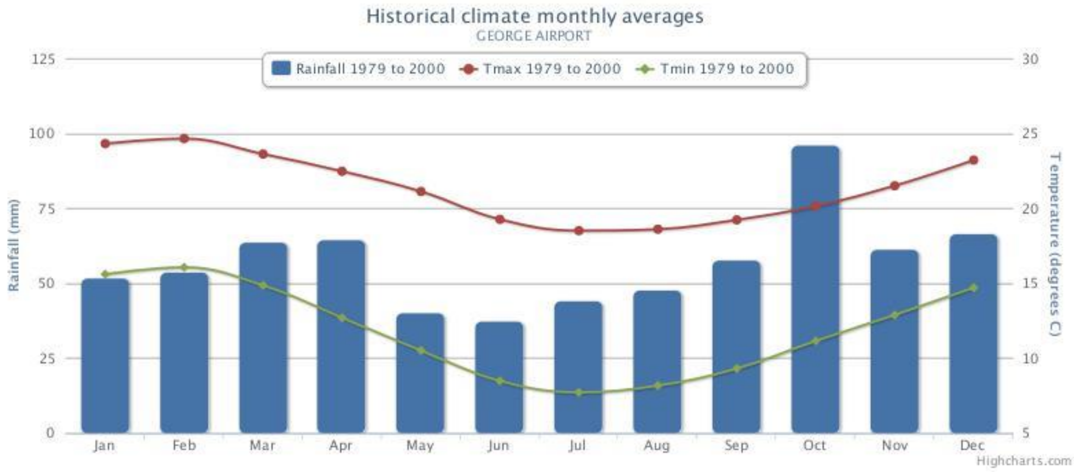

Figure 6: Historical Climate Monthly Averages for George (Climate System Analysis Group 2017b)

3.1.1 Rainfall

The Western Cape climate is classed as Mediterranean and as such is largely a winter rainfall region. Winter rainfall is the result of mid-latitude disturbances commonly known as cold fronts. While these frontal systems continually pass to the south of the country all year round, during winter their tracks move northwards and their influence on the regional climate is significant. Flood events are often associated with strong cold fronts or their closely related cousins, cut-off low pressure systems, which are more frequent during the transition seasons (i.e. spring and autumn).

The southern coastal areas, including the Garden Route district, experience rainfall almost all year around. This is a result of the onshore flow of moisture from the south (over the warm Agulhas Current), rising up the coastal mountains and producing summer rainfall. Additionally, moisture originating from the tropics is transported southwards towards the southern cape during the summer months, leading to occasional favourable conditions for rainfall. However the dominant strong rainfall events still occur in winter as a result of cold fronts passing across the country. It must be kept in mind that many local factors, such as topography, play a key role in the rainfall patterns of this region. This is evident when one looks at the spatial distribution of rainfall patterns across the region.

With the exception of the southeast and a small area in the west of the District Municipal Area, the Garden Route District Municipal Area has relatively low levels of mean annual rainfall (average rainfall per year) (Figure 6) (Western Cape Department of Agriculture 2017).

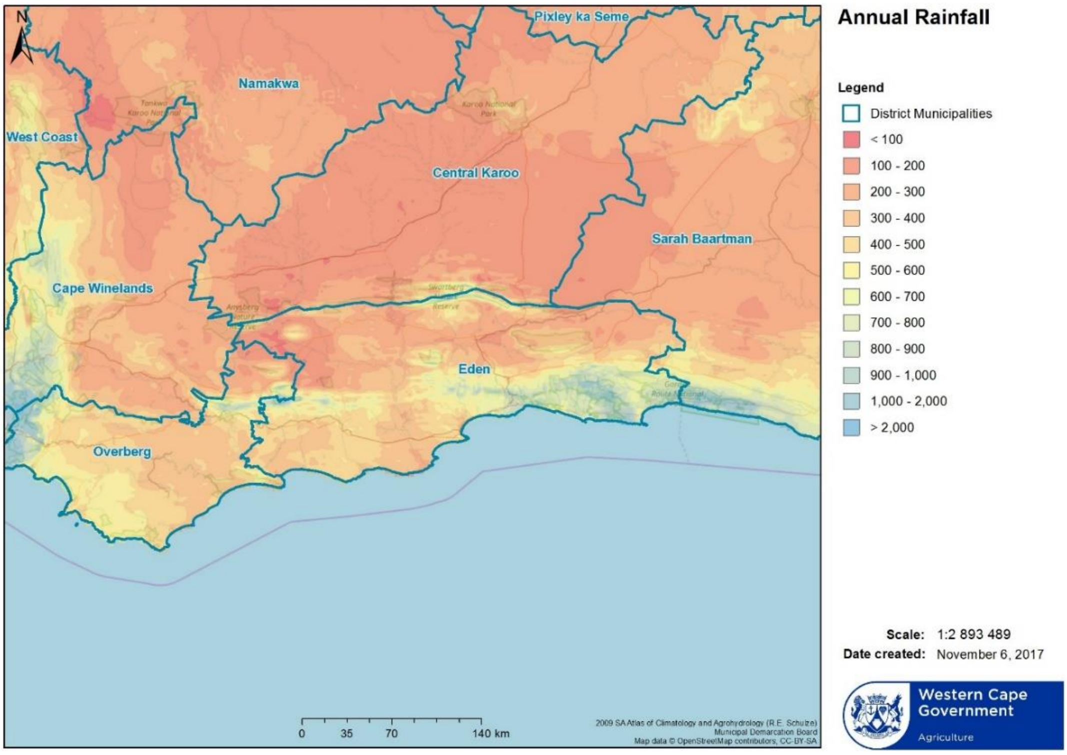

Figure 7: Mean Annual Rainfall in the District Municipal Area (Western Cape Department of Agriculture 2017)

If the mean annual rainfall is considered with the projected increases in average temperature, it is apparent that evaporation rates are expected to increase, which will increase water insecurity in the Garden Route District Municipal area, especially in the inland areas (Western Cape Department of Agriculture 2017).

3.1.2 Temperature

The Long Term Adaptation Scenarios Flagship Research Programme (LTAS) has forecast that climate change is predicted to increase temperatures and rainfall variability, while decreasing the total average rainfall in the west of South Africa (Department of Environmental Affairs, 2013c). The predicted increases in mean average temperature (Figure 7), shows that the inland parts of the Garden Route District Municipal Area are projected to experience medium to high range warming, with the expectation of the Bo-Langkloof-Outeniqua SmartAgri Zone, which is projected to experience low to medium range warming (Western Cape Department of Agriculture, 2017). Meanwhile all the coastal parts of the District Municipal Area are projected to experience a low range of warming (Western Cape Department of Agriculture, 2017).

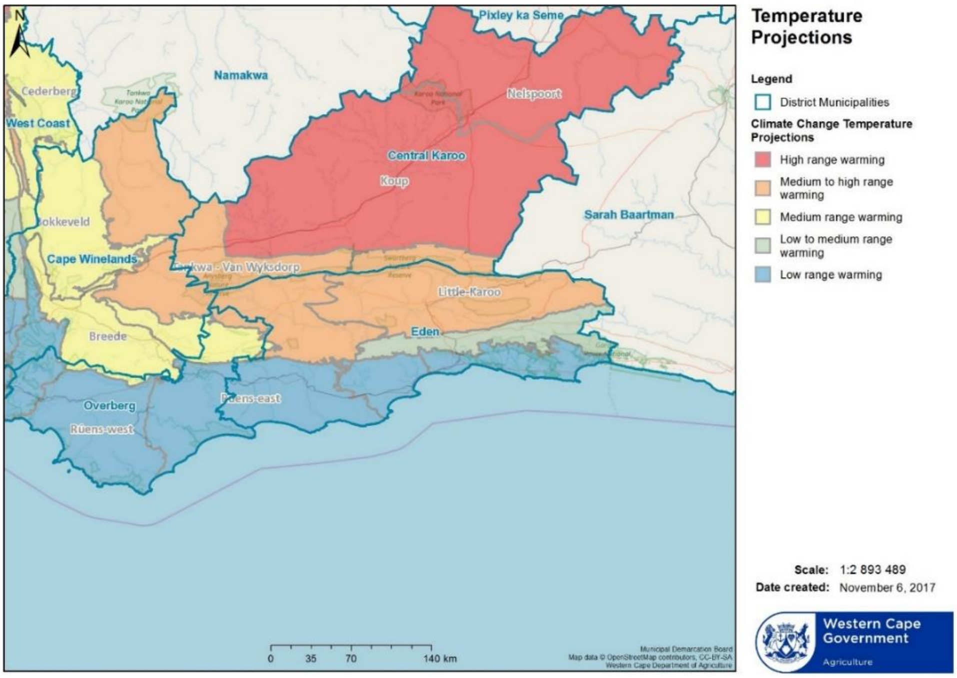

Figure 8: Temperature projections in the District Municipal Area (Western Cape Department of Agriculture 2017)

3.2 Future Climate Change Projections for the Garden Route District

Climate change is predicted to have an impact on rainfall patterns in South Africa. Future rainfall projections for the Garden Route District Municipality (using the measuring station at George) for the period 2020 to 2040 has been made by the University of Cape Town's Climate Systems Analysis Group, using the Representative Concentration Pathways (RCP) 4.5 greenhouse gas concentration trajectories (Climate System Analysis Group, 2017a). The bar chart (Figure 8) show the potential change in rainfall, with the blue bars indicating a potential increase in average rainfall and the red bars indicate a potential decrease in average rainfall (Climate System Analysis Group, 2017a). The grey lines represent the various models used for this projection. It is therefore projected across most of the models that Garden Route District could experience an increase in rainfall in the months of January, February, March, April, July, September, October and December, and a decrease in rainfall during May, June, August and November (Climate System Analysis Group 2017a).

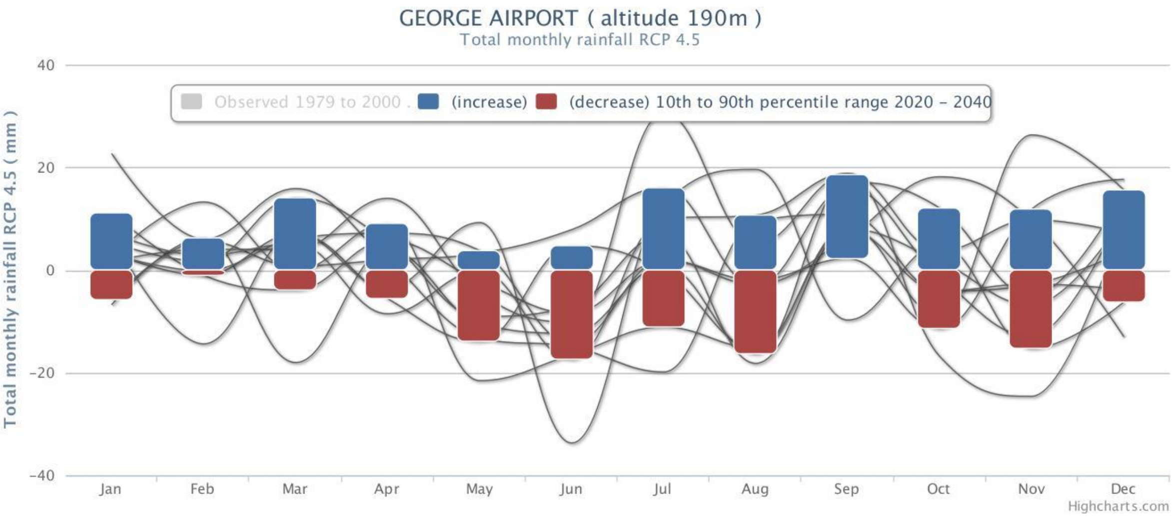

Figure 9: Rainfall Projections for George (Climate System Analysis Group, 2017a)

Climate change impacts for the Western Cape carry a high degree of uncertainty due to the complexity of the frontal systems and their interaction with the complex topography of the region. However there is a fairly confident message present in two strong climate drivers, which adds weight to some of the changes projected. The first is the shift in the South Atlantic High Pressure systems further south. Many models produce a similar shift south in the future and the result is to push the winter cold fronts further south, away from the country, during winter.

However, a counterpoint to this is the increase in atmospheric moisture due to a warmer climate. Orographic (mountain) rainfall is a significant component of rainfall in the mountainous regions of the Western Cape and the magnitude of such rainfall is often limited by the moisture content of the air flowing over the mountains. Increases in the moisture content could produce more orographic rainfall in mountain locations. The net result is a possible shift towards generally drier conditions but with wetter conditions in mountain locations (e.g. coastal region of the Garden Route district). Many river catchments include large portions of mountainous regions and hence the impact of climate change on river flows is likely to be complex and require a considerable modelling effort.

Finally, many projections suggest that changes in rainfall will occur through shifts in seasonality. Most distinctly, through decrease in peak winter rainfall but possible increases in the transition or “shoulder” seasons of autumn and winter. This shift agrees with the two large scale drivers discussed above as the shoulder season rainfall is often dominantly orographic while the core season rainfall is dominantly driven by strong cold frontal systems which, under climate change, could shift further from the continent.

There is some evidence that some of these changes are already being experience which adds further weight to the evidence for general drying, seasonal shifts, and increased mountainous rainfall. Climate change is predicted to increase the number and severity of droughts, fires and floods in the in the Garden Route District area (Garden Route District Municipality, 2014). To counter these risks, the Garden Route District Municipalities should conserve their water resources, wetlands and biodiversity, through updated land-use and settlement plans that take disaster risk management criteria into account, and by increasing public awareness regarding water conservation, droughts, fires and floods (Garden Route District Municipality, 2014, 2017a). This is particularly pertinent given the recent devastating fires in and around the Garden Route as well as the severe ongoing drought in the Western Cape (Garden Route District Municipality, 2014, 2017a).

4 Major Climate Change Impacts of Extreme Concern in Garden Route District

The district's vulnerability to climate change impacts is attributed to its physical location, topography and general climate conditions (Garden Route District Municipality, 2017a). In addition, increased vulnerability to climate change has been caused by rapid urbanisation and informal developments (Western Cape Government, 2013). Urbanisation has increased because of in migration of the youth from the Eastern Cape and the elderly to the coastal towns (Garden Route District Municipality, 2017b). However, housing delivery has not been able to keep up with the migration, hence the ongoing increase in informal dwellings in the District (Garden Route District Municipality, 2017b). Furthermore, the natural and scenic beauty of the District is a major tourist attraction that could be negatively affected by the impacts of climate change (Garden Route District Municipality, 2017a).

The following climate change impacts have already been observed in the District: increased average temperatures; shifts in seasonality; increased frequency of veld fires; increased magnitude and frequency of storm events accompanied by strong winds; more frequent and severe storm surges; and, increases in rainfall variability and the number of dry days (Garden Route District Municipality, 2014). In addition, sea level rise and associated hazards are a major concern for coastal areas within the District (Garden Route District Municipality, 2012). Sea level rise impacts are likely to include inter alia coastal erosion, flooding, destruction of infrastructure and salt water contamination of fresh water bodies (Western Cape Government, 2013).

The Garden Route district experienced regular flooding, droughts and fire disasters, and an increase in the frequency of these disasters, causing significant impacts in the district, ranging from loss of life, property damage, large scale infrastructural damage, agricultural losses, costly response measures, and economic loss. Climate change is expected to increase the frequency and severity of these disasters (Garden Route District Municipality, 2014). Additionally, financial losses in the District, due to these climate hazards, has already been high (Garden Route District Municipality, 2014) For example, it was estimated that the 2009/2010 drought cost the District R 300 million, while the cost of the 2011 floods was estimated to be R 350 million (Garden Route District Municipality, 2014). Furthermore, approximately 45% of the District’s disaster relief budget is allocated to the repair and maintenance of road infrastructure after flood damage (Garden Route District Municipality 2014). Another 45% of the District’s disaster relief budget is spent on fire-related disasters (Garden Route District Municipality, 2014).

With recent climate trends in the district causing rising temperatures (maximum, minimum and mean) and reductions in the number of rain days in autumn and summer, the area is expected to be particularly hard hit by the combination of warming and additional stress on already constrained water supplies (DEA&DP and UCT, 2022). The low water storage capacity, especially in the Klein Karoo area, has resulted in a higher vulnerability to periods of low rainfall.

Concerns are also expressed regarding the risks to infrastructure and ecological risks caused by flooding within the Garden Route District area. Due to the climate change trends, the area is experiencing increases in extreme flooding, more frequent and longer dry spells, reduced seasonal rainfall, and more frequent summer rainfall.

4.1 Floods, Drought and Water Security

Climate change projections for the Garden Route district indicate a strengthening of conditions which will give rise to orographic rainfall in autumn and spring, the poleward contraction of rain-bringing storm tracks during winter, and possibly more energetic mid-latitudes, which may result in more intense storm systems and resultant flooding (DEA&DP and UCT, 2022). Flood events and overflows are projected due to more frequent extreme precipitation caused by these storm systems.

Climate change is also likely to cause potential shifts in the seasonality of rainfall and runoff and an increase in the magnitude and frequency of flood events (DEA&DP and UCT, 2022). Projections indicate heavier rainfall events in shorter periods, and in degraded areas poor infiltration will cause more run off and erosion, leading to sedimentation of groundwater and other water systems (DEA&DP and UCT, 2022).

Many of the water challenges and shortages at municipalities, and also in the agricultural sector, can be attributed to climate change. Based on the current understanding of climate processes, climate change will cause shifts in locally important climate systems or processes within the Garden Route district (DEA&DP and UCT, 2022). A rapid pace of El Nino conditions is occurring, and whereas before we would have droughts spaced out between four or five years, we are now seeing these occurrences almost every two years (DEA&DP and UCT, 2022).

Climate modelling shows that future increased temperatures, which exacerbates drought conditions across the region are almost a certainty, with all research model projections in agreement. Rainfall changes in some area in the Garden Route district, and during some seasons, are statistically significant and could be as large as a 40% reduction (Oudtshoorn and Kannaland areas) (DEA&DP and UCT, 2022). Climate change projections indicate changes in mean annual rainfall, the spatial distribution of precipitation, and seasonal cycles (DEA&DP and UCT, 2022). The climate models indicated that the 1-in-10 drought event under current conditions is projected to shift towards a 1-in-2 event (five events per decade) by mid-century when the effect of increasing temperature on evaporation is considered (DEA&DP and UCT, 2022). The area show fairly consistent drying projections, again with statistically significant strong drying projected by some models (DEA&DP and UCT, 2022). This model data point to increases in drought conditions resulting in physical water scarcity in the Garden Route District (Figure 9). The predicted warming and drying in certain areas may lead to increases in the frequency and intensity of droughts.

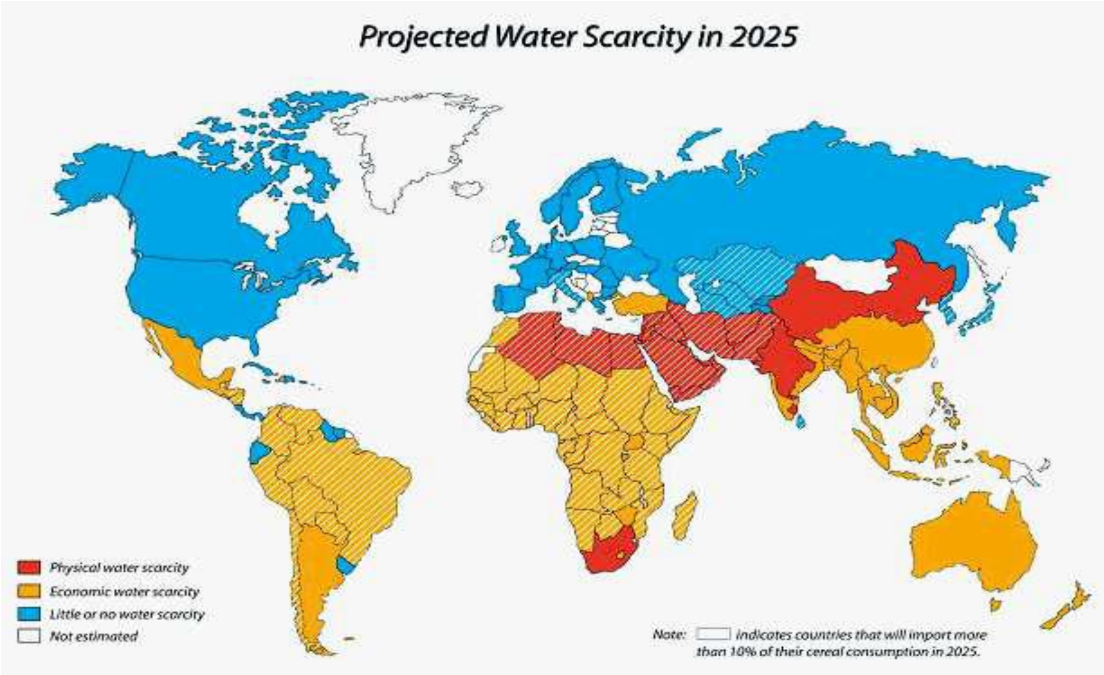

Figure 10: Global water scarcity projections for the year 2025 (DEA&DP and UCT, 2022).

The projections of decreasing rainfall and increasing temperatures (Figures 10 and 11) will result in increasing water demand (supply versus demand) and water quality impacts, especially in the summer months, with a high trend of variability.

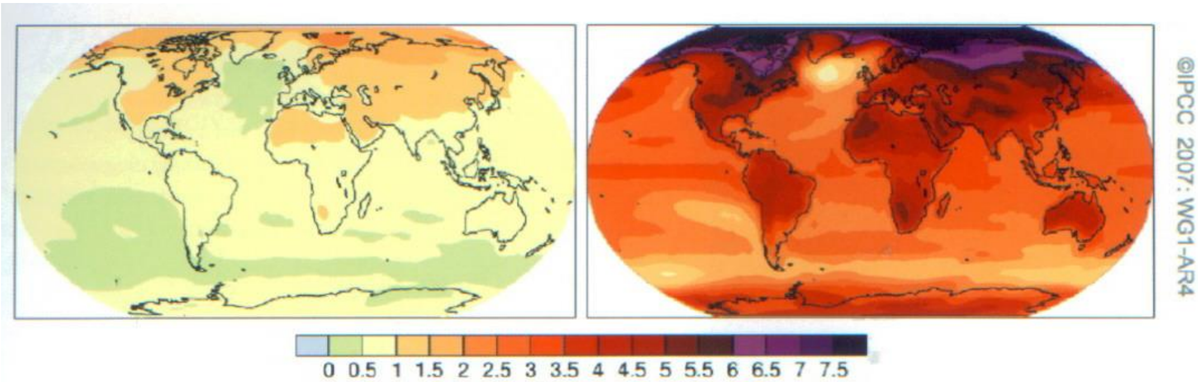

Figure 11: Changes in mean annual global temperatures (^{0}C) by 2020 – 2029 (left) and 2080-2099 (right) (IPCC, 2007).

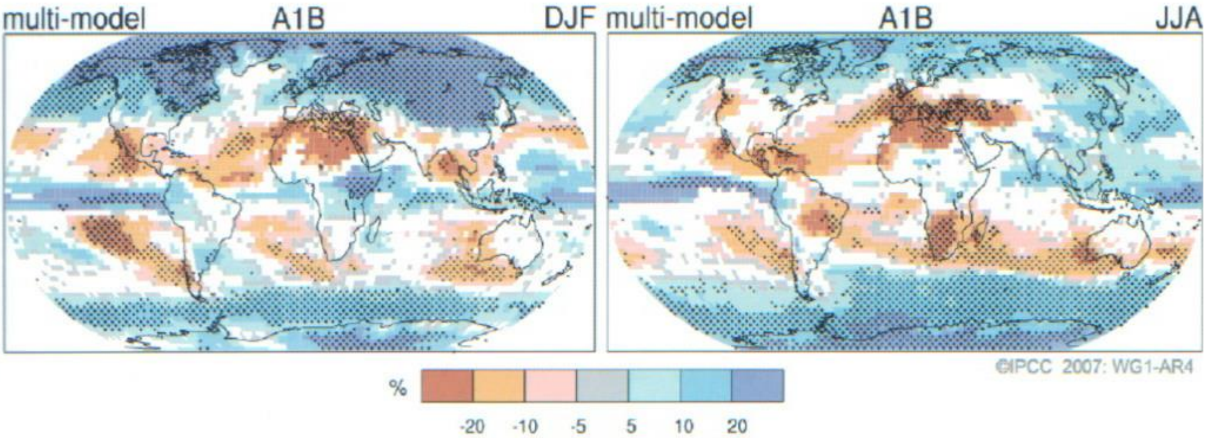

Figure 12: Changes in mean annual rainfall by 2080-2099 (%) in the austral summer (left) and austral winter (right). Stippled regions refers to regions where more than 66% of the models agree on the projected change (IPCC, 2007).

4.1.1 Declining Water Quality

Water quality is also a major concern and poses a significant risk as it is extremely sensitive to warming, climate variability and extreme rainfall. The river quality within the Garden Route district area is mostly in a poor state, which means that many rivers have lost their resilience against climate change shocks and impacts, and are therefore unable to contribute towards river ecosystem biodiversity targets (SANBI, 2011). Furthermore, there are several aquifers in the Garden Route district area that are already highly vulnerable to contamination by pollution, however more of the aquifers in the district have a medium vulnerability (Figure 12). Residents in some of the inland parts of the district already rely to varying degrees on groundwater and if these aquifers were to become polluted or over-utilised, water security in the district would diminish (Western Cape Government, 2016; Garden Route District Municipality, 2017a).

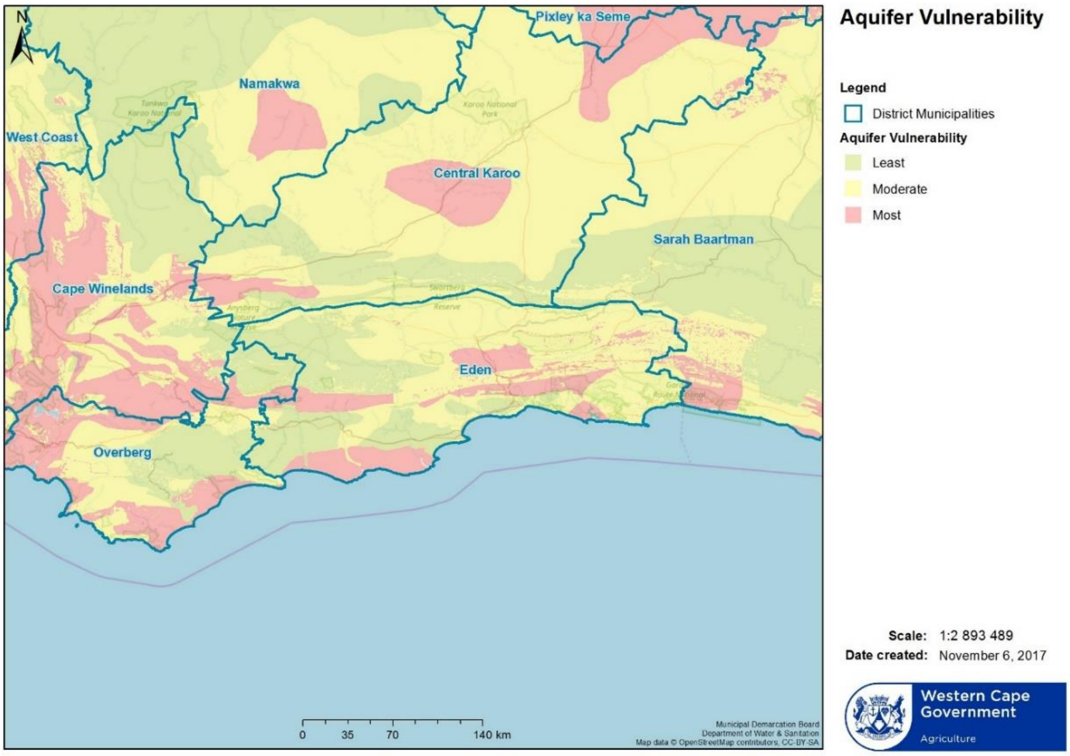

Figure 13: Aquifer vulnerability in the Garden Route district (Western Cape Department of Agriculture, 2017).

The groundwater quality in the Garden Route district area is mostly in the lower categories of electrical connectivity (Figure 13), however, groundwater in some western parts of the district already had very high levels of electrical connectivity (Western Cape Department of Agriculture, 2017). These electrical connectivity categories represent how salty the groundwater is, which is one way of measuring the water quality in the aquifers (Western Cape Department of Agriculture, 2017). The higher the level of salts in the water, the poorer the groundwater quality is (Western Cape Department of Agriculture, 2017).

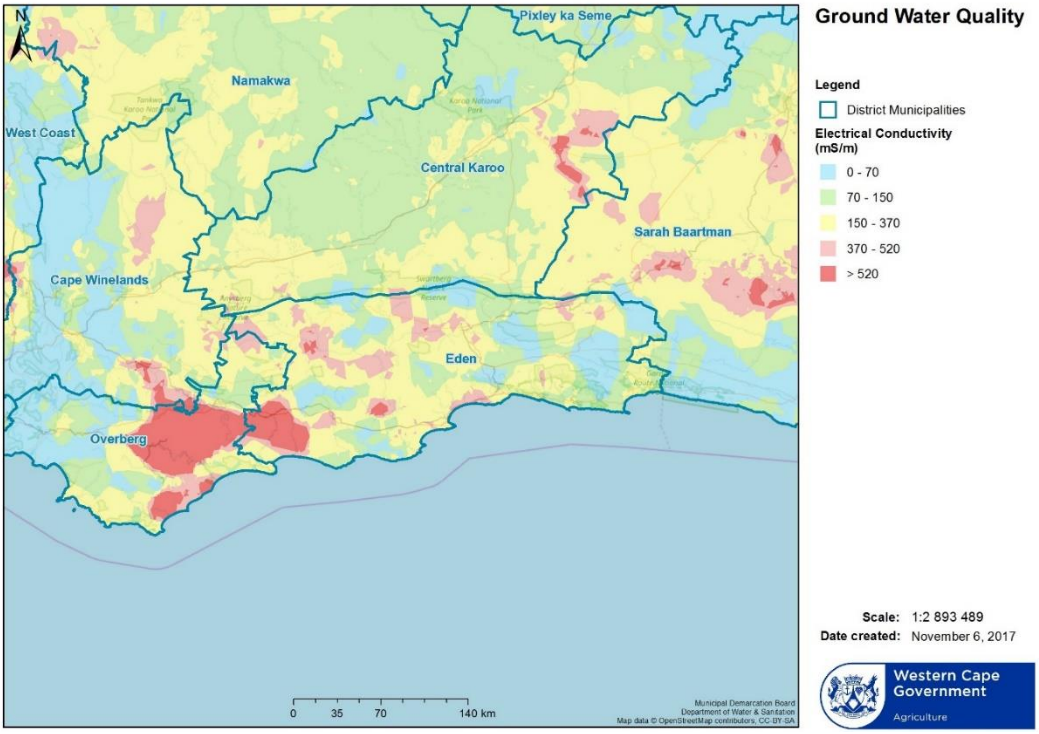

Figure 14: Groundwater quality in the Garden Route district (Western Cape Department of Agriculture 2017).

4.1.2 Impact of Floods and Droughts on Agriculture

The changing weather patterns, including shifting rain periods, will also put great pressure on farmers in the Southern Cape. Reduced soil moisture from an increase in temperature, coupled with a decrease in average precipitation, will impact on productive land use and crop activities resulting in yield reductions, and loss of livelihoods (DEA&DP and UCT, 2022). The agricultural effects will impact on food security, with some emergent farmers losing their entire livelihoods.

The predicted changes in average rainfall and temperature are forecast to reduce the areas that are suitable for viticulture or shift them to areas that are higher or cooler than current locations (Department of Environmental Affairs, 2013c). The reduction in rainfall (and runoff) is forecast to reduce the yields of fruit and vegetables, notably deciduous fruit and rain-fed wheat production in the Western Cape (Department of Environmental Affairs, 2013c). Furthermore, the production of fruit (such as apples and pears) and sugar cane will be increasingly vulnerable to damage from a predicted expansion of the areas affected by agricultural pests (Department of Environmental Affairs, 2013c).

The predicted seasonal increases in short bursts, but large volumes, of rainfall events will also lead to extreme flood events, which will result in agricultural crop damages and losses, as well as the erosion of large quantities of fertile top soil, leaving the land barren and unfertile, thereby decreasing agricultural crop yields and quality.

By decreasing agricultural yields, climate change could also impact the agriculture sector by reducing profitability and job opportunities in the sector as well as increasing food security risks, especially amongst subsistence farmers and their dependents (Department of

Environmental Affairs, 2013c; Garden Route District Municipality, 2014, 2017b). Indeed, the Garden Route District Municipality's 2017/2018 Integrated Development Plan has noted that climate change impacts could have dire consequences for the agriculture sector in the Garden Route District Municipal area (Garden Route District Municipality, 2017a).

Farming systems that restore and rehabilitate croplands, rangelands and build up the soil carbon and soil water holding capacity can contribute to reducing carbon in the atmosphere. Climate resilient agricultural practices holds huge potential for both mitigation and adaptation, especially when it comes to controlling topsoil erosion and increasing soil water holding capacity (GRDM, 2017).

4.1.3 Responding to Flood and Drought Risks and Impacts

The above climate change trend impacts and risks will cause serious human and ecological flooding and drought disaster risks, and an assessment of these risk and impacts requires an integrated view of the linkages between climate drivers, its direct and indirect consequences within the district, and the social and economic context.

Responding to climate-related risks involves decision-making in a changing world, with continuing uncertainty about the severity and timing of climate change impacts, and with limits to the effectiveness of adaptation. Assessment of the widest possible range of potential impacts, including low-probability outcomes with large consequences, is central to understanding the benefits and trade-offs of alternative risk management actions. Iterative risk management with multiple feedbacks will be a useful approach for climate change adaptation to floods and drought impacts in the Garden Route District.

The Garden Route District is generally highly exposed, and highly sensitive, to climate variability and climate change, leading to significant flood and drought risk impacts. The complexity of adaptation actions towards these risks across scales and contexts means that monitoring and learning are important components of effective adaptation. There is now an increased urgency to develop disaster risk reduction and action plans to prepare for further climate shifts across the district.

4.2 Increasingly Frequent and Intense Fire Events

Wildfires are a major hazard in the Garden Route District and are responsible for large areas burned every year. As climates become hotter and moisture regimes change, and as elevated CO2 levels change the rate of fuel accumulation, new and different fire regimes will come into play in the Garden Route District landscape. Burned areas result mainly from the interaction of flammable vegetation (fuel) that can support combustion and the prevalence of hot, dry spells or seasons which predispose these landscapes to burn whenever there is a source of ignition (Schulze and Schütte, 2016). Fires are thus driven by dry spells and other weather anomalies such as heat waves, by low humidity and strong winds, each of which can play a major role in determining fires. Extreme episodes, such as long dry spells, can be most relevant in determining fire season severity, and improvements in weather forecasting (daily, seasonal, annual) may allow for developments in fire danger and risk prediction.

Veld fires occur mainly between November and February, however, in Knysna they occur throughout the year (Western Cape Government, 2013). Increases in the frequency and intensity of veld fires have had negative impacts in the agricultural, forestry and tourism sectors (Garden Route District Municipality, 2014). The risk of veld fires is high for most of the Garden Route District Area, however, there are areas of extremely high veld fire risk in the south and low veld fire risk in many parts in the north and west of the District (Figure 15) (Department of Agriculture, Forestry and Fisheries, 2010). There are also several areas of medium veld fire risk spread throughout the District (Department of Agriculture, Forestry and Fisheries, 2010).

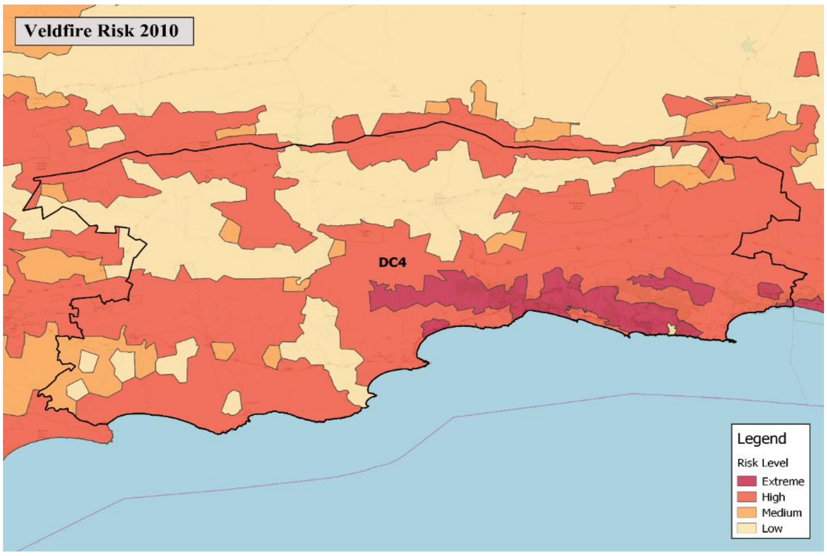

Figure 15: Veld fire risk for the District Municipal Area (Department of Agriculture, Forestry and Fisheries 2010)

Looking into the future, climate and natural land cover conditions within the Garden Route district are projected to continue to change. The capacity of our ecosystems to cope with anticipated changes in climate and fire thus need to be evaluated. A schematic representation of the main cascading impacts resulting from environmental changes caused by climate change is shown in Figure 16. In the Figure the direct flow of impacts is represented by large arrows. Important indirect impacts are shown as feedbacks. Climate change-fire-biodiversity effects operate throughout the complex cascade, as they are affected directly by environmental changes to disturbance regimes such as temperature, CO2 or rainfall, interactive effects on species and ecosystems (Boxes 2 to 5; Individual biology to Ecosystems), and by the choices society makes about various landscape values (Box 6; Societal values). Fire regimes interact with all these processes.

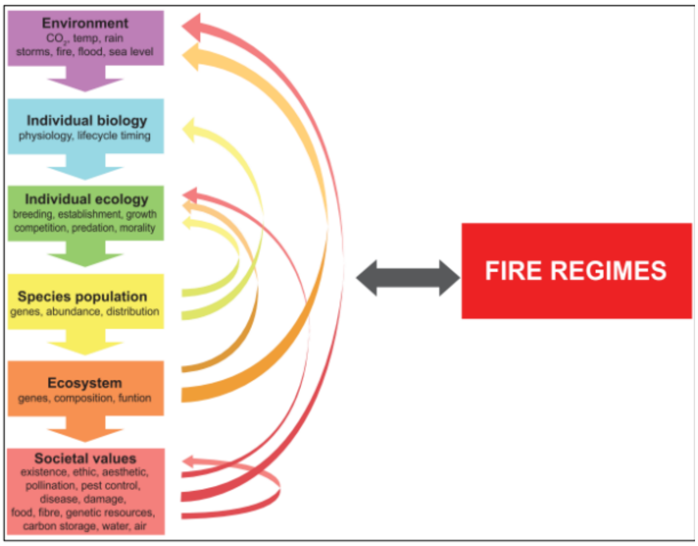

Figure 16: Schematic representation of cascading impacts resulting from environmental changes caused by climate change (Morena, 2014).

Going into the future, weather as well as climate and fuel factors are hypothesised to respond non-linearly to climate change, and specific responses, which are so critical for accurately predicting fire frequency, intensity and burned areas, will be highly locality dependent.

Some points to reiterate and remember in regard to fire and climate change include the following:

- The projected increased temperature and consequent changes to the moisture regime will affect fire behaviour as a result of hotter and, in places, drier summers, often subject to extreme episodes of high temperature and droughts, as well as affecting fire behaviour through changes in fuel loads which depend, inter alia, perturbations in seasonal water status and live / dead vegetation ratios.
- Attributing changes in fire regimes to climate change requires differentiating the role of climate from other confounding factors.
- Wildfire simulation models can be used with different planning strategies, from tactical and strategic planning of wildfire management, to firefighter training, and in a climate change perspective modelling can assist policy makers and management agencies to evaluate risks and needs to mitigate them.
- With the sometimes significant increases that may be projected in mean fire-weather indices and length of the fire season under global warming, there may be expansions of fire risk areas into new areas in which fires were not prevalent until now, or alternatively, shift in fires from occurring only rarely to regularly in ecosystems not until now adapted to fire.
- Elevated CO2 may increase fuel productivity by its fertilization effect on vegetation, but partially also by the tendency for woody plants and shrubs to be favoured over grasses under higher CO2 concentrations, thereby increasing fuel loads. Indeed, Moreno (2014) maintains that the influence of climate change and atmospheric CO2 on vegetation growth have a larger impact on future fire than human-caused ignitions. •

- Climate change, if it lead to increased frequency and intensity of dry spells and also drought events, would also affect fuel flammability through its moisture content and dead-fuel loads, these being two of the major components controlling fire behaviour. It was found in southern Europe, for example, that prolonged droughts may enhance fire risk, but that plant and ecosystem-level adjustments may act as strong mitigators (Merano, 2014). In general, it was found by Merano (2014) that
- Plant species differ in their seasonal variability in live fuel moisture content and their vulnerability to cavitation, so fire danger modellers (and managers) must know the species characteristics to understand their system sensitivity re. combustibility under different climatic conditions.
- Climate change projections are for warming and drying over much of South Africa, and hence there is an increased risk of severe fire weather Climate change will have complex effects on fuels. On the one hand, elevated CO2 may enhance vegetation production and thereby increase fuel loads. On the other hand drought may decrease long term vegetation production, thereby decreasing fuel loads, and may decrease fuel moisture, and thereby increase rates of spread.
- Climate change is expected to affect fire regimes more in areas where the constraining factors are fire-weather related than where fire regimes are determined more by fuel than fire weather.
- Another agent of change is invasions of exotic species, which may increase into the future.
- Procedures to differentiate the role of the various factors affecting fire, in addition to climate, are a must in order to attribute climate change to changes in fire. Research should clarify the periods for which the various factors can be considered stationary to explore climate-fire relationships. Going into the future considerable added research will be required.

4.2.1 Fire Disasters within the Garden Route District

Wildfire occurrence in the Garden Route district is a function of vegetation (fuel availability, invasive alien species), climate ("fire weather” conditions, with key critical limits of dry spell duration, air humidity, wind speed and air temperature), and ignitions (lightning or human and other sources). While wildfires are a natural feature of fire-driven ecosystems, changes in climate will have adverse effects through altering the future occurrence of wildfires, and the areas burned, in various ways that involve weather conditions conducive to combustion, fuels to burn and ignition agents.

The following climate change impacts can have an impact on fire within the Garden Route District: (UNDP-GEF, 2020).

- Increased local climate variability and weather extremes are likely to be characterized by decreased intensity of rainfall and moisture in the dry period;
- The predicted increases in surface air temperatures as a result of climate change will increase rates of evapo-transpiration, and desiccate the fuel load;
- The increase in spatial and temporal variability in wind patterns are likely to result in hot and dry winds, notably in the interior areas of the country;

- An increased incidence of lightning storms; and
- The increased carbon uptake in vegetation (notably in invasive alien species) will increase the rate of increase of quantity of combustible biomass.

Together, these drivers can influence the number of days where the risks of extreme wildfire events are dangerously high.

Fire disasters within the GRDM are also exacerbated by high alien invasive species infestations, as well as high fuel load risks due to aged veldt. Figures 17 – 22 below indicates the risk of these factors within the district (GRDM, 2019). The disastrous June 2017/18 Garden Route fires are an example of the huge impact that it can have on the district, with widescale infrastructural and environmental destruction, indigenous species biodiversity losses, as well as the loss of valuable human lives. It was a wake-up call about the deleterious effects of climate change in the district, and in many ways is a case study for future approaches and preparedness for these disasters, as well as for the ensuing rehabilitation and rebuilding of the damaged environment.

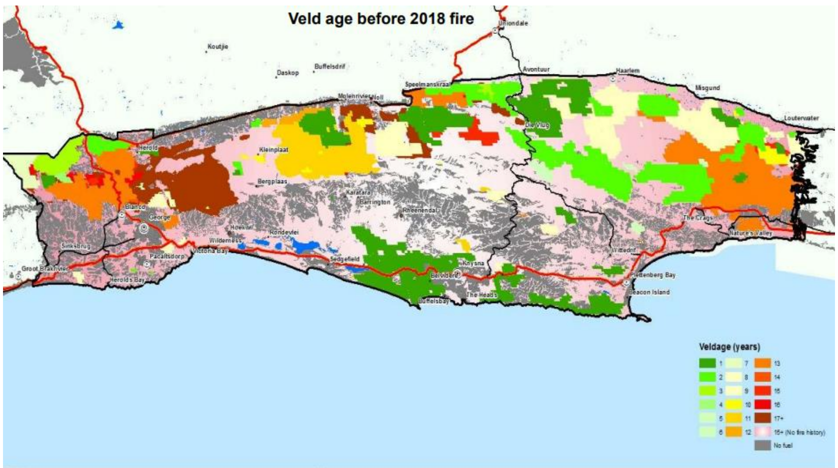

Figure 17: The veldt age within the Garden Route District before the 2017/18 fire (GRDM, 2019)

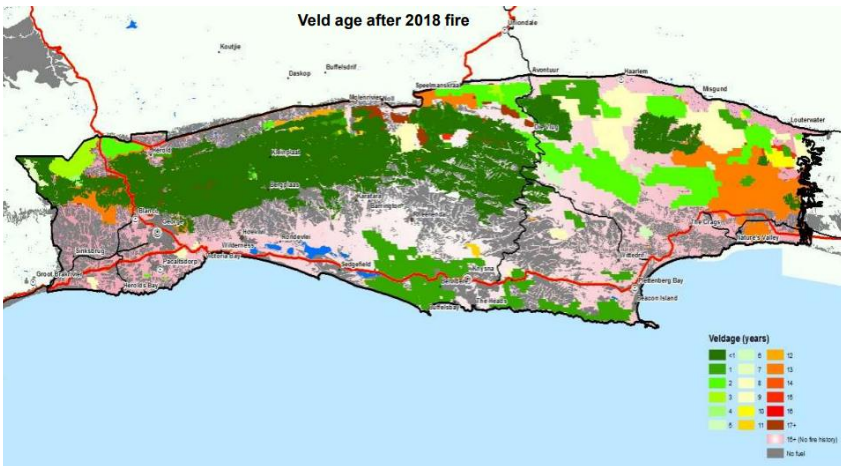

Figure 18: The veldt age within the Garden Route District after the 2017/18 fire (GRDM, 2019)

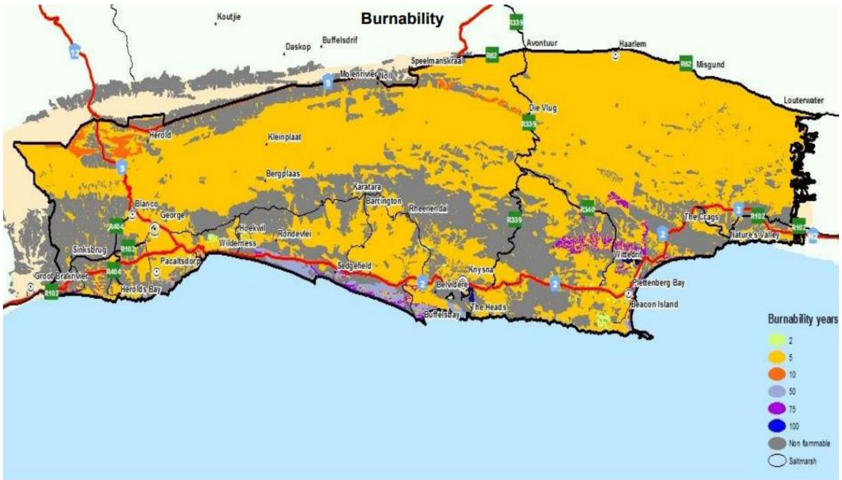

Figure 19: The burnability of the veldt within the Garden Route District (GRDM, 2019)

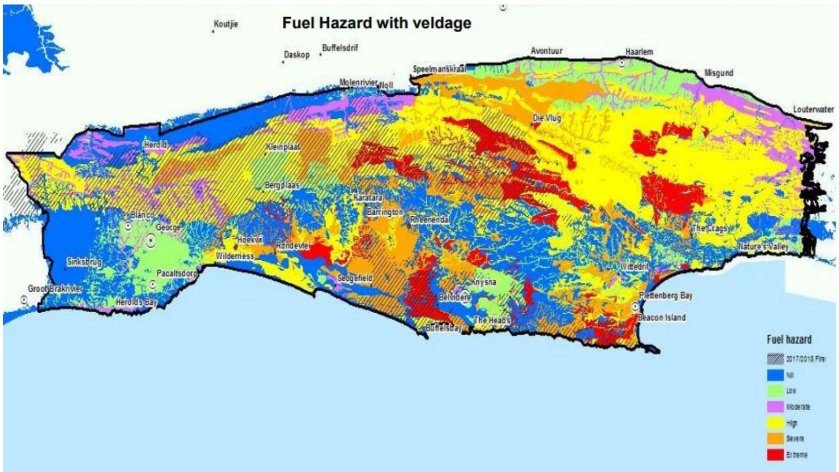

Figure 20: The fuel hazard with veldt age within the Garden Route District (GRDM, 2019)

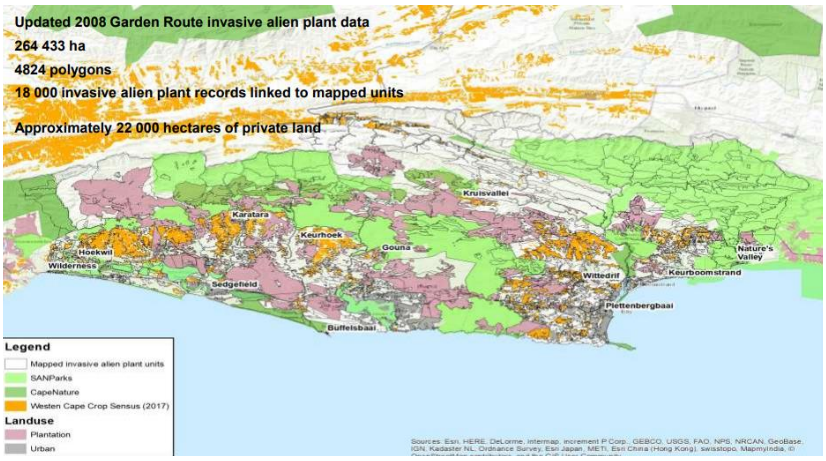

Figure 21: The updated 2008 invasive alien vegetation data for the Garden Route District (GRDM, 2019)

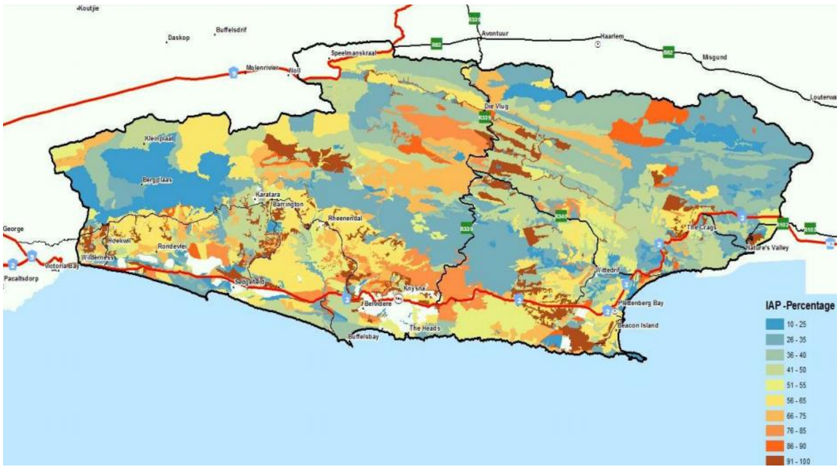

Figure 22: The percentage of invasive alien vegetation within the Garden Route District (GRDM, 2019)

According to UNDP-GEF (2020) climate change can lead to bigger wildfires that are more difficult to control. As a result, wildfire management is becoming more important in order to reduce the damage to people, the economy and the environment. Nowhere is this more evident than in the Fynbos Biome, the world's smallest floral kingdom (of six), but also the richest per unit of area. Over 9,000 species of flowering plants occur in this tiny area at the south-western tip of South Africa. The tiny biome covers about 46,000 km2, yet contains

The Garden Route District is a global biodiversity hotspot, internationally acknowledged for its unique floral diversity. Fynbos is a fire-adapted ecosystem and many plants have seeds which can only germinate after a fire. Other plants wait till after a fire to flower. But the frequency and intensity of uncontrolled wildfires – exacerbated by climate change - risk exceeding the biome's recovery capacity and causing damages on the economy and people's lives (UNDP-GEF, 2020).

4.2.2 Proposed Fire Implementation Actions and Recommendations

Effective and sustained integrated fire management to reduce the risk of uncontrolled fires due to climate change is imperative within the Garden Route district. In the past, fire management was heavily dependent on fire suppression. But as factors such as an increased natural-urban interface and greater pressure on natural resources have become increasingly significant, more advanced fire management, integrating weather prediction and modelling tools, has come more important (UNDP-GEF, 2020).

Integrated Fire Management (IFM) has been defined as a series of actions that include: fire awareness and prevention, risk mapping, hazard identification, prescribed burning, resource sharing and co-ordination with fire detection, fire suppression and fire damage rehabilitation. IFM is critical to realize a balanced, workable, and sustainable approach to manage fires with minimum harm to people and the environment (UNDP-GEF, 2020).

Integrated fire management with climate change adaptation in mind should be aimed at developing sustainable interventions to radically reform the approach to managing fires and to implement strategies to better cope with increasing fire risks and damages due to climate change. This should include the implementation of a range of adaptive IFM services which includes fire management planning, fire detection, prevention, suppression and community fire awareness (UNDP-GEF, 2020).

The delicate equilibrium of ecosystems however mean that it’s not as simple as merely controlling wildfires. Different species of fynbos plants are favoured by fires of different frequencies and moreover, this can also lead to a mass germination of invasive alien plant seedlings. If the dexterity is not in place to deal with the follow-up clearing of these invasives, it can lead to massive additional clearing costs at a later stage, and many very negative ecosystem service impacts, such as water loss, biodiversity loss, an impact on the productivity of land, amongst others, and ironically increasing the likelihood of worse fires in years to come.

A key aspect of adaptive fire management within a changing climate context, is to support communities living in high fire risk areas, and to encourage collaborations and partnerships. By supporting firefighters, landowners, NGOs and local authorities to implement IFM practices and to anticipate the impacts of climate change on wildfires, the human, infrastructure, economic and tourism losses from wildfires will be minimized, while ensuring the protection of the unique southern Cape biomes and floral fynbos kingdom (UNDP-GEF, 2020).

Understanding how such modifications in the fire controlling factors affect fire activity is utmost important for anticipating future fire risks. Policy makers and management agencies require information on wildfire probability and severity to manage fire-prone landscapes and to evaluate the efficacy of prevention plans. The incorporation of the key factors that affect wildfire propagation requires the use of a modelling approach able to provide reliable and accurate estimations of wildfire spread and behaviour in regard to fire intensities, seasonality, frequency, type and their spatial distributions (Schulze and Schütte, 2016).

An in-depth knowledge of climate / vegetation / human characteristics and their trends is essential for (Schulze and Schütte, 2016):

- Understanding the effects of fire on ecosystems and the interactions between fires and their driving factors,
- Anticipating and limiting the potential negative impacts of fires (especially in areas experiencing rapid land use changes or being newly exposed to fire),
- Supporting fire management (prevention and fighting) as it relates to land use planning, and
- Projecting future fire potential under changed environmental and social conditions.

The goal of fire management should be to reduce the district's environmental, social and economic vulnerability to the increased incidence of wildfires in order to adapt to climate change effects. This is to be achieved through a biome-scale change in the fire management approach from reactive fire-fighting to proactive integrated fire management (IFM), including managing the ecosystem through controlled burns (UNDP-GEF, 2020).

- **Outcome 1:** Early warning and hazard risk information system put in place to deal with the additional fire hazard risks associated with climate change (national level)

- **Outcome 2:** Paradigm Shift from reactive firefighting to integrated fire management system to cope with climate change-induced fire hazards and capacity built at local level to manage the predicted increased incidence and extent of fire, leading to the reducing fire risk over areas at least 150,000 km2 in the Western Cape, Eastern Cape and Free State Provinces
- **Outcome 3:** Innovative risk reduction interventions implemented, in close cooperation with the insurance industry, with the special coverage of no less than 20,000km2.
- **Outcome 4:** Good practices on adaptive management of fire risks disseminated (national and regional levels)

Furthermore, given not only changing climate conditions, but also demographic changes and the degree of urbanisation, a challenge in dealing with the wild fire problem will be to establish / re-establish the connection between all institutions involved. This would include:

- An analysis of fire management plans to identify strengths and weaknesses of current fire prevention and fire-fighting planning instruments with respect to adaptation to future fire regimes; as well as including;
- Assessments of the economic impacts associated with the projected increase in fire risk and load likely to result in South Africa, especially in light of not having enough social, financial and economic capital to address the problem adequately; and
- With the existence of a possible dis-connect between science, policy and management in regard to fire risk into the future, building / re-establishing / strengthening the necessary bridges of communication through meetings between scientists, stakeholders and fire operation managers, using the simple ideas of Mereno’s (2014).

The interactions of climate change with vegetation cover and fire regimes should be understood and appropriately considered in the planning and implementation of fire use, and it is, therefore, necessary to know the impacts of regional climate change on ecosystem properties and fire regimes to be able to adapt fire management plans and policies taking into account changes in fuel and vegetation type, burning conditions or additional fire risk due to climate change.

Given the significant value of preserving the area’s biodiversity, the prevention of increasingly out of control fires entering the forest perimeters is of high priority. Adaptation measures such as improving ecological restoration, forest fires prevention mechanisms, cooperation and partnerships with scientists, government officials, forestry enterprises, and local communities, as well as collaboration and engagement with local communities to participate in the adaptation efforts should be included in fire management implementation planning.

4.3 Impacts of Climate Change on Human Health

In the field of human health, climate change poses a major and largely unfamiliar challenge (WHO, 2005b). There is an increasing amount of information available to climate change scientists and the assessments of likely changes are no longer based on possible future scenarios and models, but rather on observations on global climate data. Thus the picture of future changes is becoming clearer, but the impact on human health has not yet been determined in depth or with narrow margins of certainty. What is clear, however, is that the increasing understanding of climate change is transforming how we view the determinants of human health (WHO 2003).

There are some fundamental factors that should be borne in mind in any discussion on climate change and the effects that its accompanying processes may have the environment and human health, such as (WHO Regional Office for Europe 2003, WHO 2003):

- Climate change does not cause novel environmental exposures, but may exacerbate the burden of climate-sensitive diseases. The size of the impact will depend on the implementation and effectiveness of timely interventions.
- Climate change results from both natural and human-induced processes. Emissions of greenhouse gases affect human health at different scales. At the local scale, particulate matter emitted by vehicles has harmful effects. At the regional scale, transport of sulfur and nitrogen oxides causes acid deposition. At the global scale, the links between climate change and local environmental factors produce a range of hazards to human health.

Broadly, a change in climatic conditions can have three kinds of health impacts (WHO Regional Office for Europe, 2003):

- Those that are relatively direct, usually caused by weather extremes. [DIRECT]
- The health consequences of various processes of environmental change and ecological disruption that occur in response to climate change. [INDIRECT]
- The diverse health consequences – traumatic, infectious, nutritional, psychological and other – that occur in demoralized and displaced populations in the wake of climate-induced economic dislocation, environmental decline, and conflict situations. [MULTI-STAGE]

Climate change has been deemed the “greatest global health opportunity of the 21st century” (Watts *et al*., 2015) and the impacts of climate change on human health are featuring more prominently in global discussion. Considerations of climate change and health at the regional level, particularly in Africa, are limited (Baker *et al*., 2012; Pasquini *et al*., 2013). Climate change is a cross-cutting concern of many sectors, especially health, and developing locally appropriate regional health strategies is often challenging for governments of low- and middle-income countries (LMICs), particularly as there is a plethora of information available from a global perspective, which may not be applicable to, or translated for, local conditions.

Climate change impacts affect the social and environmental determinants of health which include clean air, secure shelter, safe drinking water, and sufficient food (World Health Organization, 2017). Below are some general climate change manifestations and their associated impacts on human health (World Health Organization, 2017):

- Natural disasters - The frequency and severity of natural disasters has increased. Natural disasters destroy health facilities and homes. People may be forced to vacate their properties leading to increased risk to a wide range of health effects including communicable diseases and mental disorders;

- Increased storm events - These affect the supply of fresh water consequently increasing the risk of diarrhoeal diseases;
- Floods - The frequency and intensity of floods has increased. Floods pollute water supplies and increase the risk of water borne diseases. In addition, people lose their life's as a result of drowning or physical injuries, property is damaged and the supply of health services is disrupted;
- Climate change will also impact the distribution and causes of several communicable diseases including cold-influenza and dry-meningococcal meningitis among others (Singh and Kistnasamy, 2014).
- Changes in climate conditions also affect vector-borne diseases that are transported through organisms such as snails, insects and other cold-blooded animals. With climate change the transmission season will lengthen and the geographic range of some vector borne diseases will change;
- Increased temperatures and variable rainfall are likely to reduce agricultural yields consequently increasing the prevalence of malnutrition and hunger as a result of food insecurity;
- Increased heat stress leads to death which can be attributed to cardiovascular and respiratory diseases;
- Increased air pollution and increased occupational health problems.

Approximately 9.86 % of the Garden Route District Municipal area's households are involved in agricultural activities (Statistics South Africa, 2011). People, who work outdoors, like those involved in agricultural activities, are especially vulnerable to the impacts of extreme weather conditions. Moreover, climate change is forecast to exacerbate the frequency and severity of extreme weather events (Department of Environmental Affairs, 2013c). Consequently, predicted impacts for households involved in agriculture include reduced agricultural yields and water security as well as increased food insecurity.

The main disaster risks that are likely to affect human health in the Garden Route District area are wild fires, drought, severe storms and floods (Garden Route District Municipality, 2014). It is predicted that these disasters will be exacerbated by climate change (Garden Route District Municipality, 2014). Figure 23 depicts the main climate change and health risk factors for the Western Cape as identified in a study conducted by the University of Cape Town and the Western Cape Government (UCT and Western Cape Government, 2018).

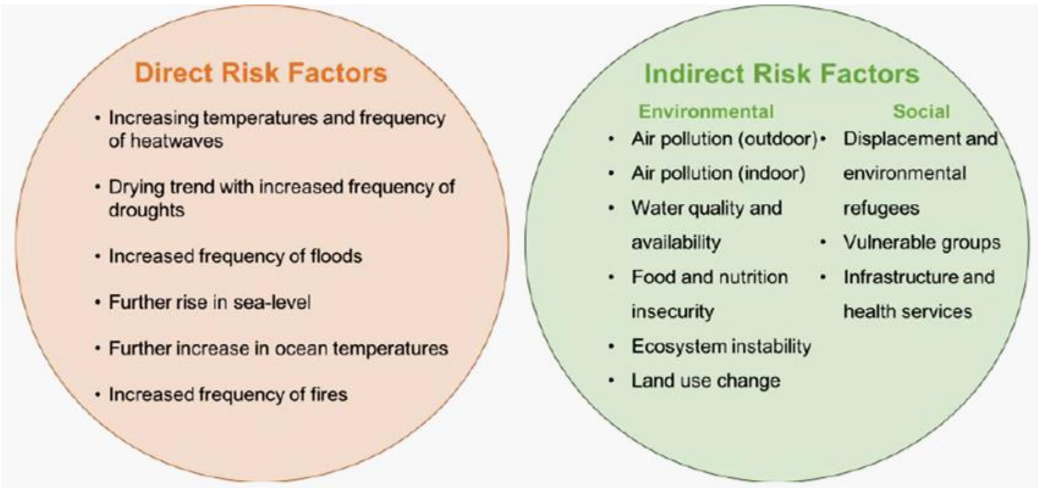

Figure 23: The climate change and health risk factors for the Western Cape (UCT, Western Cape Government, 2018).

4.3.1 Health Risk Factors

Direct, climatic risk factors are of a hotter and drier future for the Garden Route district, with further increases in sea-level rise and increased frequency and severity of extreme events such as heatwaves, droughts, floods and fires. These direct risk factors present several health challenges requiring adaptation strategies (Godsmark & Rother, 2018). Climate change-related risk factors for human health that are not directly the result of climate or extreme events, but are rather indirect risks, include environmental and social issues, as are detailed in Figure 24.

Regarding direct risk factors, the long-term projection (to 2100) of a hotter and drier future for the Western Cape with further increases in sea-level rise and more extreme events such as heat waves, droughts, floods and fires presents several health challenges requiring adaptation strategies. This is particularly the case for vulnerable populations. Specifically, climate variability in the Western Cape will result in both direct and indirect risk factors that will need to be addressed. Suggested interventions from the global sphere are presented in the interventions section below. Climate change-related risk factors for human health that are not directly the result of climate or extreme weather events but are rather indirect risks include issues that we have grouped within two broad areas: environmental (e.g. air pollution) and social (e.g. environmental refugees). Often an indirect risk factor might span both areas. Any adaptation strategy for addressing health impacts of climate change in the Western Cape will need to include addressing these risk factors so as not to undermine the efforts of the strategies.

The WHO estimates that globally, climate change is projected to account for an additional 250 000 deaths annually between 2030 and 2050 (WHO, 2017). Although the risk factors identified play a key role in increasing the health impacts from climate change, there are several climate change-specific health impacts that may be directly or indirectly climate-related that the Garden Route District Municipalities should be considering in climate change adaptation strategies. Figure 24 provides a summary of the main health outcomes of projected climatic risk factors for the Western Cape.

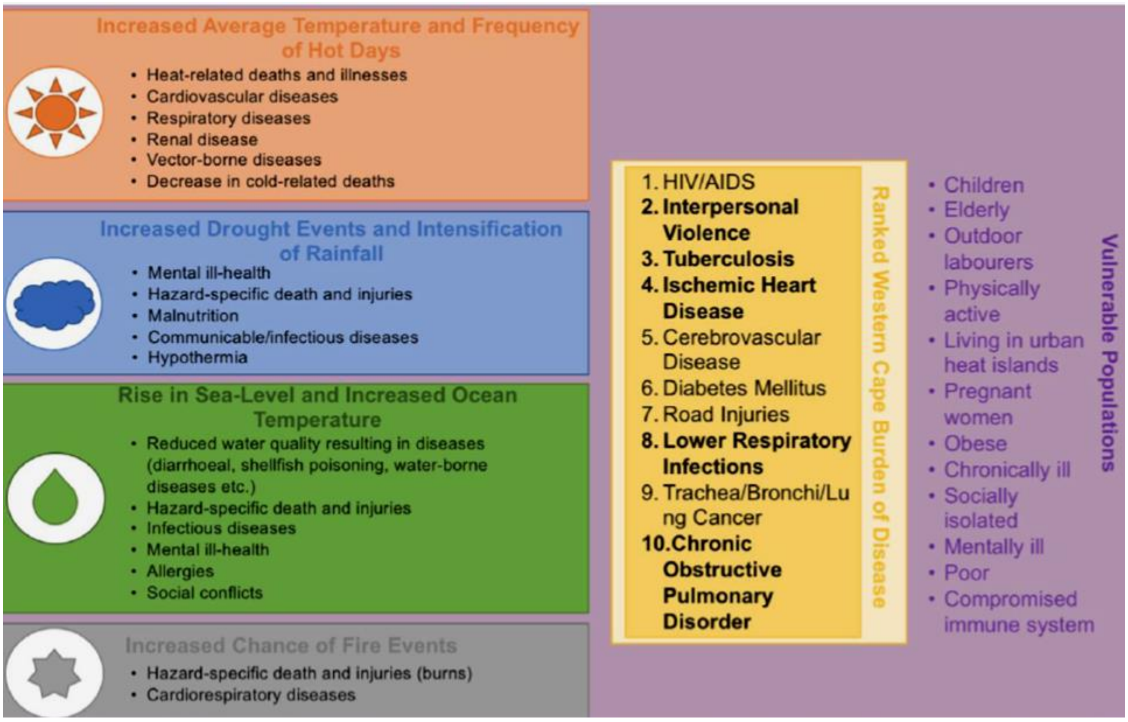

Figure 24: The main projected climate change and health risk factors for the Western Cape (UCT, Western Cape Government, 2018).

The findings from the University of Cape Town (UCT) and Western Cape Government report (2018) identified some key climate change research gaps for the Western Cape, as showed in Figure 15 below.

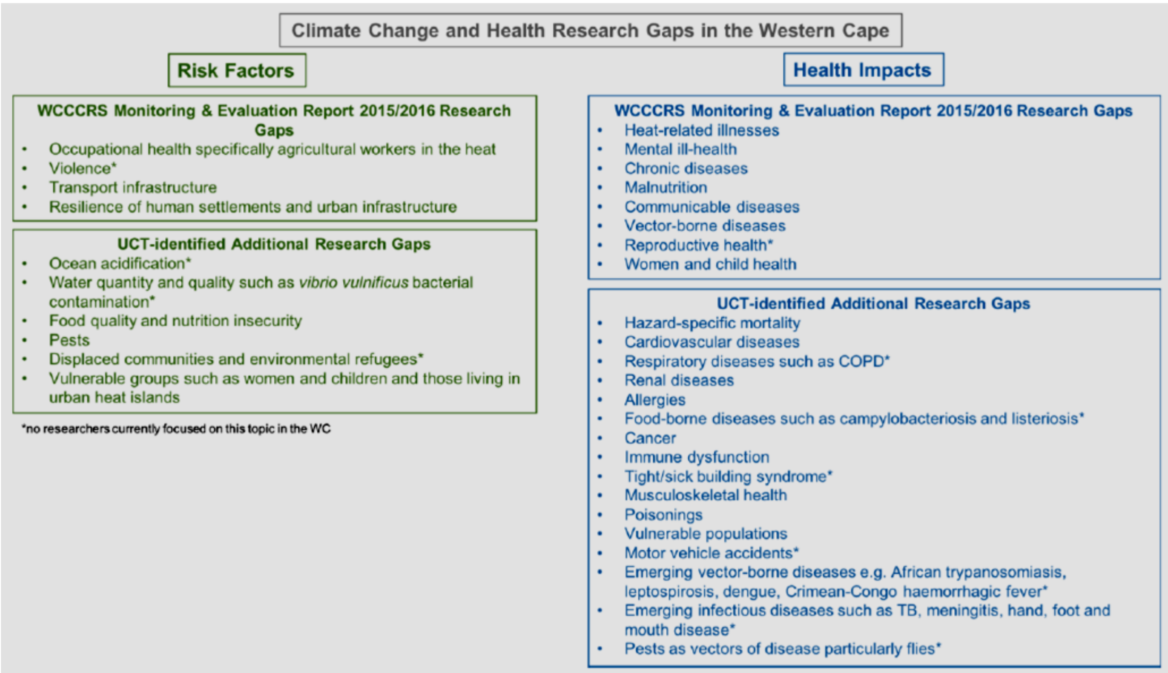

Figure 25: Climate change and health research gaps for the Western Cape (UCT, Western Cape Government, 2018).

Because human health is intricately bound to weather and the many complex natural systems it affects, it is probable that projected climate change will have measurable impacts, both beneficial and adverse, on health (National Assessment Synthesis Team, 2000). However, health outcomes in response to climate change are highly uncertain. The anticipated health impacts of climate change for the district fall into the broad categories of: communicable diseases, NCDs, vector- and pest-borne diseases, food-borne diseases, hazard-related injury and mortality, violence, mental ill-health, water-borne diseases, food and nutrition insecurity-related diseases, and reproductive health (Godsmark & Rother, 2018). Table 4 lists the direct and indirect potential effects of changes in temperature and specifically refers to the disturbance of ecological systems (WHO, 2003).

Table 4: The direct and indirect potential effects on health of changes in temperature and weather (Adapted from: Haines et al (2000).

Mediating Process	**Health outcome**
Direct effects	
-Exposure to thermal extremes -Changed frequency or intensity of other extreme weather events	-Changed rates of illness and death related to heat and cold -Deaths, injuries, psychological disorders; damage to public health infrastructure
Indirect effects (disturbances of ecological systems)	
-Effect on range and activity of vectors and infective parasites -Changed local ecology of water-borne and foodborne disease -Changed food productivity (especially crops) through changes in climate and associated pests and diseases -Sea level rise with population displacement and damage to infrastructure -Biological impact of air pollution changes (including pollens and spores) -Social, economic and demographic dislocation through effects on economy, infrastructure and resource supplies	-Changes in geographical ranges and incidence of vector-borne disease -Changed local ecology of water-borne and foodborne disease -Malnutrition and hunger (or increase sector of population malnourished) with consequent poor recovery from illness and impairment of child growth and development -Increased risk of infectious disease, psychological disorders -Increase in asthma and allergies; other acute and chronic respiratory disorders and deaths -Wide range of public health consequences: mental health and nutritional impairment, infectious diseases, civil unrest

4.3.2 The Impact of Climate Change on Vector Borne Diseases

Vector organisms that do not regulate their internal temperatures and are therefore sensitive to external temperature and humidity transmit many important infectious diseases. Climate change may alter the distribution of vector species (increasing or decreasing) depending on whether conditions are favourable or unfavourable for their breeding places (such as vegetation, host or water availability) and their reproductive cycle. Temperature can also influence the reproduction and maturation rate of the infective agent within the vector organism and the survival rate of the vector organism, thereby further influencing disease transmission.

Climate affects a variety of biological processes in vectors, influencing their presence or absence at a particular time and place, their abundance and their ability to transmit disease. These aspects are best described for anthroponotic diseases such as malaria. The overall ability of a vector population to transmit disease can be summarized as the 'vectorial capacity'. Vectorial capacity has various formulations (Garret-Jones, 1964; Dye, 1992), but is a function of the following parameters:

- Human-biting rate (the daily biting rate of a female mosquito)
- Human susceptibility (the efficiency with which an infective mosquito infects a human)
- Mosquito susceptibility (the chance that an uninfected mosquito acquires infection from biting an infectious person)
- The probability of daily survival of the mosquito
- The incubation period for the parasite inside the mosquito

Changes in climate that can affect the potential transmission of vector-borne infectious diseases include temperature, humidity, altered rainfall, soil moisture and rising sea level. Determining how these factors may affect the risk of vector-borne diseases is complex. The factors responsible for determining the incidence and geographical distribution of vector-borne diseases are complex and involve many demographic and societal as well as climatic factors. Transmission requires that the reservoir host, a competent vector and the pathogen be present in an area at the same time and in adequate numbers to maintain transmission.

It is strongly recommended that the Garden Route District Municipalities implement, and/or strengthen, a database capturing all implementation projects. Additional funding mechanisms for climate change and health research should be made available at a strategic level in order for successful adaptation and mitigation implementation plans at a local level. Table 5 provides some examples and ideas of implementation projects which could be suitable for the specific Garden Route District area.

Table 5: Examples of adaptation and mitigation projects that could be implemented within the Garden Route District

Health Impact	Example of Potential Adaptation and Mitigation Projects
Vector-borne diseases	Research on climate and water temperature rises and potential disease manifestations
Water quality related diseases	Temperature increases, evaporation, algal overgrowth, nitrification, decreased wetland purification functioning, drought and related increased dust particles in water sources,
Heat related diseases	Heat stress in the vulnerable, skin cancer, heat stroke in farm labourers/people working outside,
Allergies	Drought and increased dust particles,

4.3.3 Food Security

4.3.3.1 Foodborne Disease and Nutrition

Climate change can increase the spread of several foodborne pathogens depending on the pathogens' survival, persistence, habitat range, and transmission in a changing environment. For instance, drought has been shown to encourage crop pests such as aphids, locusts, and whiteflies, as well as the spread of the mold *Aspergillus flavus* that produces aflatoxin, a substance that may contribute to the development of liver cancer in people who eat contaminated corn and nuts. Agronomists are also concerned that climate change-based increases in a variety of blasts, rusts, blights, and rots will further devastate already stressed crops, and thereby exacerbate malnutrition, poverty, and the need for human migration. The spread of agricultural pests and weeds may lead to the need for greater use of some toxic chemical herbicides, fungicides, and insecticides, resulting in potential immediate hazards to farm workers and their families, as well as longer-term hazards to consumers, particularly children. The safety of agricultural crops and fisheries also may be threatened through contamination with metals, chemicals, and other toxicants that may be released into the environment as a result of extreme weather events, particularly flooding, drought, and wildfires, due to climate change.

The health effects of human exposure to these environmental agents via complex land and ocean food webs are not well documented or understood, but evidence from animal studies is showing that such compounds accumulate in foods at concentrations that may affect fetal development, immune function, and other biological processes. These agents often occur together and may act synergistically, producing potentially greater harm than a single agent. In one specific example, the CCSP noted the strong association between sea surface temperature and proliferation of many Vibrio bacteria species that occur naturally in the environment (including those that cause cholera), and suggested that rising temperatures would likely lead to increased occurrence of illness associated with Vibrio bacteria, especially seafood-borne disease associated with *V. vulnificus* and *V. parahaemolyticus*.

Rising temperatures and impacts on other environmental parameters such as ocean acidification may also lead to more virulent strains of existing pathogens and changes in their distribution, or the emergence of new pathogens. Increased risks from animal-borne disease pathogens could be especially acute in human populations that are highly dependent on marine-based diets for subsistence and who live where environmental effects resulting from climate change are pronounced. Increased acidity of water associated with climate change may alter environmental conditions leading to greater proliferation of microbes of a public health concern. This is a significant concern in molluscan shellfish, because ocean acidification may affect formation of their carbonate shells and immune responses, making them more vulnerable to microbial infection. The combined impact of potential contaminant-induced immune suppression and expanding ranges of disease-causing pathogens and biotoxins on food supply could be significant.

4.3.4 Extreme heat

High temperatures also raise the levels of ozone and other pollutants in the air that exacerbate cardiovascular and respiratory disease. Cardiovascular hospital admissions increase with heat. Dysrhythmias are primarily associated with extreme cold, though associations with dysrhythmias and heat illness have been reported. Stroke incidence increases with increasing temperature, as well. For all direct associations between temperature and cardiovascular disease and stroke, elderly and isolated individuals are at greatest risk.

Pollen and other aeroallergen levels are also higher in extreme heat. These can trigger asthma, which affects around 300 million people. Ongoing temperature increases are expected to increase this burden. Both increased average temperatures and increasingly frequent and severe extreme heat events produce increased risks of heat-related illness and death that can be significant: Human susceptibility to heat-related illness depends on several different factors, from physiologic adaptation to the local environment to socioeconomic status, and the impact of these changing exposures will depend on the vulnerability of exposed populations. As noted above, host factors such as age and the burden of other serious illnesses such as heart disease and diabetes that might exacerbate heat-related problems are important. Socioeconomic factors also determine vulnerability; economically disadvantaged and socially isolated people face higher burdens of death from heat.

4.3.5 Human Shelter/Natural Disasters and Variable Rainfall Patterns

Rising sea levels and increasingly extreme weather events will destroy homes, medical facilities and other essential services. More than half of the world's population lives within 60 km of the sea. People may be forced to move, which in turn heightens the risk of a range of health effects, from mental disorders to communicable diseases.

Increasingly variable rainfall patterns are likely to affect the supply of fresh water. A lack of safe water can compromise hygiene and increase the risk of diarrhoeal disease, which kills over 500 000 children aged under 5 years, every year. In extreme cases, water scarcity leads to drought and famine. By the late 21st century, climate change is likely to increase the frequency and intensity of drought at regional and global scale.

Floods are also increasing in frequency and intensity, and the frequency and intensity of extreme precipitation is expected to continue to increase throughout the current century. Floods contaminate freshwater supplies, heighten the risk of water-borne diseases, and create breeding grounds for disease-carrying insects such as mosquitoes. They also cause drownings and physical injuries, damage homes and disrupt the supply of medical and health services.

Rising temperatures and variable precipitation are likely to decrease the production of staple foods in many of the poorest regions. This will increase the prevalence of malnutrition and undernutrition, which currently cause 3.1 million deaths every year.

4.3.6 Climate Change and Health Impacts within the Garden Route District

Below is a list of briefly summarised Climate Change and Health impacts that directly related to the Garden Route District (which includes the Klein-Karoo) climate:

- Extreme heat (especially in the Oudtshoorn/Kannaland area) is affecting agricultural crops/food security - , causing bad crop quality, shifts in types of crops which can be produced – or limitations on production. Related Increases in crop diseases, financial viability and farmers moving to other areas – all resulting in shortages, or bad quality, of food, increases in prices due to higher production costs – affecting access to food, quality, security, malnutrition
- Drought – Oudtshoorn/Kannaland is a dry, hot area, prone to frequent extreme drought events. Therefore impacting on agricultuaral production/food security – same as mentioned above.
- Heat and seasonal changes may affect the occurrence/cycles and outbreaks of zoonotic diseases, such as Avian Influenca.
- Due to the drought, many water sources can get dried up, causing birds/animals to group around remaining (much fewer) water sources/points, thereby increasing the disease transmission rates due to the increased numbers of birds/animals flocking / moving around these limited sources/points – causing these points to be sources of disease outbreaks/transmissions of diseases such as Avian influenza, rabies, etc.
- Oudtshoorn/Kannaland is very dusty due to its dry, arid climate, - thereby increasing respiratory diseases, as well as the related increase in Covid 19 symptom severity/hospitalisations as the cumulative impact of Covid 19 disease, as well as long-term exposure to dust/air pollution exacerbates the final disease impacts on the respiratory system/exacerbates symptoms/increases severity
- Extreme heat stress can increase high blood pressure and reduce overall immunity – thereby making the person more susceptible to more severe Covid-19 disease symptoms
- The changes in climate causes more extreme heat and drought events, which can cause health impacts such as respiratory diseases due to dust (arid conditions), heat stress/strokes, increases in blood pressure due to heat, water borne diseases due to water levels dropping during drought – and water sources becoming more concentrated with pollutants.
- Amid the droughts, the climatic changes are predicted to also cause sporadic, far between, rainfall events of high intensity – short burst of heavy rainfall, causing flood events, which can put human lives at risk, increase disease risks due to contaminants infiltrating drinking sources due to flooding, wastewater overflowing due to flooding – and related health risks.
- Due to the droughts, many residents have thought it best to install rainwater tanks. Due to the far between rain events, with long periods of droughts, the water

harvested in the tanks from previous rain events can end up to stand in the tank for long periods/not flowing or circulating, or fresh water entering, with the consequence of water diseases such as legionnaires disease occurring in the tanks - causing disease if someone drinks from it after a long period from the last rainfall event.

4.3.7 Climate Change and Health Adaptation and Mitigation Actions

Adaptation means taking steps to reduce the potential adverse impact of environmental change. Many adaptive measures have benefits beyond those associated with climate change. This includes public health training, more effective surveillance and emergency response systems, and sustainable prevention and control programs. Extreme weather events can have vastly different impacts because of differences in the target population's coping capacity (IPCC 2001). Climate-related adaptation strategies must therefore be considered in relation to broader characteristics – such as population growth, poverty, sanitation, health care, nutrition, and environmental degradation – that influence a population's vulnerability and capacity to adapt. Adaptations which enhance a population's coping ability may protect against current climatic variability as well as against future climatic changes (IPCC 2001). Such adaptations may be especially important for less developed countries with little current coping capacity.

In order to adapt to increasing climate change pressures and impacts, the scaling-up of existing Municipal Health interventions that are addressing the social determinants of health is essential. Basic public health programmes need to be strengthened or implemented in order to increase resilience to the health hazards of climate change, such as:

- access to safe drinking water improved sanitation,
- management of vector-borne diseases,
- food security,
- control of malaria and cholera outbreaks,
- hygiene awareness and education,
- improved housing,
- access to safe fuels,
- air quality management.

By placing health and climate change considerations at the centre of urban health policies and design, we can create safer, fairer, and more prosperous communities. There is good evidence that mortality, suffering and environmental damage can be reduced by strengthening and implementing early warning systems, strengthening health system preparedness and response and improving spatial development planning.

The following adaptation and mitigation measures can also be applicable to the health sector (DEA, 2013):

- Reduce ambient PM, ozone, and sulphur dioxide concentrations by legislative and other measures;
- Ensure that food security and sound nutritional policies form part of an integrated approach to health adaptation strategies;

- Develop and roll out public awareness campaigns on the health risks of high temperatures and appropriate responses;
- Design and implement “Heat-Health” action plans;
- Strengthen information and knowledge of linkages between disease and climate change through research;
- Develop a health data-capturing system that records data at both spatial and temporal scales;
- Improve the bio-safety of the current malaria control strategy;
- Strengthen the awareness programme on malaria and cholera outbreaks.

We can make many smart investments to avert future risks to health and health disasters:

- Local government can support public health leadership and science;
- National and Provincial government can look at provide more funding options for needed research, early response to outbreaks, and supplies for testing;
- Do much more to control the illegal wildlife trade;
- We also need to take climate action to prevent the next pandemic. For example, preventing deforestation—a root cause of climate change—can help stem biodiversity loss as well as slow animal migrations that can increase risk of infectious disease spread. The recent Ebola epidemic in West Africa probably occurred in part because bats, which carried the disease, had been forced to move into new habitats because the forests they used to live in had been cut down to grow palm oil trees;
- Rethinking our agricultural practices, including those that rely on raising tens of millions of animals in close quarters, can prevent transmissions between animals and spillover into human populations;
- Reducing air pollution caused by burning fossil fuels like coal, oil and natural gas also helps keep our lungs healthy, which can protect us from respiratory infections like coronavirus;
- To combat climate change, we need to drastically decrease greenhouse gas emissions. Generating electricity from low-carbon energy sources like wind and solar decreases harmful air pollutants such as nitrogen oxides, sulfur dioxide, and carbon dioxide that lead to more heart attacks and stroke as well as obesity, diabetes, and premature deaths that put further strains on our health care systems;
- Preparation for pandemics is also about keeping people healthy at baseline. We have to provide more education and awareness on the health impacts of obesity and diabetes.

We need to invest in a healthier and more climate-resilient district through scaling-up our investments in low-carbon technologies.

Other Actions:

Break down the barriers

Establish links across sectors and departments. Addressing the health impacts of climate change provides an opportunity for the integration of public health and climate change knowledge. Integration requires reciprocal understanding of terminology, goals and methods. Beyond this, it requires working together to achieve the goal of reducing deaths, disease and disabilities. We need to work together on forums to enable an integrated approach taken by health, environmental and developmental decision makers (WHO, 2017)..

Use of legislative powers

As policy-makers, legislative powers can be used to institutionalize the changes discussed above. In the Garden Route District, policy options should include early warning systems, health system preparedness and response, urban/settlement planning and housing improvements. A comprehensive early warning system should involve multiple agencies, such as municipal management, environmental health, social services and emergency medical services (WHO, 2017).

Actions could include education of doctors, nurses and other staff to identify and treat environmental health related problems; and a personnel plan that ensures extra staff are in place if needed. Communications should be developed to advise people of appropriate behaviour during extreme weather events. Air pollution reduction measures might need to be taken during extreme heatwaves. If the threat is contaminated water after a flood, a similar set of steps could be taken to alert and prepare officials, practitioners and the public about the dangers related to climate change and ways of coping with them (WHO, 2017)..

Link health to carbon reduction plans

For high carbon emission areas within the Garden Route District, conduct a baseline health and emissions inventory, adopt an emissions reduction target, develop and implement local action plans. Monitor progress and report results; for example, install roadside pollution meters and announce the readings to the public on a daily basis. These recommendations would need to be adapted for low carbon emitting environments (WHO, 2017).

Enhance local authority advocacy leadership

Local authorities can use their knowledge and experience to inform and influence action in key environmental health processes that guide policy and resources for work on climate change (WHO, 2017).

Table 6 is also depicting additional actions by categorising adaptation and mitigation measures.

Table 6: Some other potential adaptation and mitigation projects that the Garden Route District could review.

Health Impact	Global Examples of Adaptation (A) and Mitigation (M) Projects
Heat-related illnesses	Covering buildings with living edible vegetation to lower indoor temperature (**A&M**) [Green Curtains, Japan, 2018]
Cardiovascular diseases	Encourages active transport to reduce CO2 emissions (**M**) and increase exercise (**A**) [Healthy Streets for London, 2017]
Renal diseases	Provision of water, mobile shade and rest stations (**A**) [Water.Rest.Shade, Central America, 2016]
Mental ill-health	Preparing for climate-related mental health outcomes (**A**) [Mental Health and our Changing Environment, USA, 2017]
Allergies	Educational awareness and early warning systems on climate change and respiratory effects (**A**) [Asthma and

	Allergy Foundation of America, 2018]
Social conflicts	Contextual scenario-based planning approaches to social conflict and climate (**A**) [Saferworld, Nepal, 2011]
Hazard-specific death & injuries	Educational awareness programs to promote sun safety and skin cancer prevention as people spend more time outdoors in warmer weather (**A**) [SunSmart, Australia, 2018]
Water quality-related diseases	Using green infrastructure to manage storm water during current and future periods of heavy precipitation (**A**) [Green Infrastructure, USA, 2015]
Vector-borne diseases	Communications project distributing preventative health information to curb epidemics (**A**) [MHSS, Quebec, 2016]

The Garden Route Climate Change Adaptation Strategy are rooted in the key elements of an environmental health approach to climate change. The following actions are also proposed to increase the districts health resilience to climate change:

- **Climate Change and Health Steering Committees**

Municipal Health Sections need to establish Municipal Health Climate Change Adaptation Committees (MHCCAC's), with the important task of steering the implementation of key activities, including inter-sectoral interventions. Under the umbrella of the MHCCAC's, various working groups may be established to address specific area or issue-based concerns.

- **Capacity building interventions**

Public participation is essential for a successful climate change adaptation strategy. An important foundation for public participation is communities that is highly informed about the process and consequences of climate change, and that identifies and agrees with the key adaptation actions.

- **Public Awareness strategy**

The implementation of long-term and comprehensive communications strategies to raise public awareness of climate change impacts, and the advantages of early attention to adaptation are critical. Such education campaigns should inform and encourage citizens to adapt their actions and behaviours to minimise environmental damage. It should also prepare individuals to cope with, for example, heat stress, improved ventilation and an increase in the frequency of disasters or service disruptions. Such campaigns may include encouragement of a culture of disaster preparedness and the measures to be taken on very hot days.

- **Monitoring and Surveillance**

Health impact resilience to climate change should include a review of public health monitoring and surveillance systems to increase the ability to detect climate change and health trends at an early stage. The early detection of trends in disease is vital to facilitate early intervention. Every effort must be made to integrate monitoring and surveillance systems across sectors, for example, health, environment, agriculture and human settlements.

- **District Vulnerability Assessments**

To identify high-risk locations and groups, it is important that detailed vulnerability assessments be undertaken that are focusing specifically on health related aspects and impacts. Knowledge of such groups and locations will steer climate change adaptation toward those in greatest need, and will inform the strengthening of the health system and the management of risks. The negative impacts of climate change on the socio-economic standing of the most vulnerable communities, and the consequences in terms of food security and the nutritional status of individuals within these communities threatens to further undermine their resistance to diseases such as HIV/AIDS and tuberculosis. Women, as primary care-givers, are put under additional strain looking after sick and elderly household members whilst maintaining a household. This leaves them less time to earn a livelihood putting cyclical pressure on them as they often neglect their own health in prioritising the health of others. In densely populated urban areas, air pollution resulting primarily from the burning of fossil fuels may have serious health effects. Whilst South Africa's air quality is generally good, stagnant air episodes in cities can create extremely poor air quality conditions and there are indications that climate change may increase the number and intensity of such events.

- **Research and Development**

Long-term climate change and health research programmes must be initiated to ensure that decisions and planning are evidence-based, and that adaptations implemented are the most cost-effective and efficient. Information and knowledge of linkages between diseases and climate change must be strengthened through education. More and more climate change research still needs to be conducted especially on impacts of health.

- **Health Impact Assessments**

Environmental Health impact assessment (HIA) procedures must be adopted. HIA is often seen as a component of environmental impact assessments. HIA has a role to play in avoiding further contributions to climate change (for example avoidable emissions), as well as the negative downstream health consequences. HIA processes may also be used to identify health co-benefit opportunities contained within the development policies and programmes of non-health sectors. For example, housing design and construction may hold opportunities to keep dwellings cooler in hotter or warmer in winter – hence avoiding additional energy use to keep warm.

- **Inter-Sectoral Action for Climate Change and Health**

The emergence of climate change, and the need to adapt to it, has added increasing urgency to the efforts on inter-sectoral approaches taken in order for strategies to become more effective, efficient, and sustainable than would have been achieved by the health sector acting alone e.g. liaising with the Department of Human Settlements, as well as relevant provincial and local government authorities to ensure that housing meets the minimum health requirements in terms of the National Building Regulations and Building Standards Act (RSA, 1977), may dramatically improve public health and reduce vulnerability to climate change.

- **Health System Readiness**

Health system readiness is crucial to ensure outbreak response teams' readiness to act rapidly to prevent further spread in case of disease outbreaks resulting from extreme weather events. The links between weather and disease are well established – for instance, studies have shown a strong association between extreme weather events such as droughts and flooding and the incidence of water borne diseases such as cholera.

4.4 Invasive Alien Species and Climate Change

Over the past few decades globalisation has increased the movement of people and goods around the world, leading to a rise in the number of invasive alien species (IAS) introduced to areas outside their natural ranges. A 2017 study in the journal *Nature Communications* found that over one third of all introductions in the past 200 years occurred after 1970 and the rate of introductions is showing no sign of slowing down. Invasive alien species are an animal, plant or other organism that is introduced by humans, either intentionally or accidentally, into places outside its natural range. Some alien species – classed as 'invasive' – become established and negatively impact native biodiversity, as well as ecosystem services on which humans depend.

IAS are compounded by climate change, which facilitates the spread and establishment of many alien species and creates new opportunities for them to become invasive. Extreme climatic events resulting from climate change, such as storms, floods and droughts can transport IAS to new areas and decrease the resistance of habitats to invasions. Alien invasive vegetation species' germination rates are also increased due to increasingly frequent fire events due to a drying climate. Climate change is also opening up new pathways of introduction of IAS. Climate change can cause IAS to have the ability to expand rapidly to higher latitudes and altitudes as the climate warms, out-pacing native species. Alien species that are regularly introduced by humans but have so far failed to establish may succeed in doing so thanks to climate change, creating new sets of invaders. Some habitats, such as temperate forests and freshwater systems that currently have thermal barriers limiting the establishment of IAS will become more suitable for alien species as the climate changes. The increase and geographic redistribution of IAS will have diverse societal and environmental impacts. Biological invasions are a major threat to food security and livelihoods, with developing countries being the most susceptible.

Invasive alien plant (IAP) infested natural habitats suffer reduced capacity to produce ecosystem services that help support a healthy and productive living environment for people. Availability of natural products, such as medicinal plants, fodder and building materials is decreased, and disease-carrying pests such as mosquitoes and rats may be more numerous due to a reduction in natural predators with declining ecosystem functioning (Terblanche *et al*., n.d.). The aesthetic, recreational and cultural values of the natural environment are also significantly decreased where IAP's take over. IAP's also threaten local and national water security. The notable reduction of South Africa's water resources from IAP infestations has far-reaching ecological, economic and social implications. In KwaZulu-Natal, IAP's have been estimated to use approximately 576 million m3 of water per annum. This is 5% of the province's Mean Annual Run-off (MAR), and is equivalent to 230mm of rain falling across KZN per year being used up by IAPs (Terblanche *et al*., n.d.). Every large invasive alien tree, such as Eucalyptus grandis, can use between 100 and 1,000 litres of water per day – which is significantly more than the average indigenous tree (Terblanche *et al*., n.d.). Considering that South Africa is a drought-prone country that already uses 98% of its available water resources, the increasing loss of water through IAPs is a serious issue (Terblanche *et al*., n.d.).

Invasive alien plant species are especially negatively impacting on the Garden Route District's indigenous biodiversity, ecosystem services or human well-being. IAP's are reducing the district's resilience of natural habitats, making the area more vulnerable to the impacts of climate change. The high alien invasive plant infestations withing the Garden Route district is resulting in the occurrences of severe fire disasters within the district by significantly altering the natural fire regimes, especially in areas that are becoming warmer and drier. This increases the frequency and severity of wildfires and puts habitats, urban areas and human life at risk.

4.4.1 Adaptation Strategies towards Alien Invasive Species Control

The following adaptation strategies towards alien invasive species control might apply, amongst others:

- Adopting an integrated and adaptable approach to Controlling IAPs is essential;
- Proper planning is essential to achieving cost-effective and successful IAP control;
- Municipal departments and stakeholders should collaborate to implement a 5 year plan that optimises resources and effort in order to ensure optimal efficiency and impact. Effective integration of various IAP management activities within and between municipal departments, as well as with external partners, will allow for better and wider implementation at lower costs;
- Government funded programmes should be used to boost the development of coordinated IAP management to ensure optimal long-term benefits;
- New projects should be aligned with existing projects to enhance control programmes already underway. This requires better and ongoing communication between departments and stakeholders, resulting in effective control over larger, more contiguous areas;
- There also needs to be increased synergies within the different Government departments. Collaborative action results in higher removal success through increased knowledge sharing and dovetailing of projects. All partners should coordinate their planning efforts to minimise overlaps;
- It is important that a clearing programme does not remain static but that it is reviewed from time to time and adapted to fit changing circumstances;

- Riparian areas (rivers, streams, wetlands) should be a priority when planning the phasing of IAP clearing work;
- Effective control requires clearing the entire catchment of IAPs and therefore needs all relevant land-owners/managers involved, including the public;
- Clearing needs to start from the head of a catchment (or highest point in a valley) and move downstream/downslope to ensure that any potential sources of IAP seeds and other regenerative plant material are minimised/eliminated from upstream of the working area;
- Indigenous vegetation – including individual indigenous trees located amongst stands of IAPs – must be protected from damage during the IAP clearing process.

4.5 Climate Change Impacts on Coastal Environments

The coastal zone in South Africa includes the inshore, offshore and estuarine ecosystems. It is a continually changing area where land and ocean meet, and includes beaches, rocky shores, estuaries, wetlands and the ocean near the coast (Nelson, 2013; Provincial Government of the Western Cape, 2005). A coastal zone extends seaward up to the boundary of the exclusive economic zone, which is 200 nautical miles (roughly 370 km) out to sea, and inland up to one kilometre after the high-water mark (Republic of South Africa, 2014).

Climate change is predicted to result in several changes to South Africa’s coastal zone (Department of Environmental Affairs 2013e, 2012). It is forecast that climate change will:

1. increase impacts on marine and benthic ecosystems;
2. increase impacts on estuary ecosystems;
3. increase impacts on coastal livelihoods, and;
4. increase impacts on infrastructure and property due to sea level rise.

With regards to impacts from sea level rise, the Long-Term Adaptation Scenarios specifically considers all land under 5.5 metres (m) above the current mean sea level to be part of the coastal zone (Department of Environmental Affairs 2013f). The reason for this is that 5.5 m is the maximum estimated height of land that could be affected by the predicted increases in storm surges, sea level rise and tidal fluctuations by the year 2100 (Department of Environmental Affairs, 2013f).

Theoretical, observational and numerical studies all show that predicted changes in the next fifty years shows that the large-scale current systems around South Africa will change in their average physical properties and behaviour due to anthropogenically induced alterations to the earth’s atmosphere. These predicted changes to the large-scale ocean currents will impact on the coastal zone and change the average properties and circulation patterns as portrayed in Figure 26.

Figure 26 illustrate the mean shelf circulation regimes, the offshore current systems, and the export and import of water masses across the seaward boundary of the coastal zone. The coastal zone fish species are all dependent on the various coastal currents and enclosed coastal ecosystems for the successful completion of their life cycles.

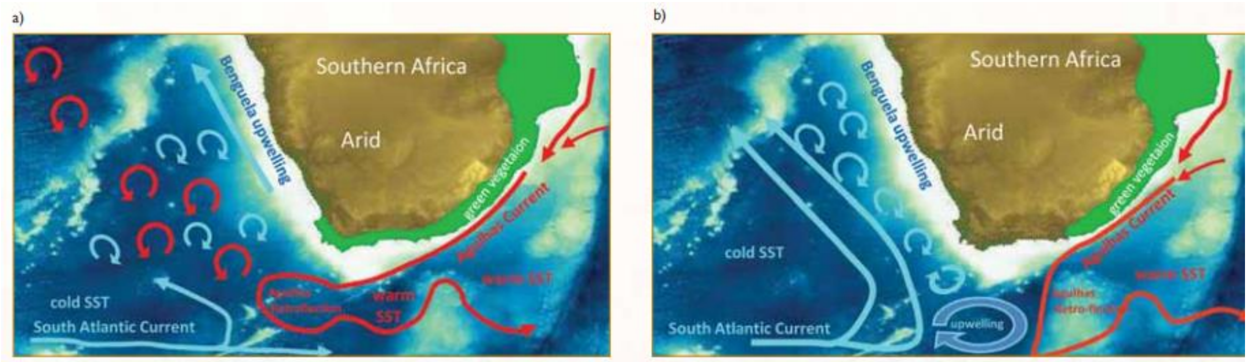

Figure 26: Current regimes around South Africa a) Normal downstream mode of the Agulhas Retroflection, leading to Agulhas Leakages via warm core Agulhas Rings. b) Upstream Retroflection mode leading to a reduction in Agulhas Leakage and cooler SST along the south and west coasts of South Africa. The change in coastal vegetation is indicated for the two modes. Red = warm SST, blue = cooler SST (Lutjeharms, 2006).

Lutjeharms and de Ruijter (1996) showed that the Agulhas Current will exhibit increased meandering, which will force the current (on average) further offshore from its contemporary mean position. In the present global climate regime the Agulhas Current is located within 15 km from the shore along the east coast of South Africa 77% of the time. However, perturbations in the form of large intermittent meanders force the current's core up to 300 km offshore. The meander modes of the Agulhas Current impact between four to six times a year. Lutjeharms and de Ruijter (1996) suggest that the meander modes will increase in frequency due to global warming and that the current will on average be located further from the coastline. This will impact on the socio-economics of the eastern and southern coastal zones (Figure 27).

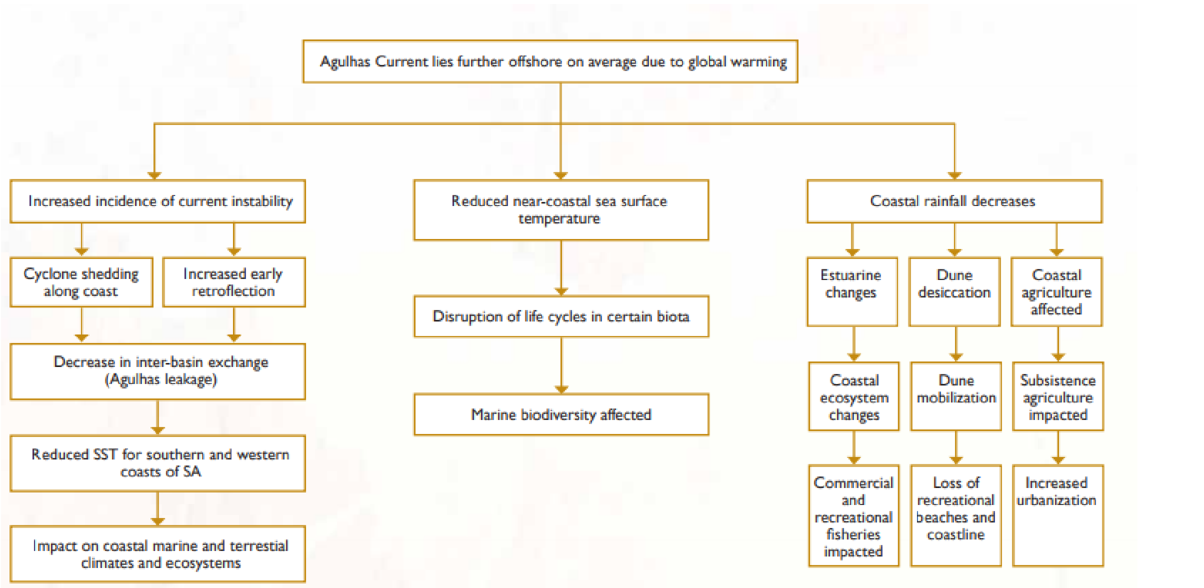

Figure 27: Flow diagram of a thought experiment on the possible environmental - and attendant socio-economic - effects along the east coast of South Africa of a substantial seaward shift of the Agulhas Current (Lutjeharms and de Ruijter, 1996).

The western coastal zone, which consists mainly of the Benguela Upwelling System, will exhibit more intense upwelling due to a predicted increase in wind stress over the southern Atlantic on account of global climate change (Lutjeharms et al., 2001). This will induce much cooler sea surface temperatures (SST) along the west coast of South Africa than at present. However, an intensification of the South Atlantic Sub-tropical gyre may also lead to increased atmospheric subsidence, fewer clouds, increased insolation6 and higher air temperature. The latter will result in warming of the surface water, which may negate the increased upwelling and offshore transport of cooler waters.

The coastal zone fish species are all dependent on the various coastal currents and enclosed coastal ecosystems for the successful completion of their life cycles. The exchange of large quantities of warm water from the Indian to the Atlantic Ocean (Agulhas Leakage) via the Agulhas Retroflection influences the entire coastal zone of South Africa (Figure 26). It has been shown that during Upstream Retroflection, when most of the warm saline Agulhas Current waters are diverted eastward at 25o S, negative SST anomalies are created south and west of South Africa. A stronger Agulhas Current transport has been predicted due to global warming.

The increase in surface temperatures leads to an increase in sea levels through the interaction of various processes such as thermal expansion of the oceans and melting of glaciers. It is predicted that climate change may also bring greater storm intensities. This makes coastal settlements vulnerable, especially considering that coastal zones are densely populated and growing rapidly. Coastal resources are expected to be affected by a number of consequences of climate change, namely higher sea levels, higher sea temperatures, changes in precipitation patterns and sediment fluxes from rivers, altered oceanic conditions as well as changes in storm tracks, frequencies and intensities.

According to the Coastal Hazard/Vulnerability and Mitigation Assessment conducted by the CSIR in 2015 (Figure 28), some important potential consequences of climate change and resultant global warming on southern African coast are:

- Potential changes in ocean winds and local wave regime - direct wave impacts;
- Extreme inshore sea water levels due to sea level rise and storms - flooding & inundation;
- Coastal erosion and under-scouring due to sea level rise and sea storms;
- Complexities, thresholds, and non-linearities - e.g. sand transport;
- The combination of extreme events (sea storms during high tides + sea level rise) will have greatest impacts - these will increasingly overwhelm existing infrastructure.

These impacts are expected to affect all coastal district municipalities in South Africa (Department of Environmental Affairs, 2013e).

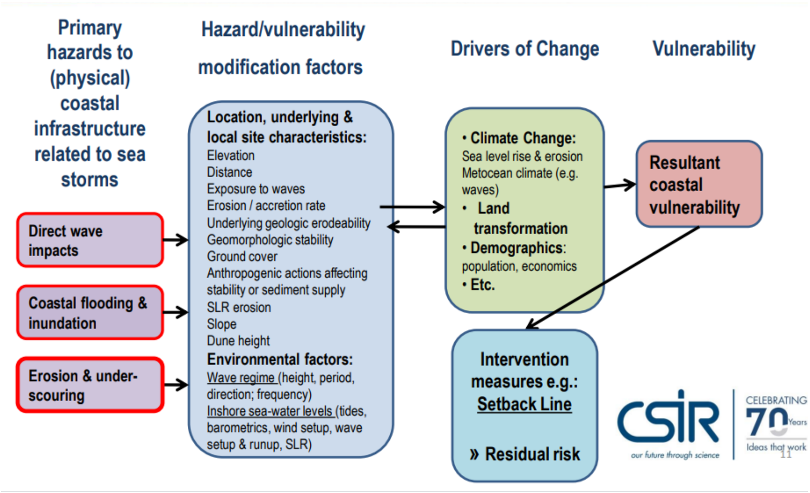

Figure 28: Coastal Hazard/Vulnerability & Mitigation Assessment conducted by the CSIR (CSRI, 2015).

Climate change may also have a negative effect on coastal livelihoods (Department of Environmental Affairs, 2013e). Predicted increases in the severity and frequency of storms and sea level rise may reduce the number of feasible fishing days and cause damage to shore-based infrastructure (e.g. harbours and launch sites) and fishing boats (Department of Environmental Affairs, 2013e).

In addition to the predicted effects of climate change, the coastal zone in South Africa is susceptible to anthropogenic impacts such as ecosystem overuse (e.g. overfishing) and degradation, increased pollution, and the increased nutrient runoff from coastal developments leading to eutrophication of wetlands, estuaries, etc. (Department of Environmental Affairs, 2013e). The anthropogenic and climate change impacts have already negatively affected biodiversity and ecosystems services in the coastal zone (and across South Africa) and are expected to worsen these issues unless climate change adaptation and mitigation responses are developed and implemented (Department of Environmental Affairs, 2013e).

4.5.1 Extreme Storm Events and Sea Level Rise

Climate change can cause extreme storm events which can result in coastal erosion and flooding disasters along the coast. Our oceans have absorbed about 90% of excess heat connected to rising greenhouse gas emissions from human activities in recent decades (Aster et al., 2023). That excess energy increases the ocean wave energy which can cause a higher frequency in damaging waves and more severe storm surge events along our coastline.

As part of a research study conducted by Aster et al. (2023), the increase in ocean wave energy due to global warming was tracked over the period of four decades. The study results indicated that 41 (79%) of the wave monitoring stations around the world showed highly significant and progressive increases in wave energy over the decades, which coincides with increasing storminess attributed to rising global temperatures (Aster et al., 2023). This increasing ocean wave heights can pound coastlines, damaging infrastructure and cause severe coastal erosion. This impacts of increasing wave energy are further compounded by ongoing sea level rise fuelled by climate change and by subsidence. This effects emphasizes the importance of mitigating climate change and building resilience into coastal infrastructure and environmental protection strategies (Aster et al., 2023).

It is important to determine which parts of the coast are more vulnerable than others under present conditions. Another important issue to predict is how areas that are already vulnerable to erosion may become more prone to damage in the future due to the effects of climate change. It is well known that the prime factors leading to damages in the past and increased risk in the future, are developments located too close to the sea. Thus, there is a need to determine safe areas, which requires prediction of future shoreline locations. Studying the risks due to climate change in coastal areas will aid design and safe location of new developments and infrastructure, and will also help to identify other adaptation options for existing developments that are at risk.

In order to mitigate the risks of sea level rise, it is important that clear coastal management lines are developed (Department of Science and Technology, 2010). This is a line landward of which fixed structures (such as houses and roads) may be built with reasonable safety against the physical impacts of the coastal processes (such as sea storms, wave erosion and runup). The predicted management lines will be useful for anybody involved in coastal zone management, municipalities and city planners as well as developers and home owners. The development of coastal management lines will enable authorities to better plan future developments, to develop the coast according to natural cycles and to manage coastal development in a sustainable manner.

The development of future coastal management line will demarcate safe coastal areas as well as those that are at risk of being eroded, and infrastructure or areas that are vulnerable to the effects of sea-level rise. For example, an erosion setback line determined to be safe from present coastal conditions (i.e. present seawater levels and storm intensities) cannot be expected to remain safe under more extreme climate-changed conditions (i.e. raised seawater levels and/or more stormy sea conditions). The determination of coastal management lines that are safe in the long term needs an acknowledgement and quantification of risks, mobilisation of resources, solid policy guidelines and planning, as well as appropriate legislation (Department of Science and Technology, 2010).

Planning of adaptation options can further be enhanced with information about realistic scenario modelling, regional connectivity modelling and calculation of regional sediment budgets, as predicting the actual response of the coast to climate change will depend on the holistic understanding of its effects on the coastal system (Department of Science and Technology, 2010). The determination of coastal management lines for the Garden Route district’s coastline will be done by the Western Cape Department of Environmental Affairs and Development Planning (DEA&DP): Coastal Management Section, and the project is currently in the planning phases. This development of future coastal management lines will demarcate safe coastal areas as well as those that are at risk of being eroded, and infrastructure or areas that are vulnerable to the effects of sea-level rise along the Garden Route district coastline.

Climate change is expected to reduce the diversity and quantity of fishes and other biota in estuarine ecosystems (as well as inshore and offshore ecosystems) through changes to:

land and sea surface temperatures; frequency and distribution of precipitation; water runoff patterns; increased coastal storm frequency and intensity; oxygen levels; and wind (Department of Environmental Affairs, 2013e). Sea level rise may also cause salt water intrusions into estuarine and agricultural lands which can lead to a reduction in their ecosystem services (Atkinson and Clark, 2005).

4.5.2 Adaptation Strategies for Coastal and Marine Environments

As the coast changes and options are considered in response to the cross-cutting pressures caused by these changes, which are also expected to be exacerbated by climate change, the Garden Route district needs to apply a multi-disciplinary approach in resolving and adapting to such challenges. Wind, wave action, long shore sand transport, erosion and accretion, and storm action are powerful drivers of coastal systems, which are considered during maintenance management plan development and will inform and guide coastal development and ancillary opportunities. The determination of the most appropriate and sustainable course of action for addressing coastal erosion and storm surges requires sensitive navigation through the multiple and often conflicting interests of the various stakeholders, including private developers, property owners, government officials (across all three spheres), beach users, civil society and environmental pressure groups.

The Garden Route district is committed to make decisions, and take actions, around the protection of coastal, marine and estuarine resources as well as essential coastal dynamic processes by:

- Ensuring the healthy functioning of coastal ecosystems by strengthening the natural defences that protect people and coastal systems, such as the protection of sand dunes, sea grass, estuaries and beaches are physical buffers.
- Ensuring that the extraction and use of natural resources does not compromise the sustainability of vital coastal ecosystems. Reducing or eliminating non-climate stresses and unfavorable trends helps to achieve functional ecosystems that are more resilient to climate change and variability.
- Ensuring that illegal sand and gravel mining in coastal riverbeds, estuaries and beaches is stopped.
- Ensuring that marine fisheries are healthy and resilient to climate change, by reducing overfishing and destructive fishing thereby strengthening fish populations and restoring fish habitats.
- Restricting and/or eliminating industrial fishing vessels from operating within 15 km of the coast;
- Ensuring that coastal, marine and estuarine ecosystems are functioning and healthy. Functional ecosystems provide goods and services that are important to human society in the face of climate change (storm protection, flood mitigation, shoreline stabilization, erosion control, water storage, groundwater recharge, and retention of nutrients, sediments and pollutants).
- Reducing estuarine pollution and securing a safe breeding habitat for marine and estuarine species.

- The identification of coastal locations that are more stable during periods of global climate change can serve as Marine Protected Areas, thereby offering a refuge for stressed species coming from the neighbouring vulnerable areas.
- Ensuring that the required estuarine freshwater inflows for estuaries are upheld in order to maintain the environmental flow requirements.
- That coastal development strictly complies with the defined coastal management setback lines as developed by DEA&DP for the Garden Route district;
- Implementing integrated disaster risk management and preparedness actions to reduce the risks to human health and safety as well as coastal ecosystem degradation from natural hazards such as storm surges, flooding, gale force wind, amongst others.
- Apply a consistent, cautious and risk averse approach in responding to the pressures caused by coastal erosion and storm surges;
- Favour soft engineering approaches over hard engineering solutions where possible;
- Require all new coastal developments and changes to existing developments to incorporate mitigation of and/or adaptation to coastal climate change impacts as part of their approval process;
- Ensure that coastal defences to protect private property from the threat of coastal erosion is compliant with the relevant legislation;
- To not approve coastal defence structures if such structures will compound risk to the coastal environment or its residents into the future;
- To retain the option of managed retreat over defence;
- Requiring that coastal defences be proven to reduce risk prior to being approved;
- Favouring coastal defences which are reversible, flexible, do not negatively impact on sense of place or aesthetics, and have other positive knock-on effects,
- Favour soft engineering approaches over hard engineering solutions as recommended by the Estuarine Management Framework and Implementation Strategy and Coastal Erosion Policy Document.;
- Undertaking a broadly consultative process with the public when deciding on coastal, marine or estuarine defence interventions; and
- Support the Responsible Management Authorities (RMA) to establish and implement appropriate Mouth Management Plans

Priority adaptation and response actions as identified in the Western Cape Climate Change Response Strategy (WCCCRS) Biennial Monitoring & Evaluation Report 2015/16 (Birch et al., n.d.) for the coastal sector also includes the:

- Establishment of coastal risk overlays and coastal management lines;
- Research best practice regarding responding to repeated coastal inundation in high risk areas;
- Protection and rehabilitating existing dune fields as coastal buffers /ecological infrastructure;
- Monitoring of possible linkages between climate change and fisheries industry;
- Ensuring that Estuary Management Plans take cognisance of climate change;

A key challenge that emerges is the need for improved impact and vulnerability assessments that is relevant to coastal management needs. This should include the consequences of sea-level rise and the impact of climate change on coastal areas. This will require continued development of broad-scale assessment methods for coastal management. It is also important to assess coastal adaptation and management as a process rather than just focus on the implementation of technical measures. Lastly, the uncertainties of climate change suggest that coastal management should have explicit goals, so that its success or failure should be regularly monitored, and the management approach adjusted as appropriate.

Coastal management needs to be practiced as an inclusive, strategic and adaptive process for assessment of climate change risks, planning, securing commitment and funding, implementation, and evaluation. Systematic knowledge gathering, continued learning and understanding plays a major role in guiding the wise use of coastal resources, resolving human-induced problems, and improving governance systems.

4.6 Climate Change and Energy Provision

Tourism along the Garden Route results in particular energy management and waste challenges, as infrastructure and supply has to cope with large tourism season-driven peaks. This would mean that distribution infrastructure has to be able to cope with a seasonal peak demand that is far higher than the yearly average demand. The report provides a brief energy picture for Garden Route District Municipality and highlights key areas or issues for attention.

Table 7: The Garden Route District energy picture (Department of Energy (2010; 2011).

Key Sustainable Energy Indicator	Unit of Measure	District Value 2009	Provincial Value 2009	National Value 2009
Energy consumption per capita	GJ/capita	52	64	53
GHG emissions per capita	tCO_2e/capita	7.3	8.0	7.7
Energy per GDP (R' mill)	GJ/GDP	1,626	1,428	1,094
GHG emissions per GDP (R' mill)	tCO_2e/GDP	231	178	159

The district has an average annual carbon emissions level of 7.3 tonnes per person; higher than the global average of 4 tonnes per capita, but on a close par with provincial average and the national average of 8.0 and 7.7 tonnes per capita respectively. This carbon footprint is substantially higher within industrial towns compared to non-industrialised towns. However, when looking at the of energy consumed per unit of economic output and as well greenhouse gas emissions per unit of economic value, then the area can be seen to be a relatively high user of energy and carbon emitter.

While the energy consumption in this district is small and it represents a very small part of the total provincial consumption (8% of the provincial total), important saving opportunities exist within the built environment as well as the industrial sector. The Garden Route District experiences the highest level of energy poverty of all the districts/metros. It's per capita energy and waste GHG emissions footprint is in line with the provincial average, but this masks a large range; from 3 tonnes per capita in Kannaland and Oudtshoorn, and 5 in George (the largest town after Cape Town), to 8 in Mossel Bay (a heavy industrial area). Garden Route has the second-highest vehicle ownership, which, combined with the high energy poverty, may indicate large wealth inequality. Liquid fuel represents the largest amount of energy consumed in the district, while electricity use is the cause of the most GHG emissions. Industry uses about half of the district's electricity, with the residential sector consuming a third. The following are key energy issues within the Garden Route District (Department of Environmental Affairs and Development Planning, 2013):

- Heavy industry is situated in the Garden Route District (e.g. in Mossel Bay).
- A national road runs through the district, which increases liquid fuel use that is outside the management control of local municipalities.
- South Africa's largest desalination plant is situated in Mossel Bay. Though not used often, it is very energy intensive when in use.
- The district has the highest energy poverty level in the Western Cape, when based on the percentage of non-electric fuels used for space heating and cooking.
- Peak tourist season offers energy management challenges. LPG use for cooking may be encouraged in the tourism sector to decrease electricity peak load demand.

4.6.1 Adaptation Strategies towards Energy Efficiency and GHG Emissions Mitigation

Priority responses towards addressing energy efficiency and renewable energy identified in the Garden Route district includes:

- Implementation of building energy efficiency programmes and awareness raising, including improved energy efficiency within municipal and government owned buildings;
- Promotion and rollout of solar water heaters (both low and high pressure systems);
- Development of the renewable energy economy in the Garden Route district, in terms of both the appropriate placement of utility scale renewable energy generation as well as manufacturing opportunities;
- Development of waste-to-energy opportunities for both municipal and private (commercial and industrial) waste systems, and;
- Development of opportunities around small-scale embedded generation.

4.7 Climate Change and Air Quality Management

The rise in the average global temperature is due, primarily, to the increased concentration of gases known as greenhouse gases (GHGs) in the atmosphere that are emitted by human activities. These gases intensify a natural phenomenon called the "greenhouse effect" by forming an insulating layer in the atmosphere that reduces the amount of the sun's heat that radiates back into space and therefore has the effect of making the earth warmer.

While weather changes on a daily basis, climate represents the statistical distribution of weather patterns over time, and on a global scale has changed only very slowly in the past – usually over periods of tens of thousands of years or even millions of years which allows time for the earth's bio-physical systems to adapt naturally to the changing climatic conditions. Currently, the global climate is changing much more rapidly as a result of global warming, leading to, among others, the melting of polar and glacier ice, sea-level rise, ocean acidification, changes in rainfall and snowfall patterns, more frequent floods and droughts and increased frequency and intensity of extreme weather events, such as tornadoes, hurricanes and cyclones.

Climate change can impact air quality and, conversely, air quality can impact climate change. Changes in climate can result in impacts to local air quality. Atmospheric warming associated with climate change has the potential to increase ground-level ozone in many regions, which may present challenges for compliance with the ozone standards in the future. The impact of climate change on other air pollutants, such as particulate matter, is less certain, but research is underway to address these uncertainties.

Emissions of pollutants into the air can result in changes to the climate. Ozone in the atmosphere warms the climate, while different components of particulate matter (PM) can have either warming or cooling effects on the climate. For example, black carbon, a particulate pollutant from combustion, contributes to the warming of the Earth, while particulate sulphates cool the earth's atmosphere.

According to a NASA study, an increase in ozone pollution, or smog, is causing warming in the Arctic regions. Ozone in the troposphere is a greenhouse gas and also a health hazard. Ozone pollution created in the Northern Hemisphere is transported towards the Arctic during winter and spring months, which leads to warming. Ozone pollution has the greatest impact on the region where it originates, which means some areas are warming more than others. The Arctic is currently warming faster than any other region on Earth, partly because of ozone pollution, but also because of positive feedback loops, where warming melts snow and ice, which changes the Earth's surface, and leads to more warming. The warming climate is causing drastic changes to Arctic ecosystems. Because of climate warming, the Earth experiences more extreme weather, such as heat waves and drought, which can negatively impact air quality. Heat waves cause an increase in ground-level ozone pollution because the chemical reactions that create ozone in the atmosphere occur more often in hot temperatures.

Higher pollen concentrations and longer pollen seasons are also influenced by the changing climate. Airborne allergens, like pollen, decrease air quality and cause health problems. During heat waves, areas of high pressure create stagnant air that concentrates air pollutants in one area. Prolonged high temperatures due to climate warming often lead to drought conditions where forest fires, which release carbon monoxide and particulates, are more common. Dry, dusty air during periods of hot weather also increases the amount of particulate pollution.

The Garden Route District's Air Quality adaptation and mitigation activities should be linked to the National Climate Change Response White Paper. The purpose of the White Paper is to improve air and atmospheric quality, lead and support, inform, monitor and report efficient and effective international, national and significant provincial and local responses to climate change. Its functions are:

- To identify, gather, sort, collate, store, archive, analyse, synthesize, distribute and popularise complete, accurate, and current climate change and climate change response data and information that ensures informed climate change response decision-making;
- To lead and/or support, inform, monitor and report efficient and effective national, provincial and local climate change mitigation responses;
- To lead and/or support, inform, monitor and report efficient and effective national, provincial and local climate change adaptation responses;
- To prepare for, negotiate and inform the implementation of multi-lateral, mini-lateral and bilateral climate change agreements;
- To ensure that reasonable legislative and other measures are developed, implemented and maintained in such a way as to protect and defend the right of all to air and atmospheric quality that is not harmful to health and well-being.

4.7.1 Adaptation and Mitigation Strategies towards Air Quality Management

- **Garden Route District 2nd Generation Air Quality Management Plan**

  The objectives of the plan are outlined as follows:

  - **Objective 1: Set Air Quality Goals**

    A key component as no control actions can be considered without knowing if any air quality goals are being exceeded.

    - **Emissions Database**

      An emissions inventory is aimed at identifying and quantifying emissions of pollutants from all sources in the Garden Route district region. The sources can be grouped into three classes:

      - Point Sources: Industrial emissions: stacks, fugitive process emissions, etc.
      - Area Sources: Residential and refuse sources, etc.
      - Line Sources: motor vehicles, ships, aircraft, trains, etc.

  - **Objective 2: Set Up Air Quality Management System**

    - **Air Quality Monitoring Network**

      Three continuous AQ monitoring stations are in operation, one each in George, Mossel Bay (Dana Bay) and Oudtshoorn. The stations are the property of DEADP and are on loan to Garden Route District Municipality.

The Garden Route District Municipality is actively carrying out air quality monitoring programs by means of passive sampling methods in conjunction with individual municipalities. While passive sampling methods have limitations, they serve as good screening methods.

The Municipality is also actively carrying out a diesel exhaust emissions monitoring program in conjunction with individual municipalities, thus providing a supporting function to the municipalities.

These activities will be maintained, but the results obtained from the continuous AQ monitoring stations will be assessed in terms of compliance with ambient air quality standards.

- **Dispersion Modelling**

A regional dispersion modelling study was undertaken and is discussed in detail in Chapter 5 of the AQMP. As is stated in Section 3.2.1, limited vehicle data and no domestic fuel consumption data is available and both of these are major sources of air pollutant emissions. The outcome of the dispersion modelling study is, therefore, limited.

- **Air Quality Information**

Ambient Air Quality information is essential to support the right to a healthy environment as envisaged in Section 24 of the Constitution. As public funds are generally used in air quality monitoring and management functions the general public has the right to information dealing with the issue.

It is assumed that DEADP makes all data recorded at its continuous AQ monitoring stations to the South African Air Quality Information System (SAAQIS) for access via the internet. However, not all members of the public have access to the internet, data is not readily available from SAAQIS, nor are the results of Garden Route District Municipality passive sampling campaigns.

Therefore, a strategy will be defined to disseminate ambient air quality data to the general public through various media, e.g. newspapers, EDM's web site, etc.

Data reporting requirements of the Garden Route District Municipality Council need to be formalised for regular updates of monitoring data. Additional specialised reports will be supplied on demand.

The data reporting strategy will, therefore, include reporting of the results of passive sampling campaigns to the Provincial and National Government.

Objective 3: Carry Out Risk Assessments

The only way to determine the impact of air pollutants on living species is through risk assessments. Not all creatures react in the same way to the same dose (pollution). This activity is essential to assist town planners and industrialists in locating factories and roads correctly in relation to the built environment.

The following activities are involved in determining risk:

- Dose
- Health Effects
- Ecological

- **Objective 4: Assess and Select Control Measures**

Based on the air quality information generated from the AQ monitoring stations and the outcome of risk assessments, a decision must be made on the implementation of remedial actions and the source sector on which the remedial actions must be focused.

Potential interventions must be identified and ranked in order of perceived effectiveness and cost. In some instances the intervention may imply a technology solution requiring a regulatory order, e.g. reduction of emissions from a specific industry, whilst in others it may require a political decision, e.g. traffic volume restrictions, electrification of informal settlements, etc.

- **Objective 5: Implementation of Intervention and Monitoring of Effectiveness**

Once appropriate intervention measures have been identified they need to be implemented. Solutions will require the support of politicians, senior management, interested and affected parties, the public, commerce and industry in order to be effective. Consequently these solutions need to be open to scrutiny.

Once applied, monitoring the change as a result of the intervention measure may only become apparent after long-term monitoring activities due to the time-based accumulation and release of pollutants in nature.

- **Objective 6: Revise Air Quality Goals**

Should it appear that health and ecological risk assessments reveal an increased risk due to the presence of air pollutants in the atmosphere, or that industrial growth, urbanisation, etc., result in the long-term decrease in air quality, it may become necessary to revise the air quality goals adopted as an initial step to the implementation of the AQMP.

Effective statistical analyses should provide sufficient early warning of such occurrences so that air quality goals can be revised in time to prevent a serious negative impact on the environment.

Revising the air quality goals should, therefore, be an on-going objective, although not one that necessarily requires a major level of attention unless data proves otherwise. Its full impact is seen as a long-term activity. In addition it is a legal requirement of the AQA that the AQMP be revised every 5 years.

- **Objective 7: Integrate the AQMP into the IDP**

Effective environmental management, including air quality management, is dependent on inter-departmental communication, cooperation, support and financing.

Section 15(2) of the Air Quality Act requires that the AQMP be included into the Integrated Development Plan of the municipality.

There is a need to inform other departments that air quality impact need to be considered in the performance of their functions.

The Air Pollution Unit is a Licensing Authority in terms of the AQA. Section 21-listed activities are identified in environmental legislation as requiring environmental authorizations. These activities have impacts on the following decisions:

- Changes in land use, e.g. rezoning of land from agriculture to industrial / residential use;
- Upgrading and building of new roads;
- Industrial developments and processes;
- Incineration of general and hazardous waste;
- Operation of crematoria.

It is also required, therefore, that the Air Quality Management Plan be incorporated in the various sector development plans of other departments within the Garden Route District Municipality.

- **Objective 8: Compliance Monitoring, Enforcement and Control**

The Garden Route District Municipality has been authorised to serve as licensing authority in terms of the Air Quality Act. As such the Air Pollution Unit of the Garden Route District Municipality is required to carry out all of the duties associated with issuing atmospheric emission licences to industries that operate processes for which official emission limits have currently been set. These duties include evaluation of environmental impact assessments, air pollution control proposal evaluations, continuous emissions monitoring specifications, specific ambient air quality monitoring requirements, etc.

As time goes by and more air quality data is obtained, or as South Africa's international obligations so demand, it may become clear that actions are called for the achievement of a reduction in overall concentration of one or more pollutants, e.g. CO_2, greenhouse gases, etc. Once atmospheric emission licences (AELs) have been issued it is the responsibility of such licence holders to submit data about their emissions according to a time scale defined by the Garden Route District Municipality.

Should this data reveal that emission limits are being exceeded administrative steps will be taken to enforce compliance with the licences. Such steps include compliance notices, fines for non-compliance, etc. It is accepted that emissions from various sources may result in complaints from neighbouring communities. In such cases the complaints will be investigated and the sources of the pollutants inspected for compliance or, if necessary, inclusion in the Garden Route District Municipality's list of controlled emitters. If deemed necessary spot checks of pollutant concentrations may be made by Garden Route District Municipality personnel. In such cases plans must be formulated to achieve the required degree of reduction through measures deemed appropriate at that stage, e.g. revised emission licences, etc.

The issuing of AELs does not imply that emissions can continue ad infinitum, even though the emissions may fall within the limits set in the AELs. The Garden Route District Municipality will, therefore, develop a plan to audit the terms and conditions contained in AELs for revision as and when required. The audit plan must define an audit frequency, i.e. time scale between audits, the parameters that will be audited and the criteria against which audit results will be evaluated.

5. Garden Route Climate Change Vulnerability

Climate change has been identified as a key issue for the Garden Route District Municipality (Garden Route District Municipality, 2017a, 2016, 2014). Adaptive climate change planning and preparedness needs to take a more general flexible form, like budget allocations for potential disasters, and holding back on unsustainable development 'in case' it exacerbates the effects of climate change. Municipalities should conduct pro-active monitoring with a prediction and prevention focus, and focus on Focusing on climate change issues that are highly vulnerable to climate variability.

While the *Garden Route District Climate Change Adaptation Plan of 2014* primarily focused on adapting to climate change, this reviewed *Garden Route District Climate Change* Strategy also focused on the inclusion of climate change adaptation hazards as well as a vulnerability assessment. Table 6 below indicates the key climate change hazards identified for the Garden Route District:

Table 8: List of Key Climate Change Hazards in the Garden Route District

Climate Change Hazard	Vulnerable areas
Temperature dependant vulnerability:	Water; Agriculture; Environment
Extended Dry Spell periods (longer periods between rainfall events and more intense rainfall events – this does vary between areas within EDM due to different landscapes and location)	i. Water ii. Agriculture iii. Communities/Society iv. Tourism
Fire Risks (there are fire regimes that are needed i.e. Fynbos, but this focussed on unwanted fires)	i. Community/Society ii. Human Settlements iii. Environment
Increased intensity of Storm Events	i. Infrastructure ii. Human settlements – Built environment, planning, location iii. Communities/Society – safety, emergency response
Coastal areas (Storm Surge and Sea-level rise)	i. Infrastructure ii. Coastal areas, Built environment, natural barriers, dunes, ecosystem services iii. Human settlements

5.1 Garden Route Climate Change Vulnerability Assessment

A Garden Route Climate Change Vulnerability Assessment was conducted through the Local Government Climate Change Support (LGCCS) program (http://www.letsrespondtoolkit.org/) in partnership with the Western Cape Climate Change Municipal Support Programme. The LGCCS is an initiative of the National Department of Environmental Affairs and the International Climate Initiative (IKI) and is supported by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH on behalf of The Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety

(BMUB). The assessment outlines the key climate change vulnerabilities and responses to address these vulnerabilities for Garden Route District Municipality.

The three primary objectives of the LGCCSP are to:

- Perform a desktop analysis of the municipality to provide context on change vulnerabilities and responses;
- Undertake district municipal specific engagements to draft climate change vulnerabilities and responses;
- Facilitate capacity building and knowledge-transfer throughout the program to enhance implementation of prioritised climate change adaptation options.

Through the LGCCSP, a Climate Change Vulnerability Assessment Toolkit was developed to assist municipalities to identify and prioritise climate change indicators to facilitate the assessment of adaptive capacity. The LGCCS Toolkit was applied to the Garden Route District Municipality to assist with the development of its Climate Change Response Plan.

5.2 Vulnerability Assessment Results Summary

The tables below list the high and medium priority climate change indicators identified for the Garden Route District Municipality, based on the results of the Vulnerability Assessment in the Garden Route District Municipality's Climate Change Needs and Response Assessment document.

5.2.1 High Priority Climate Change Indicators

Based on the vulnerability assessment, the following indicators were identified as high priority climate change vulnerabilities for the municipality. These were shortlisted by answering "yes" to exposure, "high" to sensitivity and "low" to adaptive capacity.

Table 9: High Priority Indicators Garden Route District Municipality

No	Sector	Indicator Title	Exposure Answer	Sensitivity Answer	Adaptive Capacity Answer
10	Agriculture	Increased risks to livestock	Yes	High	Low
13	Biodiversity and Environment	Increased impacts on threatened ecosystems	Yes	High	Low
14	Biodiversity and Environment	Increased impacts on environment due to land-use change	Yes	High	Low
15	Biodiversity and Environment	Loss of Priority Wetlands and River ecosystems	Yes	High	Low
19	Coastal and Marine	Loss of land due to sea level rise	Yes	High	Low
20	Coastal and Marine	Increased damage to property from sea level rise	Yes	High	Low
26	Human Health		Yes	High	Low
30	Human Settlements, Infrastructure and Disaster Management	Increased impacts on traditional and informal dwellings	Yes	High	Low
32	Human Settlements, Infrastructure and Disaster Management	Increased migration to urban and peri-urban areas	Yes	High	Low
33	Human Settlements, Infrastructure and Disaster Management	Increased risk of wildfires	Yes	High	Low
36	Water	Decreased water quality in ecosystem due to floods and droughts	Yes	High	Low

No	Sector	Indicator Title	Exposure Answer	Sensitivity Answer	Adaptive Capacity Answer
40	Air Quality	Increase in Air Pollution	Yes	High	Low
41	Air Quality	Increase in odour complaints	Yes	High	Low
42	Air Quality	Increase in Brown haze	Yes	High	Low

5.2.2 Medium Priority Climate Change Indicators

Based on the above vulnerability assessment the following indicators were identified as medium priority climate change vulnerabilities for the municipality. These were shortlisted by answering “yes” to exposure, “medium” or “high” to sensitivity and “low” or “medium” to adaptive capacity.

Table 10: Medium Priority Indicators Garden Route District Municipality.

No	Sector	Indicator Title	Exposure Answer	Sensitivity Answer	Adaptive Capacity Answer
1	Agriculture	Change in grain (maize, wheat & barley) production	Yes	Medium	Medium
4	Agriculture	Change in Sugarcane Production	Yes	Low	Low
5	Agriculture	Change in viticulture (grapes) production	Yes	High	Medium
6	Agriculture	Change in fruit production	Yes	High	Medium
7	Agriculture	Change in other crop production areas (e.g. vegetables, nuts, etc.)	Yes	High	Medium
8	Agriculture	Increased areas for commercial plantations	Yes	High	Medium
9	Agriculture	Increased exposure to pests such as eldana, chilo and codling moth	Yes	High	Medium
11	Agriculture	Reduced food security	Yes	Medium	Low

No	Sector	Indicator Title	Exposure Answer	Sensitivity Answer	Adaptive Capacity Answer
12	Biodiversity and Environment	Loss of High Priority Biomes	Yes	High	Medium
16	Coastal and Marine	Impacts on Marine and Benthic Ecosystems	Yes	High	Medium
17	Coastal and Marine	Impacts on estuary ecosystems	Yes	High	Medium
18	Coastal and Marine	Impacts on Coastal Livelihoods	Yes	Medium	Medium
21	Human Health	Health impacts from increased storm events	Yes	Low	High
22	Human Health	Increased heat stress	Yes	Medium	Medium
23	Human Health	Increased vector borne diseases from spread of mosquitoes, ticks, sandflies, and blackflies	Yes	Medium	Medium
24	Human Health	Increased water borne and communicable diseases (e.g. typhoid fever, cholera and hepatitis)	Yes	Medium	Medium
27	Human Health	Increased Occupational health problems	Yes	Medium	Medium
28	Human Settlements, Infrastructure and Disaster Management	Loss of industrial and labour productivity	Yes	Medium	High
29	Human Settlements, Infrastructure and Disaster Management	Increased impacts on strategic infrastructure	Yes	High	Medium
31	Human Settlements, Infrastructure and Disaster Management	Increased isolation of rural communities	Yes	High	Medium
34	Human Settlements, Infrastructure and Disaster Management	Decreased income from tourism	Yes	Medium	Low
35	Water	Decreased quality of drinking water	Yes	Medium	Medium
37	Water	Less water available for irrigation and drinking	Yes	Medium	Low
39	Water	Increased fish mortality	Yes	Low	Medium

6 Sector Response Plans

The section below summarises sector responses that have been identified to address the key vulnerabilities identified above.

6.1 Agricultural Sector

6.1.1 Introduction

	Program Name
	Agricultural Sector Adaptation to Climate Change
!	**Overview of Key Issues**
	The South African agricultural sector is highly diverse in terms of its activities and socio-economic context. This sector can be described as two-tiered (commercial vs. small-holder and subsistence farmers), with activities across a wide variety of climatic conditions (especially of rainfall). Roughly 90% of the country is sub-arid, semi-arid, or sub-humid, and about 10% is considered hyper-arid. Only 14% of the country is potentially arable, with one fifth of this land having high agricultural potential. Climate is important in determining potential agricultural activities and suitability across the country, especially in smallholding and homestead settings. Irrigation and conservation tillage practices can overcome rainfall constraints, especially in the high-value commercial agricultural sector. Irrigation currently consumes roughly 60% of the country's surface water resources, with important implications for agricultural exports, and food and water security in the context of climate change. In the Western Cape the current priority areas have been identified in the WCCCRS for the Agriculture sector 1. The promotion of climate smart agriculture; 2. Promoting food security at the municipal level; and 3. Research on climate resilient and alternative crops and livestock applicable to the Western Cape Furthermore, the following priority areas have been listed in the Western Cape Climate Change Response Strategy Biennial Monitoring & Evaluation Report 2015/16 (Birch et al., n.d.) for addressing food security and an economically sustainable agricultural industry in the province. 1. Farming practices that are in harmony with nature, i.e. 'conservation farming'; 2. Climate smart agriculture;

	3. Agricultural water technologies that reduce consumption and increase efficiency (see Water); 4. Research on climate resilient and alternative crops and livestock applicable to the Western Cape; 5. Addressing climate vulnerability through the Municipal Support Programme; and 6. Assessing food security in the context of the resource nexus.
	Objectives
	The following objective has been identified through the LGCCSP as a priority area for the agriculture sector in the District Municipality.
10	Manage increasing risks to livestock

6.1.2 Identified Adaptation Responses

The Garden Route District Municipality's agricultural sector will be adversely affected by climate change. Increased temperatures, drought, and the increase in frequency and severity of storm events will impact on the crops that can be grown and potentially result in a loss of livestock.

The following key agricultural sector adaptation responses for the identified objective were identified for the Garden Route District:

No	Objective	Adaptation Response
10	**Manage increasing risks to livestock**	Commission research and improve understanding of climate change impacts livestock and land availability
		Develop a framework that will assist and educate farmers with adjusting to reduced rainfall.
		Generate and share scientific, social and indigenous knowledge that will assist with adapting to the reduction in herbage yields.
		Improve collaboration and partnership on existing programs (e.g. LandCare Programme, EPWP and River Health Programmes)
		Strengthen management plans, to enable continuous monitoring of water and herbage availability for livestock. Investigate sustainability of dairy industry, as a high-water demand industry, in the District. Develop a map indicating the best areas to produce high water demand crops as well as areas where alternative crops should be considered

6.2 Biodiversity and Environmental Sector

6.2.1 Introduction

	Program Name
	Biodiversity and Environmental Sector Adaptation to Climate Change
	Overview of Key Issues
	Biodiversity is crucial to ecosystem health, and healthy ecosystems are central to human well-being. Healthy ecosystems interlinked with working landscapes and other open spaces form the ecological infrastructure of the country and are the foundation for clean air and water, fertile soil and food. All South Africans depend on healthy ecosystems for economic and livelihood activities, including agriculture, tourism and a number of income generating and subsistence level activities. These natural ecosystems are under pressure from land use change and related processes causing degradation, as well as invasive alien species. Accelerated climate change (resulting in increasing temperature, rising atmospheric CO_2 and changing rainfall patterns) is exacerbating these existing pressures. Well-functioning ecosystems provide natural solutions that build resilience and help society adapt to the adverse impacts of climate change. This includes, for example, buffering communities from extreme weather events such as floods and droughts, reducing erosion and trapping sediment, increasing natural resources for diversifying local livelihoods, providing food and fibre, and providing habitats for animals and plants which provide safety nets for communities during times of hardship. Sustainably managed and/or restored ecosystems help in adapting to climate change at local or landscape level. In the Western Cape the current priority areas have been identified in the WCCCRS for the biodiversity and ecosystem goods and services sector 1. Prioritisation, valuation, mapping, protection, and restoration of ecological infrastructure; 2. Landscape initiatives / biodiversity corridors and identification of requirements for climate change adaptation corridors; 3. Biodiversity stewardship; and 4. Mainstreaming of conservation planning into decision making. Furthermore, the following opportunities, gaps and recommendations have been identified in the Western Cape Climate Change Response Strategy Biennial Monitoring & Evaluation Report 2015/16 (Birch et al., n.d.) for the biodiversity and ecosystem goods and services sector: 1. Better data sharing is needed between government entities 2. Finding comprehensive information on the numbers/hectares of aliens cleared is problematic 3. Informally protected areas are hard to track, as the data is often patchy or outdated. 4. Set fact-based climate change targets for this focus area.

	5. There is a need to expand the conservation estate within these corridors. 6. Local community stewardship over corridors and unprotected areas should be promoted.
	Objectives
	The following objectives have been identified through the LGCCSP as priority areas for the Biodiversity and Environment sector in the District Municipality:
13	Manage Increased impacts on threatened ecosystems
14	Manage Increased impacts on environment due to land-use change
15	Manage Loss of Priority Wetlands and River ecosystems

6.2.2 Identified Adaptation Responses

Climate change predictions include the shifting of biomes across South Africa. In the Garden Route District Municipality, it is projected that, under a high risk climate scenario, that the area currently covered by the Fynbos Biome will be substantially reduced by the Albany Thicket, Nama-Karoo, Succulent Karoo and Desert Biomes. Terrestrial, wetland, and river ecosystems and their associated species will be negatively impacted. Furthermore, development and changes in land use will impact negatively on the environment in the District.

The following key biodiversity and environmental sector adaptation responses for the identified objective were identified for the Garden Route District:

No	Objective	Adaptation Response
13	**Manage Increased impacts on threatened ecosystems**	Increase investment in ecological infrastructure that translates into financial revenue for the district such as ecosystem services bonds and market options that reduce flood risk within the region
		Completion of Invasive Species Control Plan(NEMBA) for all state owned properties in local municipalities and district municipalities.
		Research Programme investigating potential risks associated with loss of fynbos biome through involving local universities (NMMU) stakeholders, SANParks, CapeNature, etc., involving scenario planning of loss of species. 0-50 years.
14	**Manage Increased impacts on environment**	Develop program to diversify community livelihoods strategies to earn income from other activities such as ecotourism and other non-farming activities.

14	**due to land-use change**	Incentivize small scale farmers to practice sustainable and conservative agriculture
		Incorporate sustainable land use management and planning into other sectors plans.
		Research and improve understanding of land use change in the municipality.
		Strengthen institutional capacity to deal with pressure on land use change
15	**Manage Loss of Priority Wetlands and River ecosystems**	Adopt a local wetland protection by law that require vegetated buffers around all wetlands
		Control invasive wetland plants
		Encourage infrastructure and planning designs that minimize the number of wetland crossings
		Establish volunteer wetland monitoring and adoption programs
		Identify priority wetlands and River ecosystems to be conserved
		Restrict discharges of untreated wastewater and stormwater into natural wetlands
		Wetland restoration/rehabilitation programmes/projects
		Protect ecological infrastructure functioning/ecosystem services

6.3 Coastal and Marine Sector

6.3.1 Introduction

	Program Name
	Coastal and Marine Sector Adaptation to Climate Change
	Overview of Key Issues
	Climate change will affect the Coastal and Marine Environment, having various impacts on productivity and diversity of South Africa's coastal, marine and estuarine ecosystems. A changing climate is likely to result in changes in species availability and distribution impacting largely on fisheries. This could result in significant adverse impacts on subsistence fishing markets, community livelihoods as well as commercial industries. Changes in sea surface temperature, rising sea levels and increasing storm frequency will have adverse effects on coastal communities and infrastructure. To develop appropriate adaptation responses a more nuanced understanding of the challenges and options for the Coastal and Marine Sector is required, building on the insights of the existing coastal and marine plans. This understanding needs to consider the importance of associated ecological infrastructure in sustaining local economies and livelihoods as well and building resilient communities. In the Western Cape the current priority areas have been identified in the WCCCRS for the coastal sector 5. Establishment of coastal risk overlays and coastal management lines; 6. Research best practice regarding responding to repeated coastal inundation in high risk areas; 7. Protecting and rehabilitating existing dune fields as coastal buffers /ecological infrastructure; 8. Monitor possible linkages between climate change and fisheries industry; and 9. Ensure Estuary Management Plans take cognisance of climate change Furthermore, the following opportunities, gaps and recommendations have been identified in the Western Cape Climate Change Response Strategy Biennial Monitoring & Evaluation Report 2015/16 (Birch et al., n.d.) for the coastal sector: 1. Case studies and cost benefit analyses on optimal approaches to coastal protection should be developed for the Western Cape. 2. Fact-based climate change targets for this focus area need to be set out. 3. A better understanding of the fisheries sector and the impact of climate change on the sector in the Western Cape is required. 4. Monitoring standards need to be implemented for estuaries, possibly through the incorporation of a monitoring and evaluation component in all EMPs.

	Objectives
	The following objectives have been identified through the LGCCSP as priority areas for the Coastal and Marine sector in the District Municipality.
19	Manage loss of land due to sea level rise
20	Manage increased damage to property from sea level rise

6.3.2 Identified Adaptation Responses

In the Garden Route District Municipality, changes in precipitation and freshwater flow, sea-level rise, increased temperatures, and coastal storminess are predicted to negatively impact on coastal, marine and estuarine ecosystems. These ecosystem impacts are likely to result in changes in species availability and distribution impacting largely on fisheries. This could result in significant adverse impacts on subsistence fishing markets and community livelihoods in the District. Rising sea levels and increased coastal storms will pose potential risks to coastal infrastructure and communities in the District.

The following key coastal and marine sector adaptation responses for the identified objective were identified for the Garden Route District:

No	Objective	Adaptation Response
19	**Manage loss of land due to sea level rise**	Revise Spatial Development Frameworks to consider areas vulnerable to climate change impacts.
		Comment on Environmental Authorisation Applications to control unsustainable/risk coastal development
		Storm surge early warning and emergency breaching of estuaries guidelines
		Implementation of Coastal Management Lines for Garden Route district
		Education and awareness campaigns on the estuary management and mouth management plans of the Garden Route District
20	**Manage increased damage to property from sea level rise**	Protect biophysical barriers to coastal storm surges such as rehabilitation of dune systems and the establishment of coastal management zones that will restrict development within at risk areas
		Incorporate climate-related disaster information into current property valuations and insurance schemes

		Collaborative Coastal and Estuary Management Agreements
		Community collaboration programmes
		Protection of three primary dune systems in Garden Route District: Stilbaai, Wilderness and Sedgefield. To be implemented by local authority to restore the dune system by June 2020.

6.4 Disaster Management, Infrastructure and Human Settlements Sector

6.4.1 Introduction

	Program Name
	Human Settlements, Infrastructure and Disaster Management Sector Adaptation to Climate Change
	Overview of Key Issues
	South Africa is a diverse country, not just in terms of populations and biodiversity, but also in terms of its human settlements. These settlements face severe challenges, even before climate change is taken into account. The implications of the compounding impacts of climate change will be profound, and human settlements therefore represent a crucial part of national adaptation strategies. The overarching strategic framework for the development of human settlements is described in the National Development Plan (NDP) and, more specifically in relation to the implications for climate change, in the National Climate Change Response White Paper (NCCRWP). However, to develop appropriate adaptation responses a more nuanced understanding of the challenges and options for human settlements is required, building on the insights of the NCCRWP. This understanding needs to take into account the unusually diverse urban forms of human settlement in the South African context, and the importance of ecological infrastructure in supporting service delivery and building resilient communities. In the Western Cape the current priority areas have been identified in the WCCCRS for the human settlements sector 1. Mainstreaming climate change into human settlement developments; 2. Implementation of energy efficiency interventions in low income houses and communities; and 3. Improving the resilience and adaptive capacity of informal settlements.

	Furthermore, the following recommendations has been identified in the Western Cape Climate Change Response Strategy Biennial Monitoring & Evaluation Report 2015/16 (Birch et al., n.d.) for the human settlements sector for the province: Clearer understanding of what resilience means for humans settlements.
	Objectives
	The following objectives have been identified through the LGCCSP as priority areas for the Disaster Management, Infrastructure and Human Settlements sector in the District Municipality.
30	Manage increased impacts on traditional and informal dwellings
32	Manage potential increase migration to urban and peri-urban areas.
33	Manage potential increased risk of wildfires

6.4.2 Identified Possible Responses

Climate change impacts will affect Disaster Management, Infrastructure and Human Settlements in several ways in the Garden Route District Municipality. Increases in the severity of storm events and increase in flooding will damage infrastructure which may result in a loss of industrial productivity and service delivery disruptions. The impacts of storm events will particularly affect communities located in informal settlements, on flood plains and where there is poor drainage infrastructure. In addition, communities in rural areas that depend on subsistence farming may be unable to grow crops that they have grown in the past due to the changing climate. It is predicted that there will therefore be an increase in rates of rural-urban migration. Rural communities may also become more physically isolated due to extreme events impacting on key infrastructure.

The following key Disaster Management, Infrastructure and Human Settlements adaptation responses for the identified objectives were identified for the Garden Route District:

No	Objective	Adaptation Response
30	**Manage increased impacts on traditional and informal dwellings**	Commission a reliable early warning system (linked to radio stations, community leaders and social media) to alert communities and industries on the possible occurrences of storm events.

No	Objective	Adaptation Response
		Conduct a climate change risk assessment on informal dwellings.
		Conduct regular assessments of informal dwellings in order to identify priority areas for interventions to reduce climate change risk.
		In order to reduce flood and fire disaster risks, the placement of informal dwellings must receive special attention. Lessons learned must be incorporated into new housing projects.
		A district flood hazard master plan should be developed and included as part of the District SDF
32	**Manage potential increase migration to urban and peri-urban areas.**	Implement informal settlement upgrades.
		Update community emergency evacuation plans that will assist with responding to climate change related impacts/risks.
		Conduct public awareness on campaigns to save water by Disaster Management sector in collaboration with District Communications Department.
33	**Manage potential increased risk of wildfires**	Develop Integrated Veldfire management Plan for the Garden Route District.
		Strengthening of existing initiatives such as Working on Fire and the GEF climate change and fire project
		Fuel load management master plan
		Buy-in from private landowners and farmers through the construction of firebreaks.

No	Objective	Adaptation Response
		Improvement of fire safety through urban fringe management
		Fireproof alternative building/construction materials

6.5 Water Resources Sector

6.5.1 Introduction

	Program Name
	Water Sector Adaptation Responses to Climate Change
	Overview of Key Issues
	South Africa's climate is generally arid to semi-arid, with less than 9% of annual rainfall ending up in rivers, and only about 5% recharges groundwater in aquifers. In addition, rainfall and river flow are unpredictable in time and unevenly distributed in space, with only 12% of the land area generating 50% of stream flows. Decadal rainfall variability also results in extended dry and wet periods across the country. The main users of surface water resources are agricultural irrigation, domestic, industrial, mining and power generation, while plantation forestry intercepts and reduces runoff before it reaches the rivers and groundwater. Surface water resources were already over-allocated by the year 2000 in five of nineteen water management areas historically used for water planning and management purposes. The potential demand for water is expected to increase with economic growth, increased urbanisation, higher standards of living, and population growth. Because of the critical importance of water in the South African economy the country has a sophisticated water resources planning capacity, founded on a good understanding of the country's variable rainfall. This planning capacity will be a key capability for adaptation planning under ongoing and future climate change. In the Western Cape the folllowing priority areas have been identified in the Western Cape Climate Change Response Strategy (WCCCRS) Biennial Monitoring & Evaluation Report 2015/16 (Birch et al., n.d.) for the water sector 1. Invasive alien vegetation clearing;

	2. Prioritisation, valuation, mapping, protection, and restoration of ecological infrastructure in catchments; 3. Effective utilisation of irrigation water; 4. Resource nexus decision support; and 5. Develop ecosystem goods and services (EGS) investment opportunities. Furthermore, the following recommendation/s has been identified in the Western Cape Climate Change Response Strategy Biennial Monitoring & Evaluation Report 2015/16 (Birch et al., n.d.) for the water sector for the province: 1. Review the Specifications of the Regional Bulk Infrastructure Grant (RBIG), Municipal Infrastructure Grant (MIG), Accelerated Community 2. Infrastructure Programmes (ACIP) and other similar funds and allocations to determine their climate responsive state (and link to any other ongoing such initiatives). 3. Protection of Strategic Water Source Areas (SWSAs) should be a strategic climate protection priority for the Western Cape. 4. Ground water monitoring needs to become a growing priority in the Western Cape. 5. Further cooperation between IAP clearing authorities and rehabilitation programmes for wetlands and rivers will be beneficial in a changing climate. 6. Continued focus on the way in which we manage our water systems, and increased emphasis on Water Sensitive Urban Design.
	Objectives
	The following objective has been identified through the LGCCSP as a priority area for the Water sector in the District Municipality.
36	Manage decreased water quality in ecosystem.

6.5.2 Identified Possible Responses

Water resources are the primary medium through which climate change impacts will be felt by South Africans (Schulze et al., 2014). Climate change will affect Garden Route District Municipality's water accessibility, quantity, and quality (Parikh, J 2007). Drought, reduced runoff, increased evaporation, and an increase in flood events will impact on both water quality and quantity.

The following key water resource adaptation responses for the identified objective were identified for the Garden Route District:

No	Objective	Adaptation Response
36	**Manage decreased water quality in ecosystem.**	Adopt and enforce simple, innovative, adaptive engineering approaches wastewater treatment initiatives that will ease the burden on natural water dilution as water quantities decline.
		Conduct a climate change impact assessment on health risks to aquatic systems.

		Create an awareness on the reuse of wastewater thus minimising negative impacts of wastewater on aquatic systems.
		Identify and implement wastewater monitoring initiatives that will indicate risks to aquatic systems.
		Protect and rehabilitate aquatic systems so that they can provide flow attenuation and ecosystem goods and services that are required to buffer increased pollution.
		Research and improve understanding of climate change impacts on water quality and availability.
		Strengthen wastewater treatment management plans, to enable the ability to respond to the declining water reserves.
		Investigate international best-practice as well as new technology, innovation and methodologies.
		Assessing wastewater plant infrastructure and condition/implement technology and infrastructure failure risk and upgrade plans.
		Implementation of alternative water resources
		Water Resource Management Collaboration Initiatives and Partnerships

6.6 Air Quality

6.6.1 Introduction

	Program Name
	Air Quality Adaptation Responses to Climate Change
	Overview of Key Issues
	Continued reduction in air pollution and GHG emissions are essential, as they pose serious threats to both people's health and the environment. Implementation of air quality and climate change policies can provide mutual benefits contributing to clean air and reduction in global warming. Furthermore, air pollution and climate change influence each other through complex interactions in the atmosphere. Increasing levels of GHGs alter the

energy balance between the atmosphere and the earth's surface which, in turn, can lead to temperature changes that alter the chemical composition of the atmosphere. Direct emissions of air pollutants (e.g. black carbon) or those formed from emissions such as sulphate and ozone can also influence this energy balance. Thus, climate change and air quality management have consequences for each other. Linkages with air quality management was made with the energy focus area through GHG reductions as well as a contributor to healthy communities. Work is underway to align climate change priorities with goals and objectives of the Western Cape Air Quality Management Plan, which is currently being updated. Goal 4 of the Air Quality Management Plan is focussed on supporting climate change programmes that include the reduction of GHG emissions.

In the Western Cape the following priority areas have been identified in the Western Cape Climate Change Response Strategy (WCCCRS) Biennial Monitoring & Evaluation Report 2015/16 (Birch et al., n.d.) for the air quality sector

1. Particulate matter (PM10) – below threshold but shows steady increase
2. Nitrogen oxides (NO, NOx) – acceptable but problems at certain locations
3. Sulphur dioxide (SO2) – below threshold
4. Green House Gases (GHG) – levels increasing

Furthermore, the following recommendation/s has been identified in the Western Cape Climate Change Response Strategy Biennial Monitoring & Evaluation Report 2015/16 (Birch et al., n.d.) for the water sector for the province:

1 Review the Specifications of the Regional Bulk Infrastructure Grant (RBIG), Municipal Infrastructure Grant (MIG), Accelerated Community
2 Infrastructure Programmes (ACIP) and other similar funds and allocations to determine their climate responsive state (and link to any other ongoing such initiatives).
3 Protection of Strategic Water Source Areas (SWSAs) should be a strategic climate protection priority for the Western Cape.
4 Ground water monitoring needs to become a growing priority in the Western Cape.
5 Further cooperation between IAP clearing authorities and rehabilitation programmes for wetlands and rivers will be beneficial in a changing climate.
6 Continued focus on the way in which we manage our water systems, and increased emphasis on Water Sensitive Urban Design.

	Objectives
	The following objective has been identified through the LGCCSP as a priority area for the Water sector in the District Municipality:
40	Increase in air pollution
41	Increase in odour complaints
42	Increase in brown haze

6.6.2 Identified Possible Responses

The linkage between Air Quality and Climate change is well documented. Controlling the Air Quality environment is directly correlated to Climate Change mitigation. The District Air Quality section therefore play an important role in climate change mitigation.

The following key air quality sector adaptation responses for the identified objectives were identified for the Garden Route District:

No	Objective	Response
40	**Increase in air pollution**	Set up air quality goals that are linked to climate change mitigation and which talks to all the applicable legislation.
		Maintaining the current Garden Route Air Quality emissions inventory and the NAEIS system..
		Maintaining and expanding the Garden Route monitoring network.
41	**Increase in odour complaints**	Passive sampling programmes
		Diesel vehicle emission testing programmes with the B-authorities.
42	**Increase in brown haze**	Carrying out of regional dispersion modelling studies
		Define a strategy to disseminate ambient air quality data to the general public through various media, e.g. newspapers, EDM's web site, etc.
		Investigate international best-practice as well as new technology, innovation and methodologies.
		Carry out Risk assessments
		Link the Air Quality Climate change interventions and projects with the IDP in order to secure the necessary funding.

7 Concluding Remarks

Climate change is predicted to shift the biomes in South Africa, resulting in a change to the ecosystems and vegetation found in the Garden Route District Municipal Area. If the biodiversity and related ecosystem services in the Garden Route District Municipal Area are badly reduced, it could have direct negative consequences for the economy and social structures in the Garden Route District Municipality. These consequences could have a detrimental effect on efforts to reduce poverty, inequity and unemployment in the Garden Route District Municipal Area. Furthermore, it is predicted that climate change will exacerbate these challenges and their effects on the biodiversity and related ecosystem in South Africa.

Climate change is predicted to result in several changes to South Africa's coastal zone. In addition to the predicted effects of climate change, the coastal zone in South Africa is susceptible to anthropogenic impacts such as ecosystem overuse (e.g. overfishing) and degradation, increased pollution, and the increased nutrient runoff from coastal developments leading to eutrophication of wetlands, estuaries, etc. (Department of Environmental Affairs 2013e). The anthropogenic and climate change impacts have already negatively affected biodiversity and ecosystems services in the coastal zone (and across South Africa) and are expected to worsen these issues unless climate change adaptation and mitigation responses are developed and implemented (Department of Environmental Affairs, 2013e).

Climate change is forecast to exacerbate the frequency and severity of extreme weather events (Department of Environmental Affairs 2013c). Consequently, predicted impacts for households involved in agriculture include reduced agricultural yields and water security as well as increased food insecurity.

The main disaster risks that are likely to affect human health in the Garden Route District Municipal Area are wild fires, drought, severe storms and floods (Garden Route District Municipality, 2014). It is predicted that these disasters will be exacerbated by climate change (Garden Route District Municipality, 2014).

From the information above, the predicted impacts of climate change on human health and health services are mostly negative. Hence, there is a need for climate change adaptation (and mitigation) to limit the negative impacts and encourage any positive effects of climate change on human health in the Garden Route District Municipal Area.

The district's vulnerability to climate change impacts is attributed to its physical location, topography and general climate conditions (Garden Route District Municipality, 2017a). In addition, increased vulnerability to climate change has been caused by rapid urbanisation and informal developments (Western Cape Government 2013). Urbanisation has increased because of in migration of the youth from the Eastern Cape and the elderly to the coastal towns (Garden Route District Municipality, 2017b). However, housing delivery has not been able to keep up with the migration, hence the ongoing increase in informal dwellings in the District (Garden Route District Municipality 2017b). Furthermore, the natural and scenic beauty of the District is a major tourist attraction that could be negatively affected by the impacts of climate change (Garden Route District Municipality, 2017a).

The following climate change impacts have already been observed in the District: increased average temperatures; shifts in seasonality; increased frequency of veld fires; increased magnitude and frequency of storm events accompanied by strong winds; more frequent and severe storm surges; and, increases in rainfall variability and the number of dry days (Garden Route District Municipality, 2014).

In addition, sea level rise and associated hazards are a major concern for coastal areas within the District (Garden Route District Municipality, 2012). Sea level rise impacts are likely to include inter alia coastal erosion, flooding, destruction of infrastructure and salt water contamination of fresh water bodies (Western Cape Government 2013).

Major climatic hazards in the District Municipal Area include: drought, floods and veld fires (Garden Route District Municipality 2014, 2017a). Climate change is expected to increase the frequency and severity of these hazards (Garden Route District Municipality 2014). Additionally, financial losses in the District, due to these climate hazards, has already been high (Garden Route District Municipality, 2014)

Despite the potential for expanding agricultural production in the Garden Route District Municipal Area, it is predicted that climate change will affect the agriculture sector both positively and negatively.

The predicted changes in average rainfall and temperature are forecast to reduce the areas that are suitable for viticulture or shift them to areas that are higher or cooler than current locations (Department of Environmental Affairs 2013c). The reduction in rainfall (and runoff) is forecast to reduce the yields of fruit and vegetables, notably deciduous fruit and rain-fed wheat production in the Western Cape (Department of Environmental Affairs, 2013c). Furthermore, the production of fruit (such as apples and pears) and sugar cane will be increasingly vulnerable to damage from a predicted expansion of the areas affected by agricultural pests (Department of Environmental Affairs, 2013c).

Climate change is also predicted to increase the number and severity of droughts, fires and floods in the in the Garden Route District Municipal Area (Garden Route District Municipality, 2014). To counter these risks, the Garden Route District Municipality intends to conserve water resources, wetlands and biodiversity, through updated land-use and settlement plans that take disaster risk management criteria into account, and by increasing public awareness regarding water conservation, droughts, fires and floods (Garden Route District Municipality, 2014, 2017a). This is particularly pertinent given the recent devastating fires in and around the Garden Route as well as the severe ongoing drought in Western Cape (Garden Route District Municipality, 2014, 2017a).

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