USING CLIMATE DATA TO HELP SOUTH AFRICAN WATER SERVICES INSTITUTIONS IMPROVE WATER SAFETY AND WASTEWATER RISK ABATEMENT PLANNING AND ENHANCE RESILIENCE TO CLIMATE CHANGE AT LOCAL AND CATCHMENT LEVEL

Philip de Souza, Shawn Moorgas, Thabisa Manxodidi, Matthew Damons and Unathi Jack

Project Technical Report

WATER RESEARCH COMMISSION

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Using Climate Data to Help South African Water Services Institutions Improve Water Safety and Wastewater Risk Abatement Planning and Enhance Resilience to Climate Change at Local and Catchment Level

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This report is Part One of a set of two reports. The other report is *Integrating Climate Information in Water Safety Planning and Wastewater Risk Abatement Planning: A Guidance Note* (WRC Report No. TT 876/2/22).

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Executive Summary

Background

Source water quality in South Africa is affected by both natural processes such as seasonal trends, the underlying geology, weather, and climate change, as well as by human activities. Significant water quality issues of concern include salinity, eutrophication, microbial pollution, sedimentation, and acidification (e.g. from gold mining activities). The pollution of freshwater resources has been accompanied by a decline in water quality, bringing with it potential public health issues, but also a reduction in the economic value of the available water. With continued population growth, investments need to be made in terms of the improvement and maintenance of water treatment and supply infrastructure, and associated sanitation and wastewater facilities as they also contribute to source water pollution when discharging non-complying effluent, resulting in water quality decline. In addition to water quality challenges, water security presents a significant challenge to South Africa's social wellbeing and economic growth. South Africa is already a water scarce country, and factors such as growth, urbanization, unsustainable use, degradation of wetlands, water losses and a decrease in rainfall present significant challenges. South Africa's water scarcity could be further exacerbated by climate change with water supply further contracting and demand escalating.

Project Overview

It is well known that South Africa is facing a long-term water crisis, with recent droughts experienced in the Western Cape and recent floods experienced in KwaZulu-Natal making it particularly challenging for Water Services Institutes (WSIs) – notably municipalities and water utilities to reliably deliver sustainable drinking water and sanitation/wastewater services. In particular:

- Less rainfall reduces runoff within catchments, leading to less water availability in dams. This could result in reduced environmental/river health, increased water restrictions and/or increased water prices (e.g. due to need for more sophisticated water treatment technologies such as desalination).
- More intense rainfall events could lead to sewer overflows, increasing possible public health risks and reduced environmental/river health. In addition, assets could be damaged from flooding leading to decreased service reliability.
- Increase in average temperatures, could result in drier conditions and increased heatwaves leading to greater demand for water and possible asset degradation (e.g. pipe bursts and blockages), thereby decreasing service reliability.
- Unreliable services and decreases in affordability can also lead to adverse impacts on customer relationships and associated payment levels (revenue reduction).

Furthermore, the potential for "water wars" with neighbouring countries indicate that addressing transboundary water issues are also of concern. Considering this, the project had a special focus in the Western Cape (recently affected by drought), KwaZulu-Natal (recently affected by flooding) and Limpopo (potential transboundary water issues with neighbouring countries).

WSIs, however, struggle to interpret and incorporate climate data/information into their planning activities as in some cases data/information is not available at a local scale. Additionally, there is very little guidance on accessing, interpreting, and incorporating climate data/information in planning activities. Given the urgency of climate change impacts to South Africa, it is an ideal opportunity to develop and implement an easy to use and robust methodology that can empower WSIs to take the necessary first steps to build climate resilience.

Development of methodology to draw basic climate impact conclusions

A methodology was developed to draw basic climate impact considerations. A literature review was initially conducted to understand the South African landscape, including climate change governance (policies, legislation, role players) and an overview of climate change and impacts to South Africa's water and sanitation sector. This included understanding climate trends and projections in South Africa, and in particular for the three provinces in focus (KwaZulu-Natal, Limpopo and Western Cape). The methodology highlights the need to consider various sources of climate data and information, including:

1. Working with stakeholders, expert groups to understand key climate risks
2. Accessing existing climate reports (e.g. Climate Vulnerability Assessments)
3. Working with existing web-based tools
4. Accessing/analyzing historical climate-related data

Most importantly, the methodology includes a detailed list of climate-related data/information sources that can be used to develop a climate summary for your area. Ultimately, the methodology developed aids the user to draw basic climate impact conclusions, and then guides the user how to incorporate these findings into their water safety planning and wastewater risk abatement planning processes.

Testing and Refinement of Methodology through piloting at 3 selected Municipalities

In consultation with the WRC, three (3) municipalities were selected to participate in this project, namely: (1) Uthukela District Municipality in KwaZulu-Natal, (2) Lephalale Local Municipality in Limpopo Province, and (3) Witzenberg Local Municipality in the Western Cape. For each of the selected municipalities, one (1) water supply system and one (1) wastewater system were selected for piloting. The aim of the pilot was not to develop a new WSP or W_2RAP, but rather to guide and assist each municipality to enhance and improve their current WSP and W_2RAP by understanding climate change impacts (both present and future) on their systems, such that they could start planning improvements to make their water and wastewater systems more resilient. As part of the pilot, the project team trained municipal officials and assisted the municipalities to identify and incorporate climate related hazards and hazardous events into their plans, such that they can determine the efficacy of existing control measures, and where required identify and implement new climate resilient control measures. Feedback obtained through the piloting process was used to further refine the approach and methodology.

Catchment Management Agency (CMA)/Water Management Area (WMA) Workshops

With the rising infections related to the COVID-19 second wave and remaining lockdown restrictions (i.e. restrictions on travel and large business workshops), the team held brief discussions with some of the key stakeholders, and indications were that these workshops should be held remotely (virtually, instead of face-to-face). To ensure that online workshops would be effective and appropriate, the team engaged with the (3) targeted CMAs/WMAs and associated pilot municipalities to gauge their ability and willingness to participate in an online workshop. Subsequently, three online CMA/WMA workshops were held via

Microsoft Teams with (1) Pongola-Umzimkulu Proto-CMA and related pilot municipality, Uthukela District Municipality (and including eThekwini Metropolitan Municipality), (2) Limpopo WMA and related pilot municipality, Lephalale Local Municipality, and (3) Breede-Gouritz CMA and related pilot municipality, Witzenberg Local Municipality. The overall feedback for the CMA/WMA workshops was positive and the proposed methodology was well received. The feedback, observations and lessons learnt from the CMA/WMA workshops were used to develop the approach to and materials for the National Workshop.

National Workshop

Originally, three (3) regional engagements were proposed (KwaZulu-Natal, Limpopo and Western Cape). However, due to COVID-19 and remaining lockdown restrictions it was decided that these workshops should be held remotely (virtually, instead of face-to-face). Furthermore, to help share the approach and learnings to a wider audience, it was decided to open the invitation to the entire WASH sector in South Africa, including all Water Services Authorities, CMAs/WMAs, relevant departments, consultants, academia, stakeholders, etc. Subsequently, a one-day National Workshop was held via Zoom. The general feedback for the National Workshop was positive, and the proposed methodology was again well received. The feedback, observations and lessons learnt from the National Workshop (and the CMA/WMA workshops) were used to further refine the approach and methodology.

Conclusions and Recommendations

The goal of this project was to promote climate change resilient water services institutions and communities by increasing understanding of climate change and improving planning and co-ordination at local and catchment level, thereby facilitating implementation of required investments in climate change adaptation and contributing to the achievement of the Sustainable Development Goals (SDGs). Responding to climate change is also one of the key elements of the Department of Water and Sanitation National Water and Sanitation Master Plan (DWS, 2018).

The following has been achieved through this project:

- Develop a South African appropriate climate assessment methodology, which can be incorporated into, and enhance existing WSP/W_2RAP processes, or used to develop new CR-WSPs/W_2RAPs.
- Pilot this methodology at three (3) selected municipalities (Western Cape (recent drought), KwaZulu-Natal (recent floods) and Limpopo (potential transboundary issues).
- Conduct workshops (3 Municipal and CMA/WMA workshops (Breede-Gouritz (WC), Pongola-Umzimkulu (KZN), Limpopo (LP)) workshops and a National Workshop) to gather feedback, refine the approach and methodology, share knowledge, raise awareness, and help advocate for more widespread use of the developed methodology.

Through this project, local government have access to easily interpretable climate information that can be used to improve their planning, and thereby facilitate increased local resilience through appropriate climate change adaptation investments. The approach and methodology will benefit municipalities (e.g. improved planning and risk management) and CMAs/WMAs alike (e.g. contribute to catchment wide strategies and plans). Importantly, the approach and methodology are appropriate for use elsewhere in Africa and beyond.

The need for such an approach and methodology has been stressed by the participating municipalities and stakeholders, and feedback received has been positive. The guideline document accompanying this technical report outlines the steps that a municipality/water utility would need to follow to develop and implement CR-WSPs/CR-W_2RAPs within their area of jurisdiction.

In general, the metropolitan municipalities in South Africa appear to be well equipped to perform climate resilient water safety planning/wastewater risk abatement planning, as they already have climate change related strategies and plans in place. The challenge, however, lies with the smaller, rural and peri-urban municipalities that do not have this capacity and require support to improve their adaptation capacity and improve climate resilience. There is need to further operationalise the approach and methodology at Water Services Institutions through: (1) Practical solutions, (2) Improving adaptive capacity, and (3) Increasing knowledge.

This project has emphasized that although there are good climate data and information tools available that are relevant in the South African context, it often remains a challenge for municipalities (and other stakeholders) to understand the relevance of climate information, interpret the information and incorporate the findings into existing risk management processes and day-to-day activities. Importantly, these processes often do not consider a holistic integrated water management approach (i.e. water supply and sanitation, including both off-site and on-site sanitation systems). An integrated water management approach will not only improve water supply and sanitation management systems through making them more resilient to climate variability and change, but also ensure water resources are safely and sustainably managed.

Climate resilience needs to be built and coordinated at both the catchment and local government/water board levels to ensure adaptation measures for water supply and sanitation systems are effective and integrated. Although the project has successfully improved understanding, planning and co-operation at both municipal and catchment level, it has also highlighted the need for improved alignment, collaboration and communication between CMAs/WMAs and their associated municipalities. Therefore, although good progress has been made in some instances, there is still much work to do. The piloting and workshops have opened channels of communication and initiated collaboration within the three selected CMAs/WMAs. These relationships need to be fostered to allow sustainable collaboration, data sharing and establishing effective partnerships that solve local challenges. All water services institutions in South Africa should be encouraged to use the developed methodology, and the collaborative approach should be duplicated at the other CMAs/WMAs to allow improved capacity and capability within the water sector at local, regional and national level.

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Water Research Commission

Reference Group

The reference group responsible for this project consisted of the following persons:

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- Ms Sameera Majam — Umgeni Water
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- Dr Joel Botai — South African Weather Services
- Mr Francios Van Wyk — Rand Water
- Dr Chris Moseki — Department of Water and Sanitation
- Ms Mapula Mametja — Rand Water

Participating Municipalities

The following municipalities are thanked for their willingness to participate and enthusiastic support in piloting the draft methodology for their water and wastewater systems:

- Lephalale Local Municipality (Limpopo)
- Uthukela District Municipality (KwaZulu-Natal)
- Witzenberg Local Municipality (Western Cape)

Collaborating Organization

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Table of Contents

List of Tables

List of Figures

Abbreviations

CMA	Catchment Management Authority
COGTA	Cooperative Governance and Traditional Affairs
CR-WSP	Climate Resilient Water Safety Plan
CR-W_2RAP	Climate Resilient Wastewater Risk Abatement Plan
CSAG	Climate Systems Analysis Group
CVA	Climate Vulnerability Assessments
DEA	Department of Environmental Affairs
DR	Disaster Risk
DWS	Department of Water and Sanitation
EWR	Ecological Water Requirements
GHG	Greenhouse Gas
IRIS	Integrated Regulatory Information System
IWA	International Water Association
IWRM	Integrated Water Resources Management
KPI	Key Performance Indicator
KZN	KwaZulu-Natal
MISA	Municipal Infrastructure Support Agent
NCCRP	National Climate Change Response Policy
NDP	National Development Plan
O&M	Operations and Maintenance
RCP	Representative Concentration Pathways
RQO	Resource Quality Objectives
SALGA	South African Local Government Association
SANBI	South African National Biodiversity Institute
SAWS	South African Weather Services
SDG	Sustainable Development Goal
SOP	Standard Operating Procedures
UNFCCC	United Nations Framework Convention for Climate Change ()
WASH	Water, Sanitation and Hygiene
WHO	World Health Organization
WMA	Water Management Area
WRC	Water Research Commission
WSA	Water Services Authority
WSPD	Water Services Development Plan
WSI	Water Services Institution
WSP	Water Safety Plan
WTW	Water Treatment Works
WWTW	Wastewater Treatment Works
WULA	Water Use License Authorizations
W_2RAP	Wastewater Risk Abatement Plan

1. Introduction

1.1 Background

Source water quality in South Africa is affected by both natural processes such as seasonal trends, the underlying geology, weather, and climate change, as well as by human activities. Significant water quality issues of concern include salinity, eutrophication, microbial pollution, sedimentation, and acidification (e.g. from gold mining activities). The pollution of freshwater resources has been accompanied by a decline in water quality, bringing with it potential public health issues, but also a reduction in the economic value of the available water. With continued population growth, investments need to be made in terms of the improvement and maintenance of water treatment and supply infrastructure, and associated sanitation and wastewater facilities as they also contribute to source water pollution when discharging non-complying effluent, resulting in water quality decline. In addition to water quality challenges, water security presents a significant challenge to South Africa's social wellbeing and economic growth. South Africa is already a water scarce country, and factors such as growth, urbanization, unsustainable use, degradation of wetlands, water losses and a decrease in rainfall present significant challenges. South Africa's water scarcity could be further exacerbated by climate change with water supply further contracting and demand escalating.

1.2 Project Overview

It is well known that South Africa is facing a long-term water crisis, with recent droughts experienced in the Western Cape and recent floods experienced in KwaZulu-Natal making it particularly challenging for WSIs – notably municipalities and water utilities to reliably deliver sustainable drinking water and sanitation/wastewater services. In particular:

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Considering the above, the project had a special focus in the Western Cape (recently affected by drought), KwaZulu-Natal (recently affected by flooding) and Limpopo (potential transboundary water issues with neighbouring countries).

WSIs, however, struggle to interpret and incorporate climate data/information into their planning activities as in some cases data/information is not available at a local scale. Additionally, there is very little guidance on accessing, interpreting, and incorporating climate data/information in planning activities. Given the urgency of climate change impacts to South Africa, the project presented an ideal opportunity to develop and implement an easy to use and robust methodology that can empower WSIs to take the necessary first steps to build climate resilience.

1.3 Project Aims

The following project aims are noted:

1. Consider current international and national best/good practice, and develop a refined simple, robust, South African appropriate methodology that WSIs (municipalities, water boards), CMAs/WMAs and other stakeholders can use to access, analyses and interpret climate change related datasets to enable development of climate resilient water safety plans (CR-WSP) and climate resilient wastewater risk abatement plans (CR-W_2RAP).
2. Consider current global and national best/good practice to identify new risks and review/amend current risks to water and wastewater system components at three selected municipalities with consideration of the impacts of both climate change and non-climate change related hazards/hazardous events.
3. Amend current water safety planning/wastewater risk abatement planning processes/steps at three selected municipalities to incorporate new climate resilience related aspects including team structure, system description, hazards/hazardous events, risk assessment, control measures, corrective actions, and subsequently prioritize risks through improvement planning activities.
4. Develop capacity and skills at three selected municipalities (and raise awareness at additional WSIs (municipalities and stakeholders)) within the three identified CMAs/WMAs (Breede-Gouritz, Pongola-Umzimkulu and Limpopo) to allow wider application of the developed methodology.
5. Improve co-operation and collaboration between municipalities, CMAs/WMAs and other stakeholders within the three identified CMAs/WMAs (Breede-Gouritz, Pongola-Umzimkulu and Limpopo) through sharing experiences, challenges, lessons learnt, etc. from the pilot exercises. Develop a guideline that provides WSIs and other organizations with a simple, robust methodology that they can use to access, analysis and interpret climate change related datasets, and incorporate conclusions drawn from these datasets to enable development of CR-WSP/CR-W_2RAP.

1.4 Overview of Project Tasks

The project aims were achieved through the following key tasks:

- Task 1: Project initiation through the inaugural reference group meeting
- Task 2: Development of methodology to draw basic climate impact conclusions
- Task 3: Testing and Refinement of Methodology through piloting at 3 selected Municipalities

- Task 4: Catchment Management Agency (CMA)/Water Management Area (WMA) Workshops
- Task 5: Training/Profiling at 3 Regional Workshops (one-day workshop/seminar)
- Task 6: Draft Report and Guideline
- Task 7: Final Report and Guideline

This project technical report summarizes key activities and outputs related to the above tasks.

2. Climate Change Governance: Policies and Legislation

South Africa's response to mitigating the impacts of climate change are constructed through an evolution of policies, strategies, and frameworks. The National Climate Change Response Strategy developed in 2004 laid the foundation on which the overall policy framework was set. Followed by the Long-Term Mitigation Scenarios (LTMS), both strategies provided a comprehensive set of mitigation options to meet the commitments agreed to in the Paris Agreement.

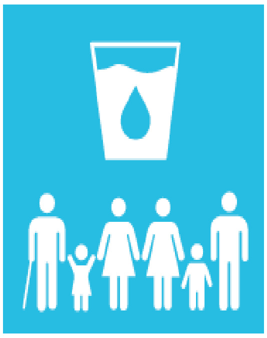
The National Climate Change Response White Paper (NCCRWP) was approved in 2011, outlining the policy framework of the National Climate Change Response Policy (NCCRP). The NCCRP outlined the role adaption and mitigation strategies by setting defined emission reduction objectives to be met and interventions in institutional sector planning, e.g. adopting a carbon budget per individual sector to reduce carbon footprint (DEA, 2012). In 2018, the Climate Change Bill came into effect with the intention to put strategic mitigation objectives and previous policy mentioned into law (Government Gazette, 2018). The Bill proposes the integrated response to mitigating climate change, enhance adaptive capacity, therefore strengthening resilience and reducing vulnerability towards climate change impacts. In August 2020 President Cyril Ramaphosa approved the National Climate Change Adaptation Strategy (NCCAS). The strategy is in line with the Paris Agreement which focusses reducing carbon emissions and preparing society for the effects of climate change.

Water is identified as a strategic resource critical for social and economic development in South Africa. The National Development Plan (NDP) states "by 2030 all South Africans will have affordable access to sufficient safe water and hygiene sanitation to live healthy and dignified lives". The National Water Policy, the National Water Act (Act 36 of 1998) and the Water Services Act (Act 108 of 1997) provide the legal framework for government to fulfil its responsibility of ensuring that all South Africans have access to adequate water supply services and sanitation services. The legal framework also makes provision for the development of a National Water Resources Strategy (NWRS) to set out the objectives, plans, guidelines and procedures relating to the protection, use, development, conservation, management and control of water resources in a manner that takes into account basic human needs of present and future generations. South Africa's water and sanitation policy and legislative regime, which is aligned to the United Nations' 2030 Agenda for Sustainable Development. Water and sanitation programmes and projects are implemented to ensure achievement of national targets stipulated in the NDP, Medium Term Strategic Framework (MTSF) and Annual Performance Plan (APP), which are all linked to targets of the Sustainable Development Goals (SDGs).

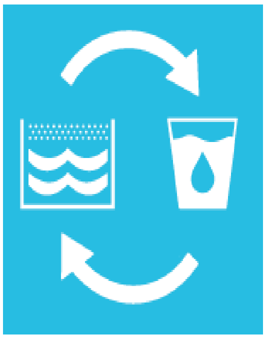
Since South Africa is a water-scarce country (30th driest country globally), greater attention will have to be paid to management and use of water. There is a growing concern over the potential impact of water related risks of which some are predicted to increase in future because of impacts of climate change on the water resource. It is important that South Africa, together with riparian states, manages the impacts of hydrological extremes through transboundary agreements. This will require strengthening of existing water monitoring networks across the entire shared basins and timely exchange of data and information between and among riparian states. The exchange of data and information among riparian states will not only assist in monitoring the riparian countries' achievement of SDG targets, but will also assist the countries to expedite the achievement of the set targets. There are eight targets set out for SDG 6 these are listed below (United Nations, 2020):

SDG 6 has 8 targets to achieve by 2030:

6.1
All have access to affordable Safe Drinking Water



6.4
Substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity



6.2
All have access to adequate sanitation and hygiene, and open defecation is eliminated

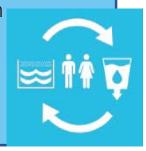
6.5
Implement integrated water resources management at all levels, including through transboundary cooperation as appropriate

6.3
Improve Water Quality by reducing pollution, minimizing release of hazardous chemicals, and halving the proportion of untreated wastewater

6.6
Protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers, and lakes

6.a By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies.

6. b Support and strengthen the participation of local communities in improving water and sanitation management.



To achieve SDG 6, there is a strong need to enable capacity building support through strengthening of municipal skills, competencies and abilities of people and communities. Therefore, the development of a climate resilient Water Safety Plan and Wastewater Risk Abatement Plan will support progress towards water and sanitation related targets including the monitoring of water and sanitation.

3. Overview of Climate Change and Impacts to South Africa's Water and Sanitation Sector

3.1 Background

Climate change is a naturally occurring process and past changes in climate have been verified using paleo-climatic information (Norström, 2008). Climate change is a slow process, where significant variations in climate take into effect after years, resulting in long-term impacts (Urama & Ozor, 2010). However, climate change has been exacerbated since the beginning of the industrial era, which is a period whereby Greenhouse Gases increased above natural levels (Hansen *et al.,* 1998). The United Nations Framework Convention for Climate Change (UNFCCC) defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods" (IPCC, 2018). It is, therefore, the interaction between natural processes and human-driven effects at local, regional, and global scales.

Global Warming is the phenomenon where the Earth's temperature gradually rises due to increased Greenhouse Gas (GHG) emissions such carbon dioxide, Chlorofluorocarbons (CFCs), water vapour, methane, nitrous oxide, etc. (IPCC, 2014a). This increased level of GHG in the atmosphere can be due to anthropogenic activities that change the landscape through deforestation or the increase in industrial processes since the 1950s (Hansen *et al.,* 1998). Climate Change is more than an increase in global temperatures (as suggested by the term 'global warming'); rather it encompasses changes in other climate components including humidity, rainfall, evaporation, etc.

Developing countries have become increasingly vulnerable to the threat of climate change as they face more frequent natural disasters (Mertz, *et al*., 2009). This vulnerability is typically due to poor adaptive capacity, poverty and slow uptake of technological advancements (Archer Van Garderen *et al.*, 2013). Water and wastewater institutions are susceptible to the impacts of climate change and therefore need to adapt as will affect service provision (IPCC, 2012). Failure to mitigate climate change is ranked in the top five of global risks in both likeliness and severity. Extreme weather events, water crises, biodiversity loss and natural disasters (such as flood and droughts), which are all associated with climate change, are in the top ten risks of both categories of likeliness and severity (World Economic Forum, 2019). To limit the impacts of climate change, in 2015 "The Paris Agreement" was signed at the UNFCCC by South Africa and 174 other nations. The agreement is a commitment by these nations to maintain the global temperature increase to below 2°C above pre-industrial levels.

The pre-industrial period 1850-1900 was chosen as a reference for warming trend analysis as this was a period of cooling and global average temperatures were not affected by the developing effects of the industrial revolution period (Schrurer *et al*., 2017).

Climate scenario projections indicate various ranges of increases in temperature, however the RCP8.5 scenario (GHG continues to increase over time, with limited mitigation measures in place) indicate that temperature may increase by 2.6°C to 4.8°C by the end of the century (Collins *et al.,* 2013). These changes in temperature may seem minor and although uncertain, it could lead to an increase in the occurrence and exposure to natural disasters such as floods, typhoons, and droughts. By way of example, increases in temperature will lead to the rapid melting of snow and ice caps (Hassani *et al.,* 2009). Rapid snowmelt will result in flash floods during melting periods and may result in reduced water quality and quantity during dry seasons (Hassani *et al*., 2019). In other areas increased evaporation brought about by climate change may also result in reduced water quality and quantity during dry seasons (Youssef and Khozinskaya, 2019).

Representative Concentration Pathways (RCP)
RCP4.5 represents a scenario whereby radiative forcing is stabilized before 2100. RCP8.5 represents a scenario whereby greenhouse gas emissions continue to increase over time, and results in high concentrations of atmospheric greenhouse gases. (Chaturvedi *et al.,* 2012)

Effective strategies to mitigate the impact of climate change on water resources are required, to reduce the impact on people. However, due to the complexity and uncertain nature of long-term climate change impacts, an innovative approach is required that considers observed climate trends, climate predictions, vulnerability and risk assessment, and an improved understanding of adaptation and resilience in the water sector.

3.2 Overview of climate change and impacts in South Africa

As a water scarce country, South Africa is particularly prone to the negative impacts of climate change. Climate change will lead to changes in terrestrial, atmospheric, and aquatic environments. Changes in these variables will have an impact on the local water balance, resulting in changes to the water balance and affecting water availability, quality, accessibility. Ultimately water demand and competition between various sectors for water will increase. Climate change will have a cascading effect and will affect food security, health, and ecosystems (Ziervogel *et al*., 2014). Early impact studies of water resources investigated the changes in the timing of flows and the movement of streamflow into baseflows and stormflows, reservoir yields, and identification of extreme hydrological events under the effects of climate change (Ziervogel et *al*., 2014). With the predicted climate change impacts, increased dry spells will reduce flows, whereas the increase in rainfall onset and duration may cause increased streamflow and flooding. Therefore, it is necessary to consider both natural variability in climate and climate change together when proposing adaptation measures (Wang *et al*., 2014).

Climate change can be considered a ‘metropolitan’ problem as it causes water insecurity, as well as water related damage to infrastructure in metropolitan or more urbanised areas (Arcanjo, 2018). There are two approaches that can be followed in dealing with climate change including:

i. mitigation by decreasing impacts or effects, and
ii. adaption by adjusting to the changing climatic environment.

Therefore, there is a need to assess climate related information when deciding how to address the impacts of climate change. Climate information is essential for assessing trends and the risks from exposure, the vulnerability to natural hazards and the sustainability of water resources. Climate information can be analysed to identify the conditions whereby extreme weather and climatic hazards develop and pose a threat to water security. Climate change and variability may reduce or increase water storage, recharge processes, flow processes, runoff length and generation.

The Intergovernmental Panel on Climate Change (IPCC) has defined 'disaster risk' as the likelihood of extreme variation in the functioning of a community due to climatic events interacting with vulnerable conditions (IPCC, 2012). Vulnerability assessments have an important role in determining the potential extent of a disaster due to climate change effects. These assessments support development of disaster relief planning for high-risk communities. By way of example, the vulnerability risk map of South Africa below (Figure 1) indicates areas of high vulnerability in the Western Cape, KwaZulu-Natal and Gauteng provinces (COGTA, 2015).

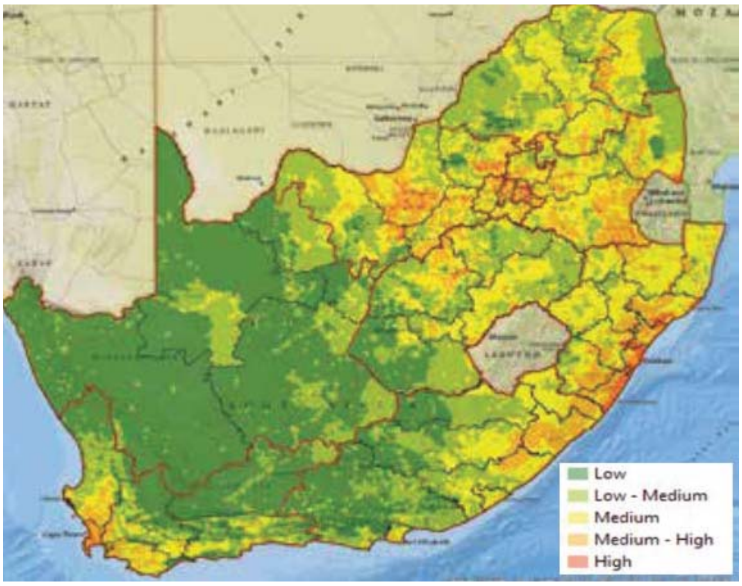


Figure 1: *Vulnerability risk map of South Africa based on social, economic and environmental factors (COGTA, 2015)*

3.3 Impacts on Water and Sanitation

Climate Change impacts on hydrological processes including, precipitation, humidity and evaporation, temperature, soil moisture and runoff. The most notable impacts to water and sanitation services are related to floods and droughts. An increase in flooding in both frequency and extent may result in infrastructure damage and source water quality changes. In addition, the safe supply of water in the system is disrupted, reducing service availability and reliability (Hummel *et al.,* 2018). The occurrence of floods and the spread of waterborne diseases have been linked such as, the increases in the rates of diarrhoeal disease after flood events (Hashizume *et al.,* 2008). Changes in runoff, due to distribution and frequency changes in precipitation, can lead to favourable conditions for the transmission of waterborne diseases due to decreased water quality (DEA, 2013).

Sea-level rise associated with climate change is likely to have impacts on unconfined coastal aquifers, with an increase in sea-water intrusion changing the water quality in coastal aquifers. This may reduce water supplies to coastal communities especially if groundwater forms an integral part of the local water supply. Additionally, salt-water intrusion may disrupt plans that seek to utilise coastal aquifers as a resource. This can become costly if groundwater forms part of the local water supply and would need maintenance and mitigation measures in place to prevent complete deterioration of freshwater aquifer (Kumar, 2012). Aquifers are typically recharged by precipitation or through the interaction with surface water such as rivers and wetlands. The influence of climate change on precipitation and surface water therefore ultimately affects groundwater systems. If the groundwater system is in interaction with the surface water system and the water quality and quantity changes, both systems may be affected (Kumar, 2012).

Increases in temperature could lead to the increase in the frequency of extreme rainfall events (Ziervogel *et al*., 2014). The predicted rainfall variability and intensity may affect catchment runoff processes, which may exacerbate sediment and pollutant transport within catchment areas. An increase of surface runoff in catchment areas can result in entrainment of sediment, nutrients, pollutants, animal waste, and other materials into raw water supplies. This results in unsafe and sometimes unusable water and will put a strain on existing water treatment works (WTW) (USGCRP, 2014). Increased soil erosion and movement of pollutants which accumulate on the surface could induce land cover changes, change downstream riverbed depth, spread disease in different populations and negatively affect ecosystem health. Additionally, reduced rainfall coupled with higher temperatures will contribute to increased algal growth and faster evaporation rates, which will further reduce water quality and increase the need for more stringent water treatment. Increased evaporation and extended periods of high evaporation can excessively reduce soil moisture and the size of open water bodies, thus reducing the availability of water. Evaporation can also lead to the concentration of salts in water bodies which can alter the water quality.

Flooding can result in sanitation facilities such as pits and septic tanks may become inaccessible and leakage from septic tanks may occur. This leakage can contaminate groundwater and nearby surface water resources and pose an environmental and public health risk, especially during periods where water tables rise. Flooding may also lead to infrastructure damage at the Wastewater treatment works (WWTW) as well as the WWTW exceeding its capacity, resulting in ineffective or partial treatment. Flooding at WWTWs and pump stations can result in the discharge of raw sewage into nearby rivers, posing a health risk to water users.

During droughts, the lack of sufficient water for sanitation services may lead to a build-up of sewerage in pipes. When flow becomes sufficient to transport this to the WWTW, this may lead to temporary exceedance of treatment capacity and poorly treated wastewater (Sherpa *et al.,* 2014) Low flows may disrupt the wastewater treatment processes, as treatment processes are designed for specific flows, influent water require more stringent treatment processes, etc. Less water is available during periods of drought to dilute wastewater discharge and irrigation return flows, impacting downstream users and ecosystem services (DEA, 2013).

3.4 Regional Climate of South Africa

South Africa has a warm climate with an average annual temperature of 17°C, and an average annual rainfall of only 450mm. Dry and wet seasons vary across the country, with Western regions typically experiencing wet winters and dry summers and the Eastern and inland regions typically experiencing wet summers and dry winter. In summer, temperatures are highest over the desert regions of the Karoo reaching up to 40°C during the day. In winter, a latitudinal gradient forms as temperatures decrease southwards resulting in high altitude regions experiencing the coldest temperatures (Davis-Reddy & Vincent, 2017).

Climate in South Africa is influenced by four main factors, these include (Nicholsen, 2000):

i. Location of the subcontinent in relation to the circulation patterns of the high-pressure systems in the Southern Hemisphere. High pressure cells on the east and west coast of the country influences climate.
ii. Movement of the Inter-Tropical Convergence Zone (ITCZ) affecting the temporal scale of rainfall. Moving South brings about wet season and moving north would bring about the dry season.
iii. Complex topography with alternating valleys and mountains. The oceans along the coast play a major role in climate conditions along the coastline and the plateau plays a major role in the climate experienced in the interior of the country.
iv. Influence of adjacent oceans where the warm Indian Ocean located to the east coast brings warm water, humid air and creates a warm humid climate. The cold Atlantic Ocean on the west coast of South Africa produces a drier climate.

All these factors interact continuously, resulting in the various climate zones within South Africa. These zones can be identified as:

- A coastal arid in the North-western region of the country,
- A semi-arid temperate zone in the interior central plateau,
- A humid subtropical zone in the low-lying southeast coastal regions, and
- A Mediterranean climate in the southern part of South Africa (Nicholsen, 2000).

3.5 Temperature trends for South Africa

Long-term observational temperature records along with the knowledge of drivers of climate change provide evidence of changing climate over the past century (Davis-Reddy & Vincent, 2017). The IPCC Fourth Assessment Report (AR4) (IPCC, 2007) revealed that mean annual temperatures in South Africa have increased by at least 1.5°C, more than double the reported global average of 0.65°C. Similar results were reported by the South African Weather Service (SAWS) after calculating the average annual temperature anomalies between the period of 1951 to 2019 (as indicated in Figure 2 below). SAWS determined that the average surface temperature was highest in 2019, and an average long-term increase of 1.6°C per decade (SAWS, 2020). This is confirmed by New *et al*. (2006) who indicated daily minimum temperatures in the interior region of South Africa was increasing at a faster rate than average daily maximum temperatures. This suggests a warming trend developing and correlating to the projected growing trend mentioned by Climate Systems Analysis Group (CSAG) (2014).

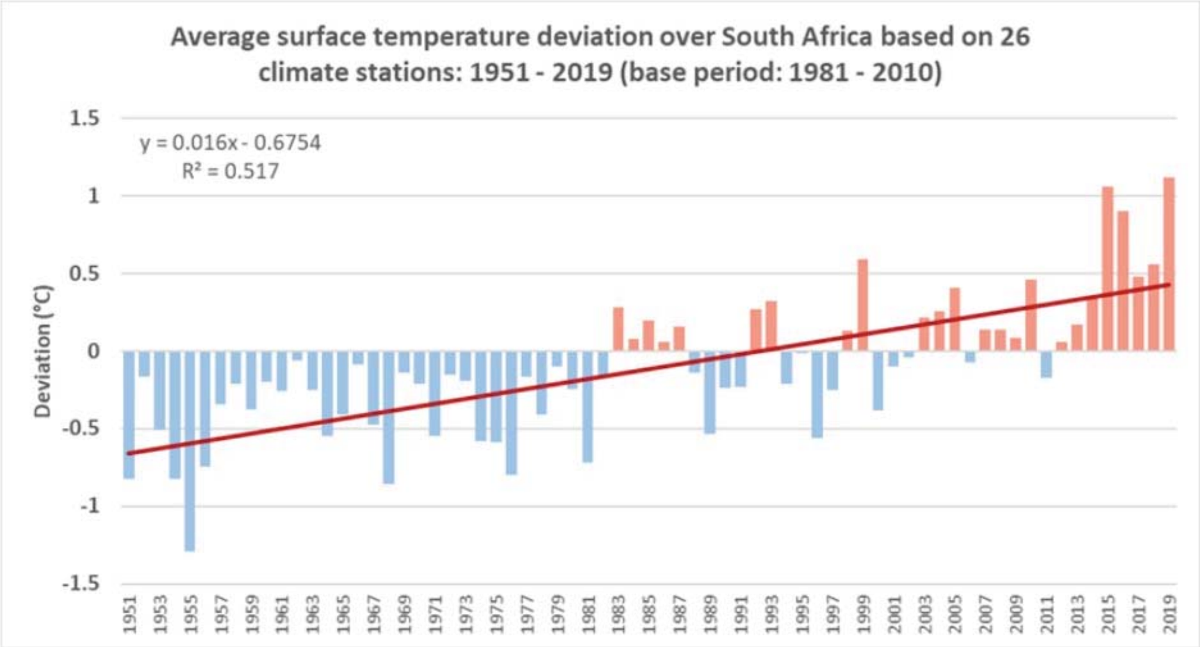


Figure 2: *showing the long-term annual mean temperature in South Africa (Source: South African Weather Service (SAWS), 2020).*

3.6 Rainfall trends for South Africa

South Africa can be subdivided into regions based on seasonal rainfall. Ocean currents and formative winds influence the spatial variation in rainfall across the country. There are two occurring wet seasons in South Africa. The north-east region of South Africa experiences a wet season in summer (November to March) and a dry season during winter (April to October). The South-West region experiences a wet season during winter (June to August) and a dry season during summer (December to February). Rainfall in South Africa is highly variable, both spatially and temporally (Fauchereau *et al.,* 2003). It was observed that between the period 1960 and 2010, there was a decrease in rainfall and the number of rainfall days across the country (MacKellar *et al.,* 2014). Davis-Reddy & Vincent (2017) observed for the period of 1921 to 2015 a drying trend in the northern regions and an increase in rainfall totals (increasing wet trend) in the southern interior. This suggests an uneven distribution of rainfall across the country and the complex variability of rainfall trends as indicated in Figure 3 below.

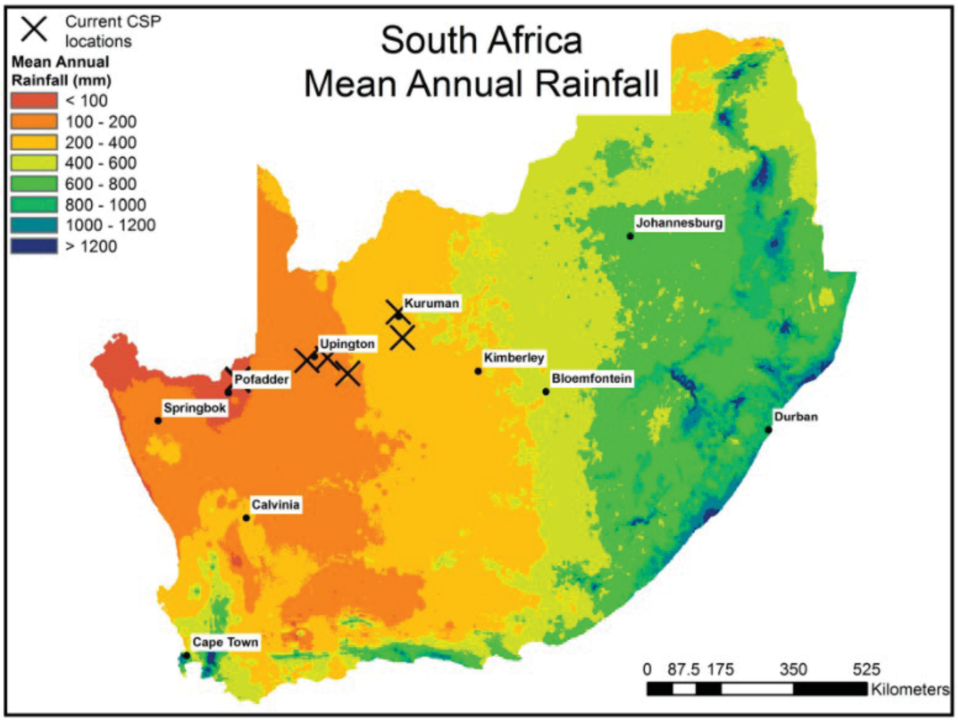


***Figure 3:** Mean annual precipitation distribution across South Africa (Duvenhage et al., 2020)*

As this project focuses on three (3) provinces in South Africa, namely the KwaZulu-Natal, Limpopo and the Western Cape, the climate in these 3 provinces will be briefly described in the sections that follow.

3.7 Climate projections South Africa

Numerous projections for climate change in South Africa have been carried out on downscaled global circulation models (GCMs) and regional climate models (RCMs). Most model projections show **drier conditions** as a result of increased warming of the region (Boko *et al*., 2007). The Intergovernmental Panel on Climate Change (IPCC, 2007) found that whilst an increase in warming is likely to occur in the Southern African Development Community (SADC), warming will not be uniform throughout the region. The number of warm days is predicted to outnumber cold days, resulting in **increased dry spells** in the region. The IPCC (2018) analysed baseline data from 1961 to 2000 and found that **daily average minimum temperatures will increase** quicker than the daily average maximum or mean temperatures. Extreme rainfall events and severe droughts have been attributed to the increased inter-annual variability of rainfall during the period of data collected.

Both RCP4.5 and RCP8.5 models project uncertainty in the amount of deviation from the mean annual rainfall. However, the overall projected trend in models indicate **mean annual rainfall will decline** in the future. Under the medium emissions scenario RCP4.5, rainfall is projected to decrease especially in coastal areas for the near future period 2015-2030. In the mid-future and far-future periods, 2040-2060 and 2080-2100, mean annual rainfall are projected to decrease and result in a pattern of drying especially in the west and southern coast regions (DEA, 2013). However, the central and eastern regions of South Africa will most likely experience a degree of increased rainfall. Under the high emissions scenario RCP8.5, rainfall is projected to decrease and result in a drying trend across the south-western Cape region, whereas in the east coast there is some uncertainty for the near future period 2015-2030. This uncertainty is due to some projections indicating increases in rainfall, whereas other indicate decreases in rainfall. In the mid-future period 2040-2060 mean annual rainfall are projected to continue decreasing around the Cape south coast. For the eastern region of the country a drying trend is most likely to occur for the same period. The far-future period 2080-2100 rainfall projections are likely to continue the same trend as the mid-future period, however at a greater intensity (DEA, 2013).

In South Africa it is projected that temperature related risks are likely to increase, as temperature increases. Under the medium emissions scenario RCP4.5, **temperatures are projected to increase** between 1°C to 2°C for the near future period 2015-2030 (Figure 4).

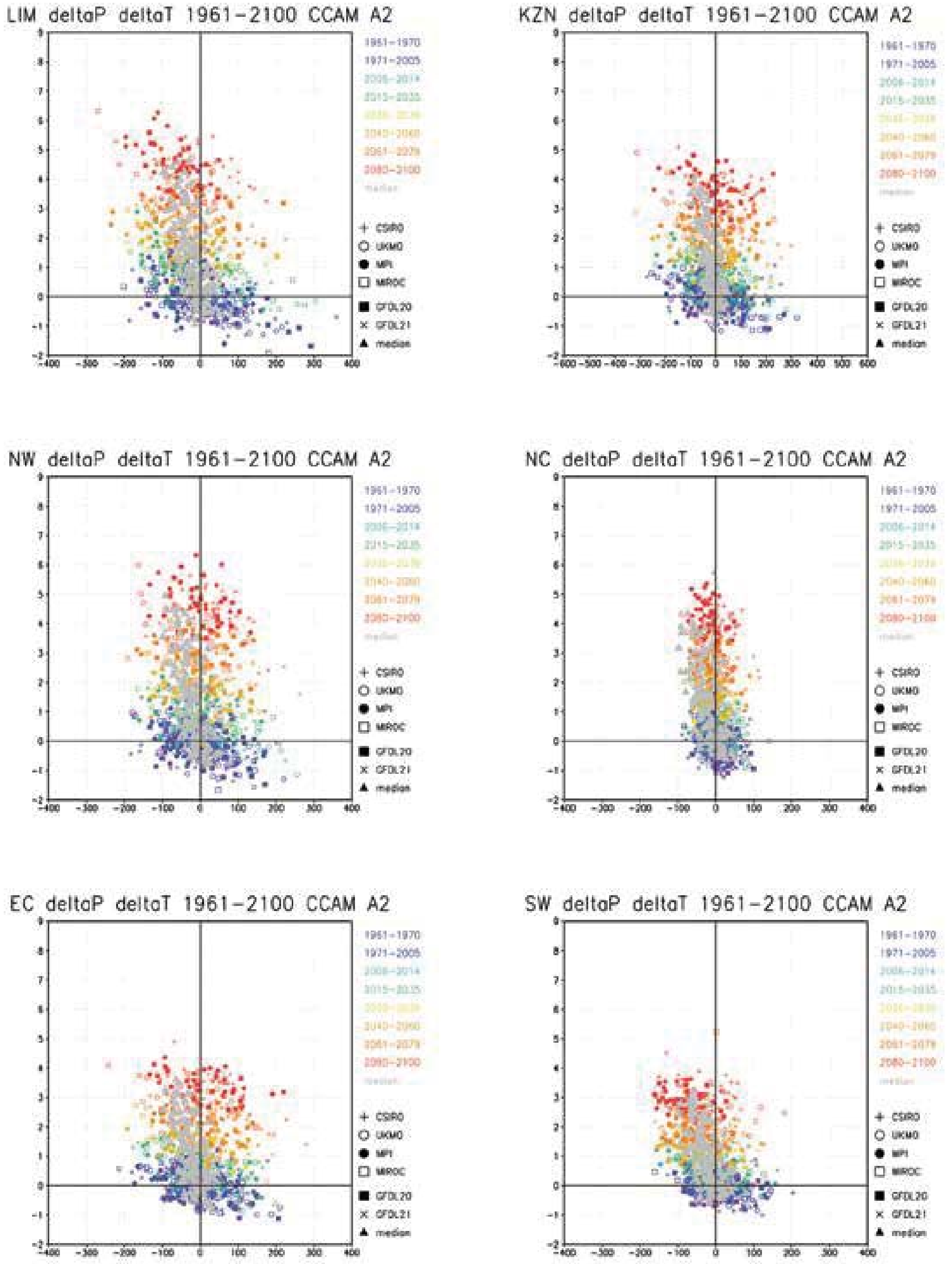


Figure 4: *Mean annual temperature and rainfall projections for the period 1960-2100 over the six hydrological zones (DEA, 2013)*

In the mid-future period 2040-2060 mean annual temperatures are projected to increase by between 2°C to 3°C. The far-future period 2080-2100 temperatures indicate some degree of stabilisation and will likely only increase by 2.5°C to 3.5°C (DEA, 2013). Under the high emissions scenario RCP8.5, temperatures are projected to increase between 1°C to 2°C for the near future period 2015-2030. In the mid-future period 2040-2060 mean annual temperatures are projected to increase by more than 3°C to 4°C. The far-future period 2080-2100 temperatures indicate drastic temperature increases in temperatures ranging between 3°C and 5°C (DEA, 2013). A summary of climate impacts that are likely to occur under current and projected climate are presented in Table 1.

Table 1: Summary of climate change impacts on water and wastewater treatment facilities

Climate hazard	Climate threat	Primary impact	Impact on water and wastewater treatment facilities
Increased temperature	Increased warm days/periods	Higher atmospheric water holding capacity	Reduced water availability for supply Reduced and more concentrated raw wastewater
	Increased warm days/periods	Drought	Reduced water quality Reduced wastewater reaching the treatment works, affect operation of processes
	Increased warm days/periods	Fires	Reduced water quality and infrastructure damage at both water and wastewater treatment facilities
	Increased evaporation	Increased evaporation	Reduced water quality, and reduced water availability More stringent wastewater treatment may be required before release into the environment Increased likelihood of thunderstorms and intense rain events that can result in flooding
	Increased warm days/periods	Heat stress	Damage to infrastructure due to exceeding temperature design specifications at both water and wastewater treatment facilities
	Increased water temperatures	Heat stress	Unsafe drinking water due to increased waterborne pathogens Increased sludge treatment temperatures can lead to growth of mesophilic organisms
Decreased temperature	Colder winter days/periods	Frost/ice development	Freezing of pipes in both water reticulation and wastewater sewers
	Colder winter days/periods	Cold stress	Reduced treatment capacity because of low temperatures lowering metabolic activity of micro-organisms
	Colder winter days/periods	Frost/ice development	Infrastructure damage especially at source waters where infrastructure was not designed to handle frost/ice.

Increased rainfall	Increased water entering system	Flooding	Water and wastewater treatment system infrastructure and process failure due to increased water entering system, as well as onsite spillages
	Increased infiltration	Higher water tables	Increased pathogens in groundwater and surface water resulting from overflow of on-site sanitation systems (e.g. pit latrines)
	Increased water entering system	Increased runoff	Increased loading of pathogens, chemicals and suspended material
	Increased water entering system	Flooding	Contaminated surface water entering groundwater through wells
Decreased rainfall	Decreased water availability	Reduced runoff/infiltration	Reduced water mix (low surface runoff and low groundwater recharge rates)
	Decreased water availability	Reduced runoff/infiltration	Reduced water quality (lack of dilution of pollutants/contaminants) More stringent wastewater treatment may be required before release into the environment
	Decreased water availability	Drought	Increased competition between anthropogenic and ecosystem requirements
	Decreased water availability	Human and environmental health	Increased treatment cost due to increased pathogen and pollution/contaminant concentrations
	Erratic rainfall	Flooding	Damage to infrastructure; over capacitated water and wastewater treatment facilities.

3.8 Climate trends in the KwaZulu-Natal Province

The KwaZulu-Natal (KZN) province is located on the east coast of South Africa and is bordered by the Indian Ocean (Figure 5).

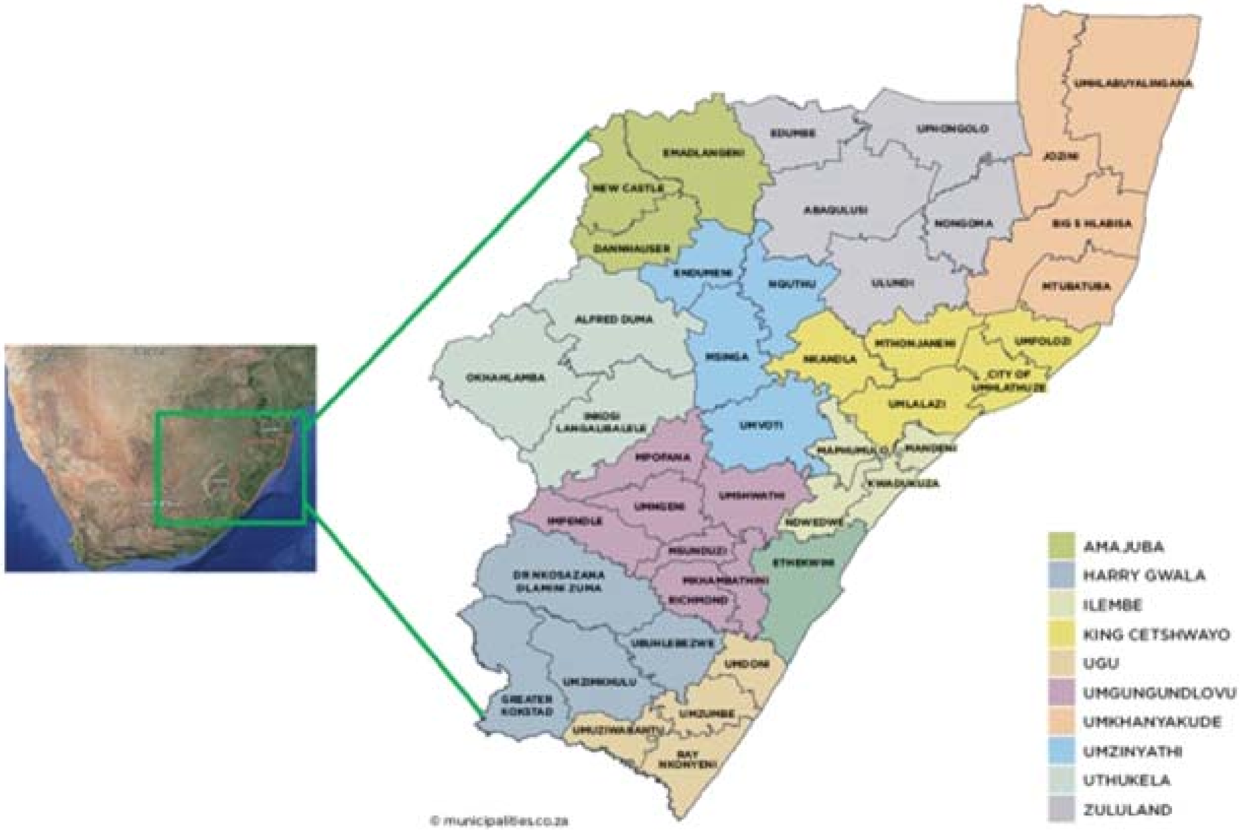


Figure 5: Location of KwaZulu-Natal Province, South Africa including eThekwini Metro, District and Local Municipalities ***NOTE****: Key indicates all District Municipalities and Local Municipalities located within them (Municipalities.co.za)*

Climate in the KZN is characterised as being subtropical and is influenced by the Indian Ocean and the warm Agulhas Ocean current (Reason, 2001 and Green *et al.,* 2012). These influences result in high humidity, temperatures, and summer rainfall (Lakhraj-Govender, 2017). Rainfall in the province typically occurs during the warm season from October to March, while the cold season is typically cool and dry (Figure 6). Average annual rainfall ranges between 813mm to 1382mm across the province (Ndlovu and Demlie, 2020). Average summer and winter temperatures are about 25°C and 20°C, respectively.

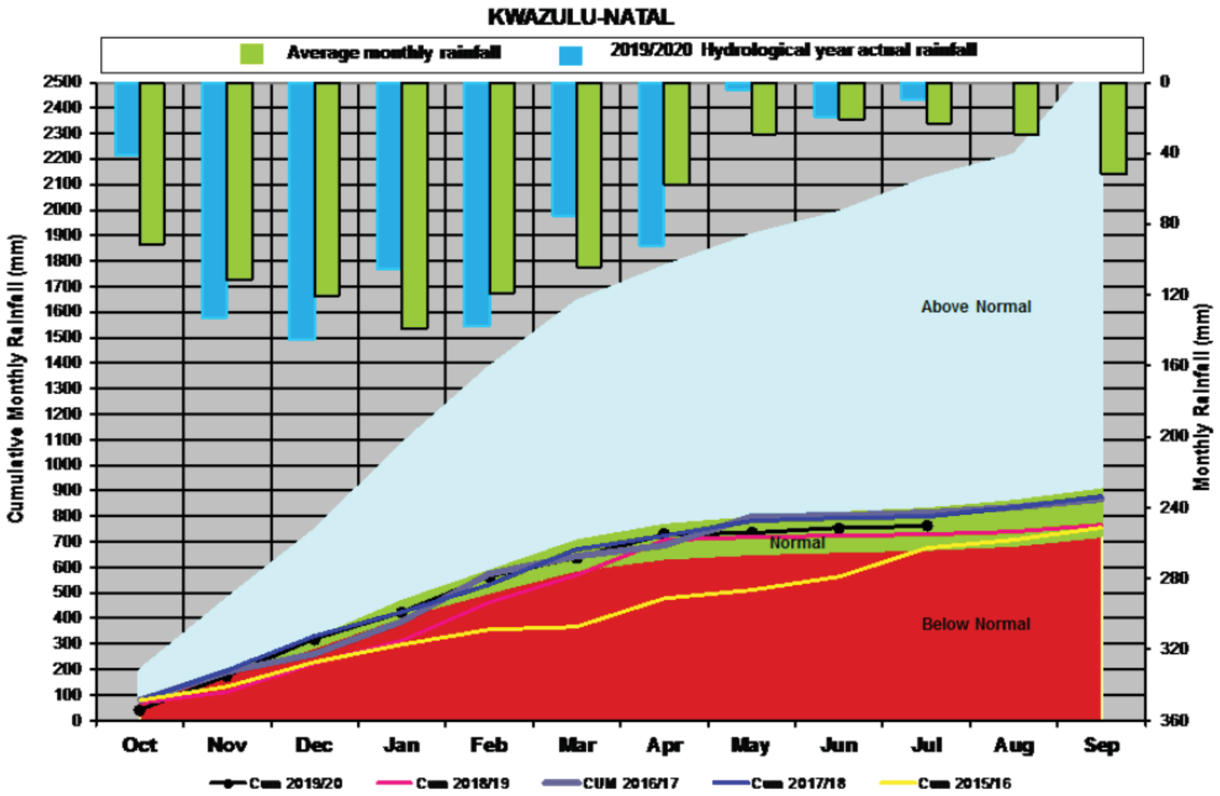


__Figure 6:__ Average monthly rainfall for KwaZulu-Natal (DWS, 2020)

Rainfall in the province indicates the relatively frequent occurrence of both wet (i.e. 125% above normal) and dry years (i.e. less than 75% of normal), however in more recent years dry years have become more common (SAWS, 2019) (Figure 7). Between 1989 and 2019, 4 dry years and two wet years have occurred while since 2014, the province has been experiencing drought (Ndlovu and Demlie, 2020).

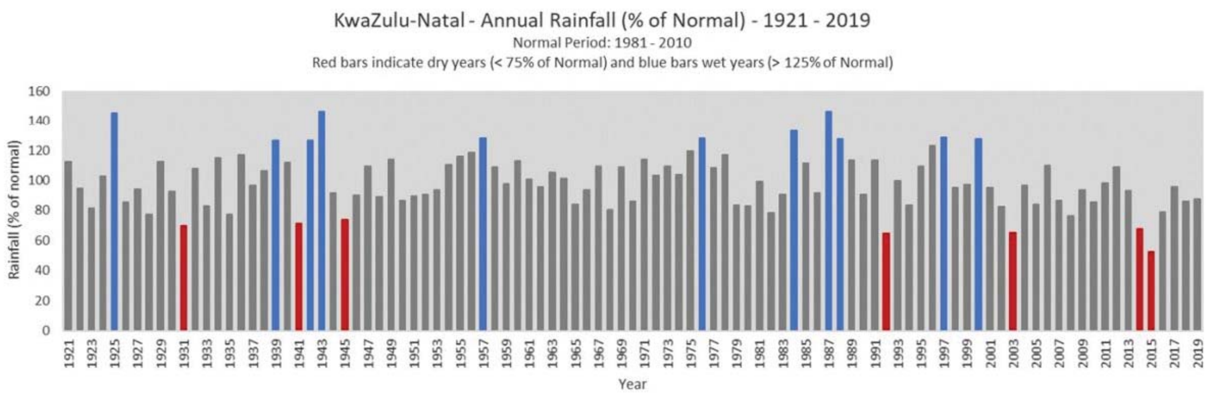


__Figure 7:__ Annual rainfall as a % of normal for the KwaZulu-Natal Province, South Africa (SAWS, 2019).

Average annual maximum temperature trends indicate decadal increases of 0.07°C across the Province. According to Lakhraj-Govender (2017), minimum temperatures across the province have increased drastically from 1930 to 2015. Minimum temperatures have been observed to increase between 0.05°C/decade to 0.34°C/decade. Considering the above-mentioned increases in maximum and minimum temperatures, it should be noted that average annual temperatures have also increased (Lakhraj-Govender, 2017) (Figure 8).

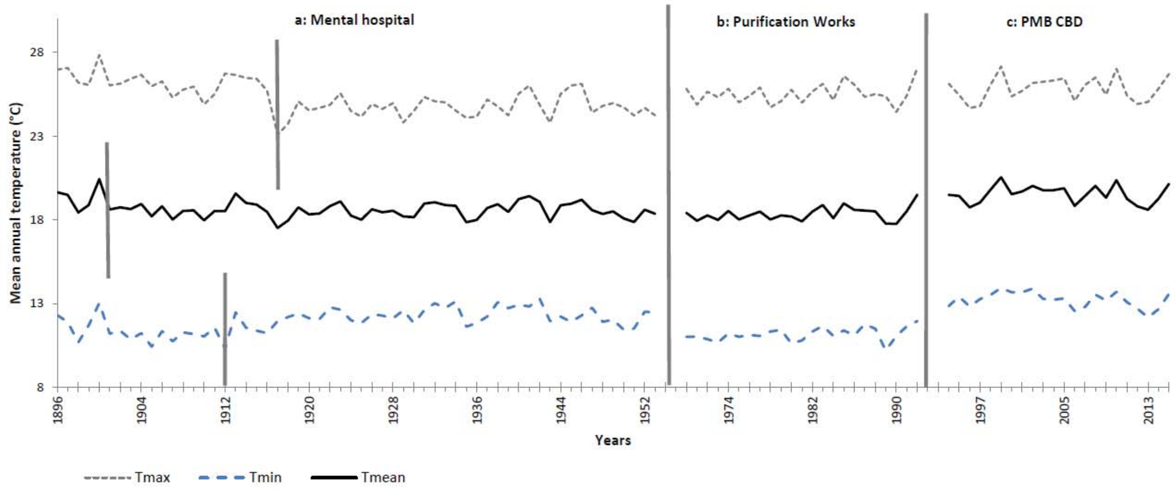


Figure 8: *Temperature trend for KwaZulu-Natal Province, South Africa (Lakhraj-Govender, 2017).*

In conclusion, it would appear as though, in general, the KwaZulu-Natal is experiencing:

- Decreasing rainfall – need to make do with less
- Increasing in frequency of dry years – increased probability of drought
- Increasing minimum and maximum temperatures – more evaporation, less water available

3.9 Climate trends in the Limpopo Province

The Limpopo province is the northern most province in South Africa, and shares international borders with Mozambique, Zimbabwe, and Botswana (Figure 9).

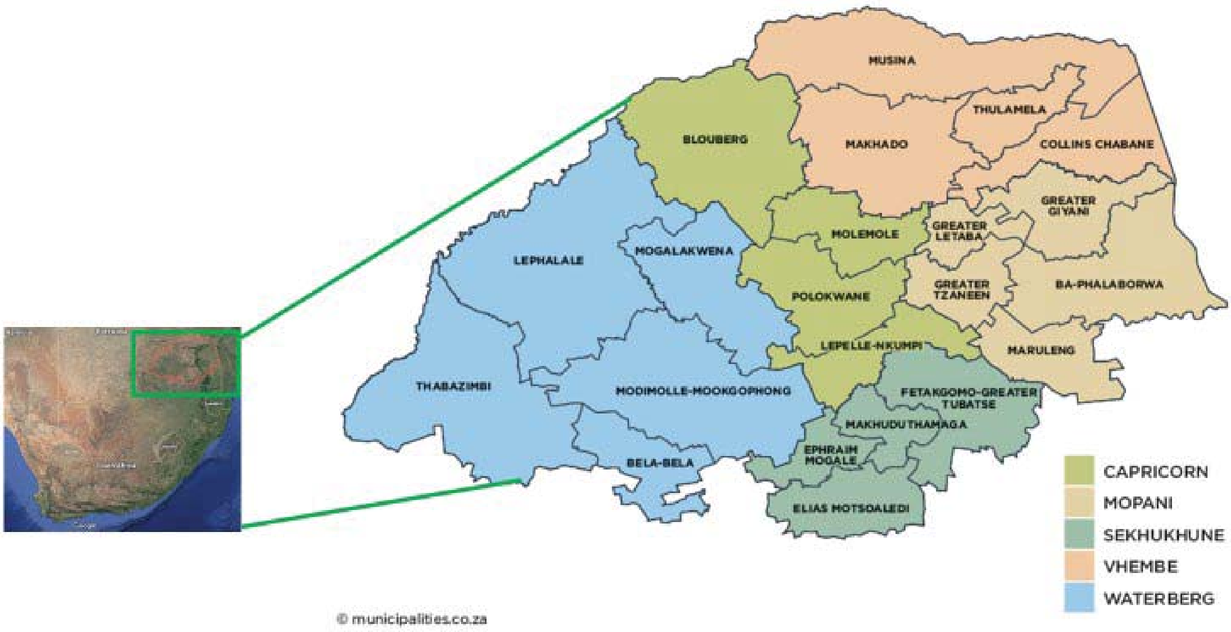


Figure 9: *Location of Limpopo Province, South Africa including District and Local Municipalities* ***NOTE:*** *Key indicates all District Municipalities and Local Municipalities located within them (Municipalities.co.za)*

Limpopo province exhibits two types of climates tropical and subtropical (Thompson *et al.,* 2012). Days in the Province are typically long hot and sunny, with thunderstorms occurring occasionally. Annual rainfall in the province generally ranges between 400mm-600mm per annum (DWS, 2020) (Figure 10). Mean annual minimum are 20°C and maximum temperatures are 27°C, respectively (Tshiala *et al.,* 2011) (Figure

11). Typical climate related natural disasters include droughts which have resulted in loss of livestock, and floods which have resulted in the loss of crops.

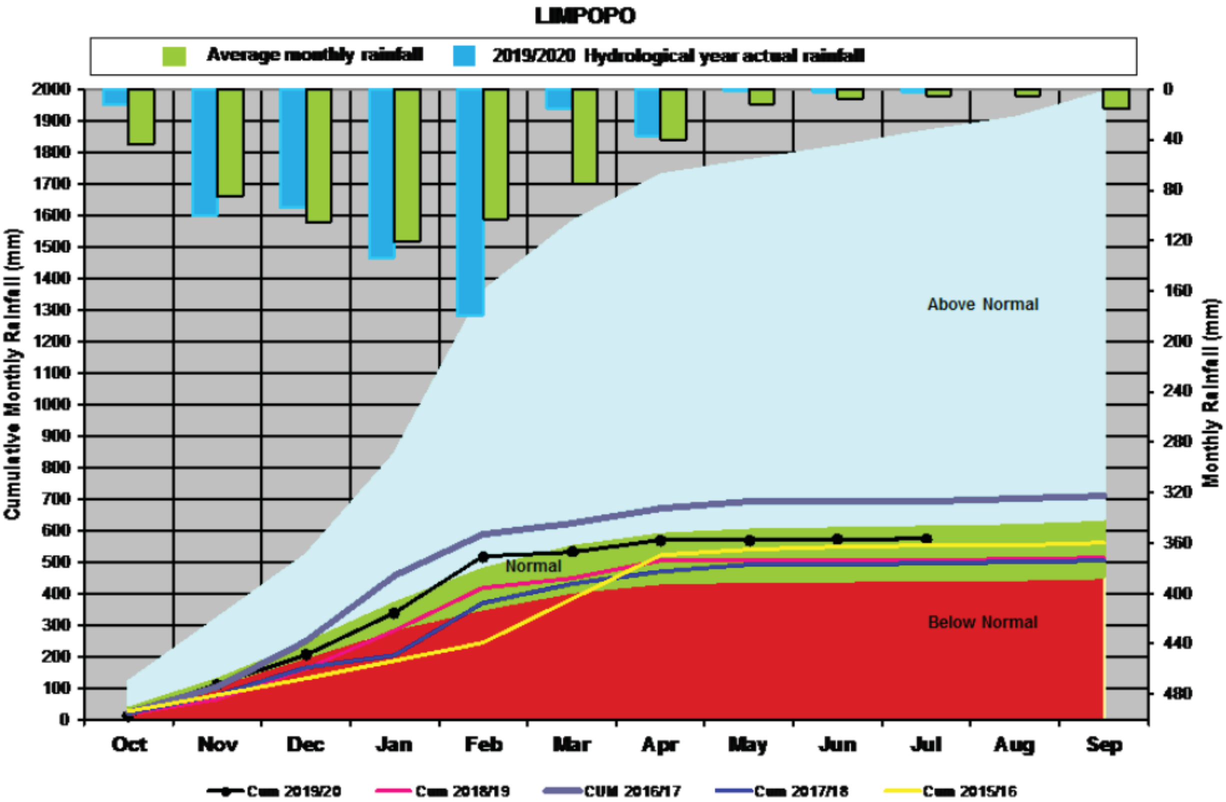


Figure 10: *Annual rainfall for Limpopo Province (DWS, 2020)*

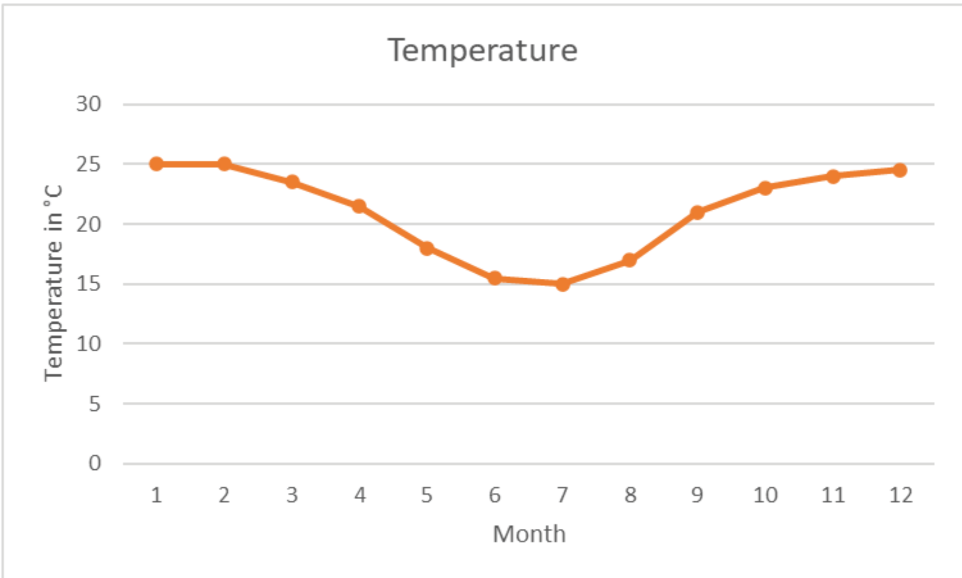


Figure 11: *Mean monthly temperatures for Limpopo province (Tshiala et al., 2011)*

According to Maponya and Mpandeli (2013) changes in climate will likely result in rainfall variability and increased temperatures. This may result in the increased frequency and duration of extreme events which include historical threats such as floods and droughts (Maponya and Mpandeli, 2013). The agricultural sector is likely to be the most affected by climate change and climate variability, with rain-fed agriculture being the most affected (Afful, 2016; Maponya and Mpandeli, 2013; Parry *et al.,* 2005).

Rainfall in the province indicates the relatively frequent occurrence of both wet (i.e. 125% above normal) and dry years (i.e. less than 75% of normal). However, during the period 1989 to 2019 (last 30 years) there were more dry years and rainfall has indicated a general drying trend (SAWS, 2019) (Figure 12). Inter-annual variability for rainfall is also observed for the province.

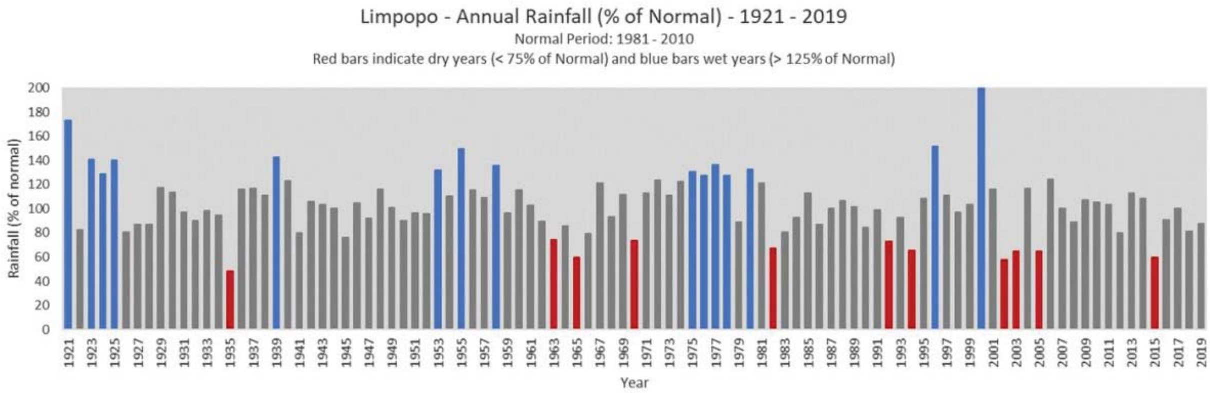


Figure 12: *Annual rainfall as a % of normal for the Limpopo Province, South Africa (SAWS, 2019).*

Temperature trends in Limpopo province indicate that maximum and minimum temperatures have generally increased over time (Tshiala, 2011) (Figure 13 and Figure 14). Seasonal increases have been also observed, with summer (wet season) and winter (dry season) indicating annual increases in temperature. The decadal increases for Limpopo Province which exhibits of 0.6°C/decade to 0.9°C/decade (Jimmy *et al.,* 2019).

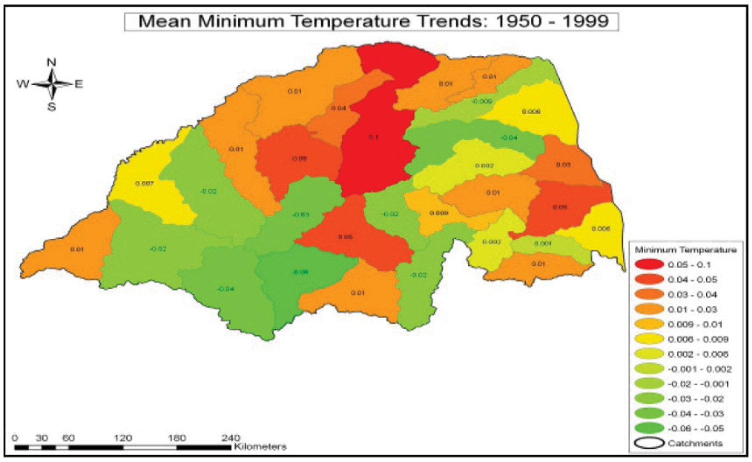


Figure 13: *Decadal change mean minimum temperatures for Limpopo Province, South Africa (Tshiala, 2011)*

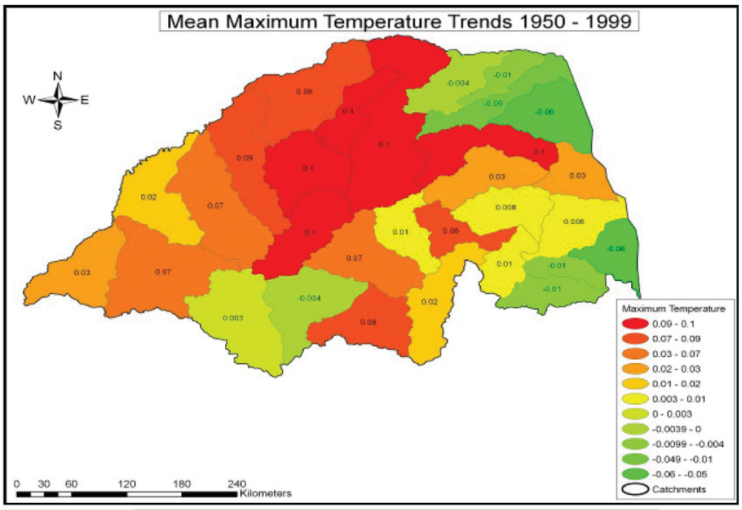


Figure 14: *Decadal change mean maximum temperatures for Limpopo Province, South Africa (Tshiala, 2011)*

In conclusion, it would appear as though, in general, the Limpopo is experiencing:

- Decreasing rainfall – need to make do with less
- Increasing in frequency in dry years – higher probability of drought
- Increasing temperatures – more evaporation, less water available

3.10 Climate trends in the Western Cape

The Western Cape Province is located on the South-Western Coast of South Africa and is bordered by the Indian and Atlantic Oceans (Figure 15).

Figure 15: *Location of the Western Cape Province, South Africa including City of Cape Town, District and Local Municipalities* ***NOTE:*** *Key indicates all District Municipalities and Local Municipalities located within them (Municipalities.co.za)*

The climate of the Western Cape is typically Mediterranean with dry hot summers and cool wet winters (Figure 16). Rainfall occurs when low pressures systems pass over the province typically during the winter months (Western Cape Government, 2018). The average annual rainfall for the province varies between 300mm to 900mm (Botai *et al.,* 2017). Summer temperatures for the province range between 15°C to 27°C, whereas winter temperatures range between 5°C to 22°C (Figure 17). Typical climate related disasters include droughts, floods, sea storm surges, fires, and hailstorms (Western Cape Government, 2018).

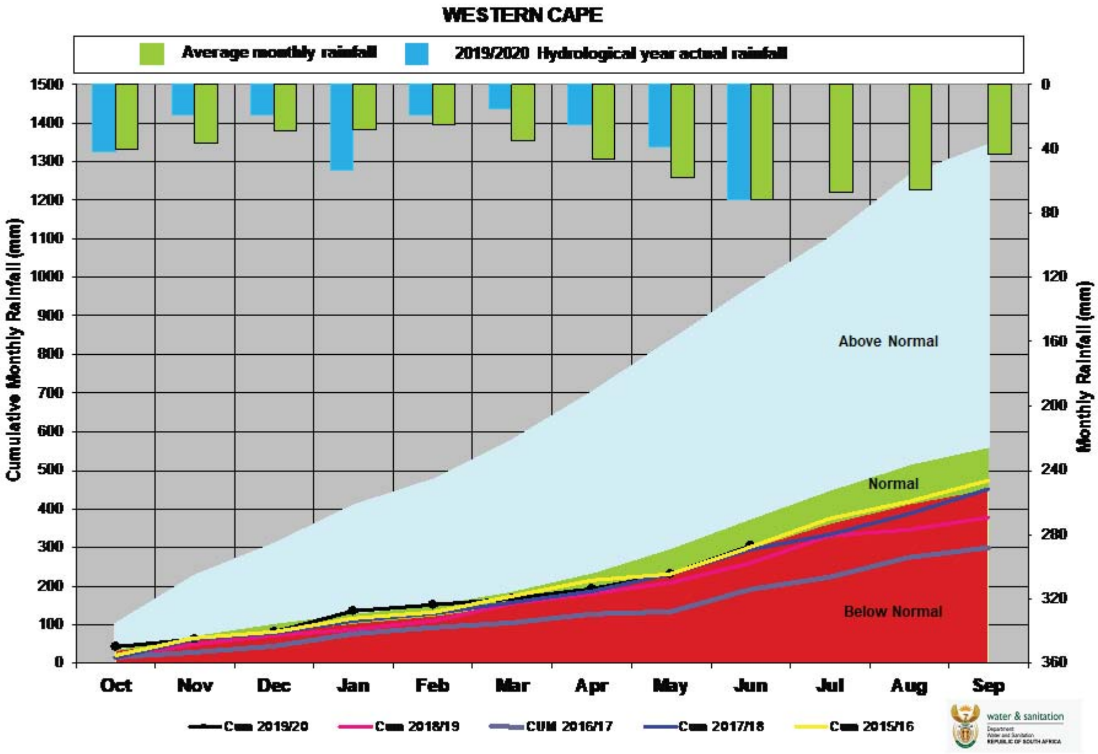


Figure 16: *Mean annual rainfall Western Cape Province, South Africa (DWA, 2020)*

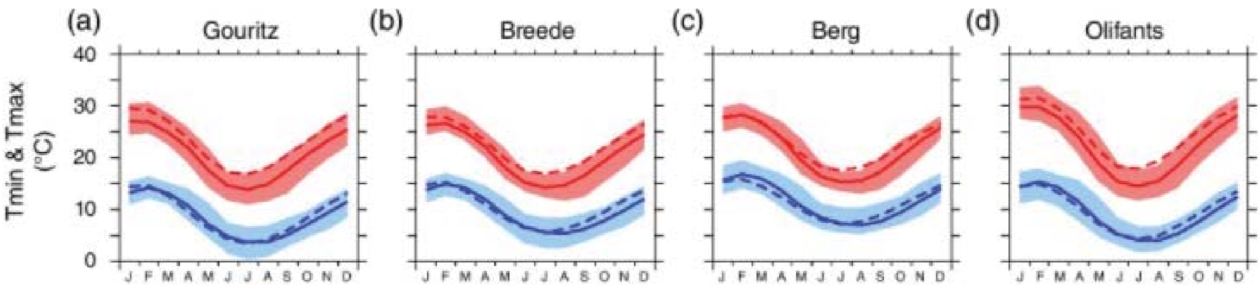


Figure 17: *Annual climate cycles for the four major river catchments in the Western Cape (Naik and Abiodun, 2019)*

Rainfall in the province shows inter-annual variability, however droughts appear to be a common occurrence throughout the province's history (Figure 18). Years with below average annual rainfall (75% or less below average annual) has occurred 11 times in the last century (1921-2019). Very few 'wet' years (125% or more above average annual) have been recorded with only four for the province in the last century (1921-2019) (SAWS, 2019).

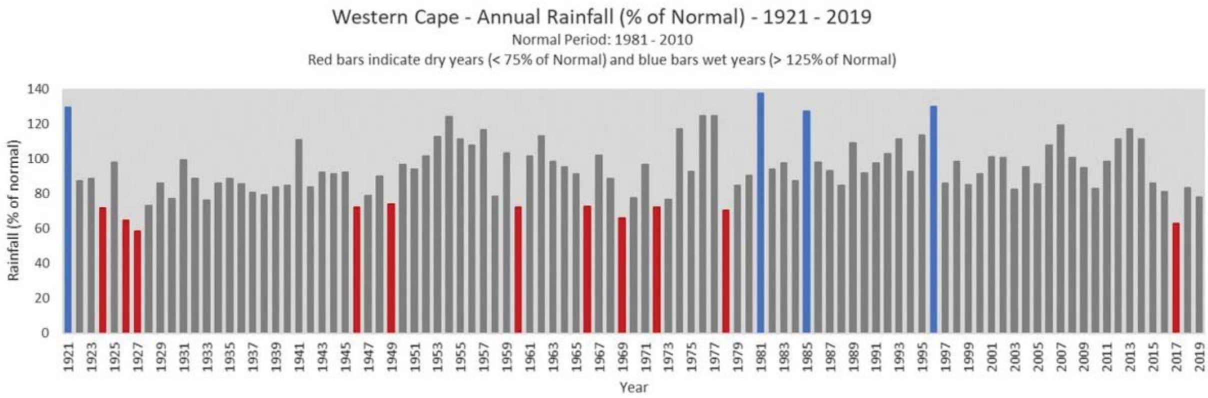


Figure 18: *Annual rainfall as a % of normal for the Western Cape Province, South Africa (SAWS, 2019).*

The temperature in the Western Cape Province has followed the same increasing trend as the rest of South Africa. Data indicates that monthly average minimum and maximum temperatures as well as annual minimum and maximum temperatures have increased between the period 1915 to 2015 (Lakhraj-Govender, 2017). Decadal changes in temperature minimum and maximum have also shown evidence of increases.

In conclusion, it would appear as though, in general, the Western Cape is experiencing:

- Decreasing rainfall – need to make do with less
- Increasing extreme rainfall events – a lot more becomes available all at once over a short period
- Increasing temperatures – more evaporation, less water available

4. Climate Related Data and Information for South Africa

4.1 Role players in Water and Climate Change

The legal and institutional response towards climate change and the management of water resources are established by three spheres of government, national, provincial, and local. The national government have a constitutional duty to provide support functions to provincial and local government in decision making and the development of strategies. Provinces and municipalities play a key role in developing and implementing adaptation and mitigation measures towards the mitigation of climate change. Climate change impacts are mitigated through the coordination on all levels of government with the alignment of policies (Giordano *et al*., 2011).

The Department of Water and Sanitation has national jurisdiction over the country's water resources (e.g. rivers, dams). Local government and municipalities are responsible for delivering water services within their respective domains of governance. In some cases, water boards are also relied on for bulk services and water resource infrastructure. Together, the national government, catchment management agencies, water boards and water service providers (either a District Municipality or a Local municipality) work to provide water services and develop water resources in South Africa (Petrie *et al*., 2018). Other key players in water and climate change include the private sector constituting of business/industry, science councils and research institutions (Table 2).

Table 2: Summary of key players, sectors and roles in the mitigating climate change and managing water resources (Imbewu, 2011; Giordano *et al*., 2011; ASSAF, 2017).

Sector	Key Player	Roles
National	Department of Environmental Affairs	Acts as lead department for climate change, providing support in developing and implementing actions to address climate change.
	Department of Water and Sanitation	Custodian of South Africa's water resources. Responsible for the availability and equitable supply of water on a national level, promote sustainable management of water resources.
	Department of Water and Sanitation	Mandated to ensure water resources are protected, managed, used, developed, and conserved in a sustainable manner for beneficial use of society and the environment.
	Department of Agriculture, Forestry and Fisheries	Monitoring of impacts of climate change on agriculture and food production (temperature, rain patterns, droughts, foods), developing and implementing adaptation measures.
	Department of Science and Technology	Responsible for the innovation and developments for climate resilience, technology transfer, adaptation, and adoption.
Subnational	Water Service Institutions: • Water Boards • Catchment Management Agencies	• Provide water services to other water services institutions within its service area. • Responsible for the co-operation and agreement on water-related matters from the various stakeholders and interested persons
Local	Municipalities and local metros	Monitor and make informed decisions of the provision of water services for local communities.
	Civil Society • E.g. Public, Media, NGOs, Unions	Comment and provide feedback to government, private sector and research and scientific community for measures of mitigating climate change. Responsible for actions towards the environment and work alongside authorities to reduce impacts of climate change.
Private	Business Industry • E.g. Sasol, Eskom, Sugar Milling Research Institute, Institute for Commercial Forestry Research, etc.	Adopt climate change mitigation measures and work with government to align policy objectives to those within the business industry, reducing carbon footprint and increase energy efficiency.
	Academic Research Institutions • E.g. University of Cape Town, University of KwaZulu-Natal, University of the Western Cape, Stellenbosch University, University of Venda, University of Limpopo, etc.	Bridge knowledge and research gaps in water and climate change topics, improve projections of climate change and their impacts, to explore mitigation and adaptation responses and implementation, development of relevant technology and its implementation.
	Science Councils: • Council for Scientific and Industrial Research • South African National Biodiversity Institute • South African Weather Services • South African Environmental Observation Network	Involved in application-oriented research ('contract research') for government departments and the private sector, contributes towards research developments, observation and monitoring of the atmosphere and climate.

4.2 Climate related assessments

Climate related assessments for the South African setting are available and cover various focal points. These focal points may be climate projections, climate change vulnerability within a sector, progress to towards implementing climate change or a summary of annual climate. The scale of these reports varies, whereas most climate reports typically provide information for South Africa as a whole, others may provide information at the provincial or municipal level (Figure 19). Sector specific reports may not report on an area; however, the information contained therein may have applications in most areas. At the provincial scale, each province has been provided a climate summary through the “Let’s Respond Toolkit". Table 3 below provides a summary of climate related assessments developed for South Africa.

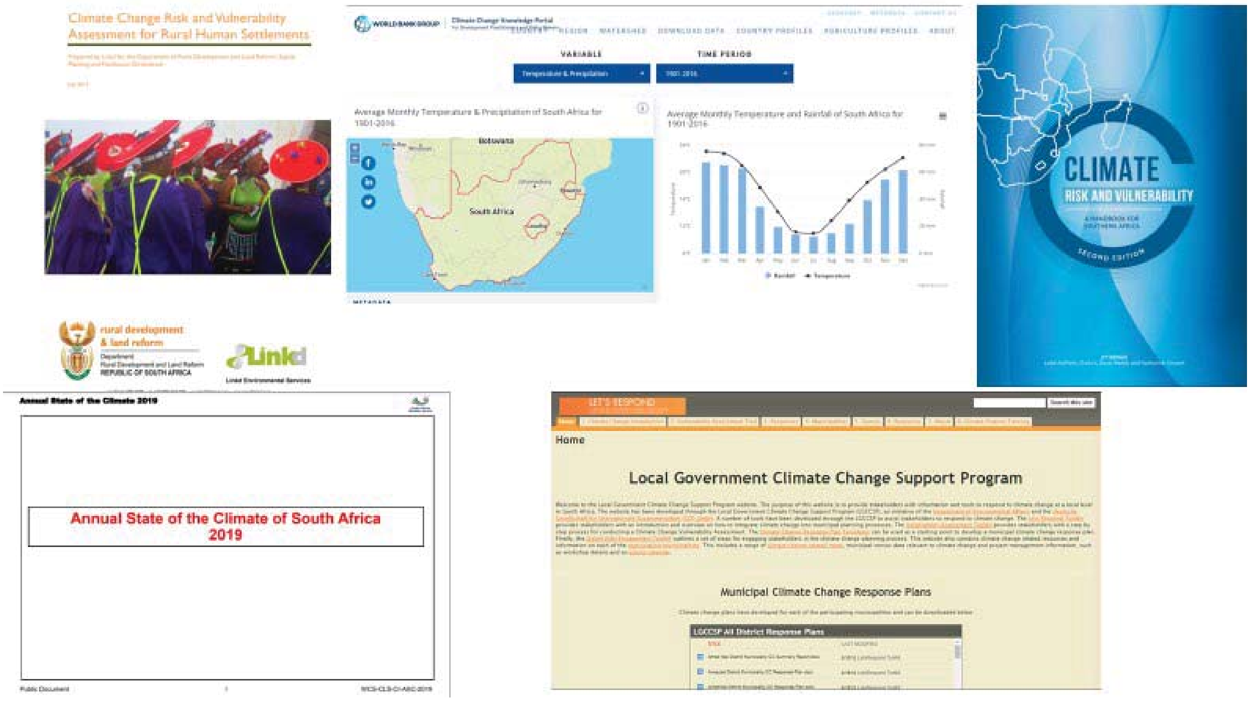


Figure 19: *Examples of climate related assessments available for South Africa*

Table 3: *Examples of climate assessment reports for South Africa*

Information source	Type of data or product	Scale of data	Coverage	Intended Audience	Access cost	Example with comments
Climate Vulnerability and Adaptation (V and A) Assessments	Assessment report	National	National	Generalists	Free	Climate change risk and vulnerability assessment for rural human settlements, 2013 http://www.ruraldevelopment.gov.za/phocadownload/spatial_Planning_Information/Climate_Change/Latest_Risk_and_Vulnerability_july_2013_09072013.pdf
Climate Vulnerability and Adaptation (V and A) Assessments	Assessment report	National	National	Generalists	Free	Annual state of climate summary for South Africa, 2019 https://www.weathersa.co.za/Documents/Corporate/Annual%20State%20of%20the%20Climate%202019.pdf
Climate Vulnerability and Adaptation (V and A) Assessments	Assessment report	Regional – Southern Africa	Regional / national International	Generalists	Free	Council for Scientific and Industrial Research, Climate Risk and Vulnerability: A handbook for Southern Africa https://www.csir.co.za/sites/default/files/Documents/SADC%20Handbook_Second%20Edition_full%20report.pdf
Climate Vulnerability and Adaptation (V and A) Assessments	Assessment report	National	National	Generalists	Free	South Africa's annual climate reports published by the Department of Environmental Affairs https://www.environment.gov.za/otherdocuments/reports/southafricas_secondnational_climatechange
Climate Vulnerability and Adaptation (V and A) Assessments	Web-based tool	National	National	Generalists	Free	World Bank Climate Knowledge portal, Country Information https://climateknowledgeportal.worldbank.org/country/south-africa
Climate Vulnerability and Adaptation (V and A) Assessments	Web-based tool	National District Municipality	National	Generalists	Free	Let's respond toolkit – Department of Environmental Affairs http://www.letsrespondtoolkit.org/

4.3 Available climate related data/datasets

Climate data and information is very well documented across the globe. Data records may span from 1901 to recent for certain areas. However, many datasets are already analysed and available in reports or on web-based tools in the form of maps or graphs (Figure 20). The availability of already analysed data provides convenience to many users especially generalists (non-technical specialists) or users with limited capacity and resources. However, it may present a challenge to technical specialists that require 'raw data' to perform their own analysis or climate modelling. Sourcing this data may also prove a challenge as there are many climate data tools/applications and reviewing all of these may prove to be a time-consuming endeavour.

Note: Data accessed from data portals/tools may not be available in a ready to use format. Many data centers/institutions store data/datasets according to their own policies and requirements. The data/datasets may need to be 'cleaned' and in some cases pre-processed to suits your needs. Users need to define what it is they need or want from the data/dataset, and setup the data/dataset accordingly.

South Africa has a very wide and well-established climate monitoring network. The type of data includes temperature, rainfall, flows and water quality. Most of this data is freely and easily accessible online, however some data may require a registration/data request or a small fee. Despite this, the data is very reliable and from trustworthy sources such as SAWS or DWS. Technical specialists who wish to perform their own analysis or modelling can use the data collected by these centres/institutions.

A comprehensive list of climate related data/information sources has been developed for South Africa (see extract in Table 4, and full list in **Appendix A**). The list identifies:

- Key questions to consider when assessing the impacts of climate change on water supply and wastewater services.
- Climate information sources – Information is provided on the potential sources of information, as well as the characteristics of that information.
- Type and spatial scale of data – This means whether at the spatial scale (i.e. local, provincial, national, etc.) information can be retrieved. In the case of automatic weather station network data, the data will be represented as single points in space. There are techniques, however, that allow users to convert such point data into spatially varying data. Finally, reports may provide summary information that covers whole regions or even countries.
- Coverage of the data (local, national) – Here, the focus is on the coverage scale of the information. For example, national reports or statistics are likely to only cover the national borders. In contrast, several international sources cover the globe.
- Intended/appropriate audience – This column provides some indication of what level of expertise is required to use the information. In some cases, raw data may only be suitable for those with technical expertise. Other information such as summary reports may be more appropriate for a more general audience.

The list also indicates potential sources of information that are most suitable to water utilities with limited capacity (time, staff, and resources) shaded in **green** **(Appendix A)**. Figure 20 and Table 4 provides examples of data resources, both national and international, where data may be retrieved:

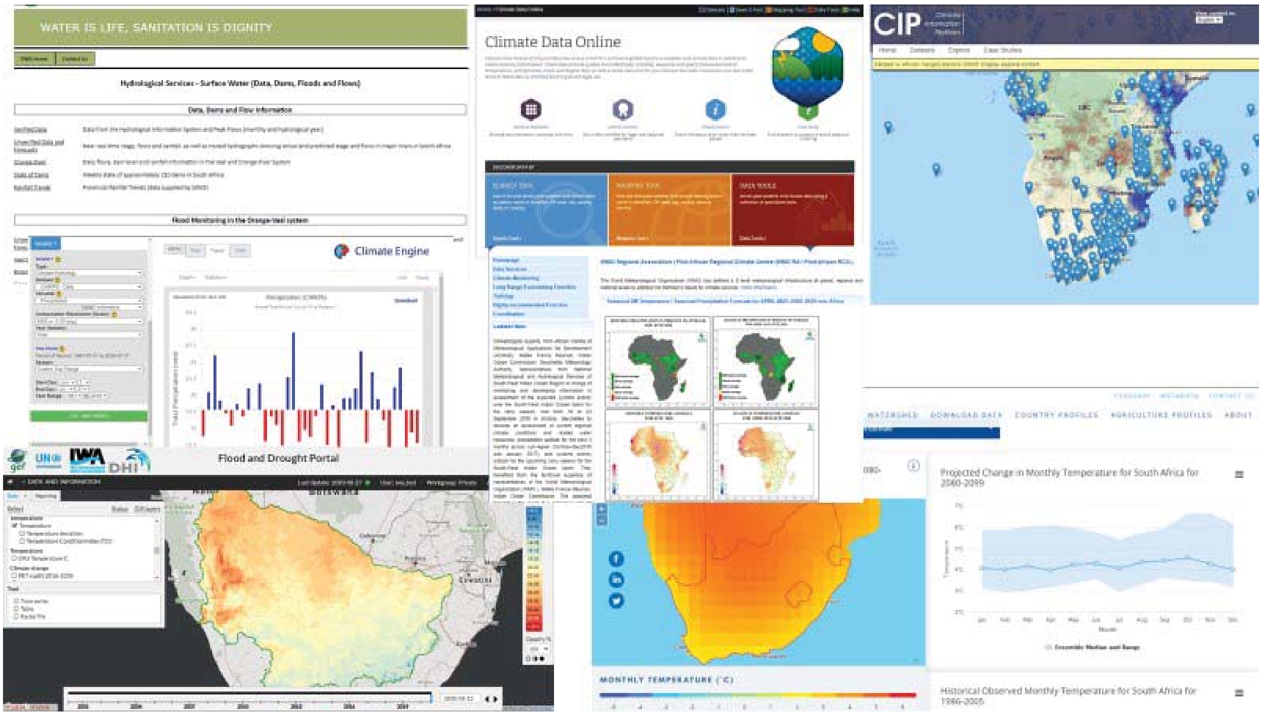


Figure 20: *Climate data sources available for South Africa*

Table 4: *Examples of climate data sources for South Africa*

Information source	Type of data or product	Scale of data	Coverage	Intended Audience	Access cost	Example with comments
Climate and meteorological services	Climate data	National Station data	National Individual locations	Technical specialist	Free	Provides users access to historical data, forecast, and projections. http://www.csag.uct.ac.za/
WTW or WWTW	Water quality and wastewater quality, Rainfall, temperature	National	Station data	Technical specialist	Free	Users can request data from the relevant stakeholders, municipal department, or institution. Data may be available on a data portal.
National Hydrological services	Hydrology data	National	Station data	Technical specialist	Free	South Africa's Department of Water and Sanitation http://www.dwa.gov.za/projects.aspx
Climate and meteorological services	Climate data	National	Station data Individual locations	Technical specialist	Paid	South African Weather Services (SAWS) https://www.weathersa.co.za/
Web tool	Temperature maps or visualisations	International	Gridded data over selected river basins	Generalist and Technical specialist	Free	IWA Flood and Drought monitoring tools http://www.flooddroughtmonitor.com/home
Web tool	Climate maps and charts (time series) or summaries	International	National or sub-national	Generalist and Technical specialist	Free	World Bank Climate Knowledge portal, Country Information https://climateknowledgeportal.worldbank.org/country/south-africa
Web tool	National summary statistics	International national	Gridded data Raw data tables	Technical Specialists	Free	International Governmental Panel on Climate Change Data Distribution Centre http://www.ipcc-data.org
Web tool	National vulnerability assessments	International national	Gridded data Raw data tables	Technical Specialists	Free	Climate Engine http://climateengine.org/app

5. Water Safety Planning and Wastewater Risk Abatement Planning

5.1 Water Safety Plan (WSP)

A Water Safety Plan (WSP) is a systematic approach that comprehensively assesses and manages risks throughout the water supply system. The WSP process covers all aspects of the water supply system, from catchment to consumer, and was developed by the World Health Organization (WHO) and International Water Association (IWA) (WHO, 2009). Since then, the WSP process has been well received by many countries and has been adopted and implemented at various levels in 93 countries around the world (WHO, 2017). In South Africa, the WSP process is a requirement of the Department of Water and Sanitation (DWS) Blue Drop Certification programme and is contained within both the Drinking Water Quality Framework (Hodgson and Manus, 2006) and SANS 241 drinking-water quality standards (SABS, 2015). The traditional WSP process considers 11 modules:

- **Module 1: Assemble the WSP team**
  This requires you to establish a multi-disciplinary team that will carry out, implement and communicate the water safety plan to all relevant stakeholders. Typical team members may include engineers, plant personnel and decision-makers.
- **Module 2: Describe your water supply system**
  This requires you to clearly outline the various steps in your water supply system and highlight key points that are vulnerable to hazards and hazardous events. The system should be described from catchment to consumer. A comprehensive catchment description should also describe local climatic conditions.
- **Module 3: Identify hazards and hazardous events and assess the risks**
  This requires you to consider what could go wrong at each point in your water supply system and assigning a risk. Assigning risk assists with the prioritization of each of the identified hazards and hazardous events, so that the team knows how and where to direct their various efforts.
- **Module 4: Determine and validate control measures, reassess and prioritize the risks**
  Control measures are those actions that are taken to mitigate the hazard and hazardous event if it occurs. Control measures should reduce the risk of hazards and hazardous events when they occur. Control measures may be short-term quick fixes or may be long-term fixes that require a few years to implement. If control measures are identified and are considered effective, the WSP team can reprioritize the risks.
- **Module 5: Develop, implement and maintain an improvement / upgrade plan**
  An improvement plan is required to ensure that control measures that are not effective, are replaced with new control measures that are effective. The new control measures that are identified as part of the improvement plan could be short-term or long-term measures, or a combination of the two. It is important that when implementing the improvement plan that the team recalculate and reprioritize the risk.
- **Module 6: Define Monitoring of the control measures**
  Control measures should be monitored for their effectiveness. If an incident occurs at a water treatment plant, then corrective action is required. If a control measure remains ineffective, the WSP team will have to revisit modules 4 and 5 to identify possible new/additional control

measures. Monitoring of control measures also requires the WSP team to prove that the control measures are indeed effective.

- **Module 7: Verify the effectiveness of the WSP**
  This requires the WSP team to audit the WSP to ensure that it is effective and identify possible improvements that may be required. Verification requires the team to consider three aspects, namely: (i) compliance monitoring, (ii) internal and external auditing of operational activities, and (iii) customer satisfaction.
- **Module 8: Prepare management procedures**
  Management procedures should be clearly outlined when the system is running optimally (i.e. standard operating procedures (SOPs)) and when an incident occurs (e.g. mitigating measures during emergencies). These procedures should be site specific and should have the input from the entire team, particularly the most experienced members of the team. Regular updates should be performed as and when required (e.g. a process is changed, added or removed).
- **Module 9: Develop supporting programmes**
  This module focuses on the continued development of plant personnel skills and knowledge so that they continue to deliver a safe product and highlights an organization's commitment to the WSP. This may require the WSP team and plant personnel to continue to attend relevant courses, and understand how other elements such as laboratory testing, equipment calibration, and maintenance functions.
- **Module 10: Plan and carry out periodic review of the WSP**
  This requires the team to meet regularly and review and update the WSP as required. A WSP can easily be out of date (e.g. with the departure of a WSP team member), and should be reviewed regularly (e.g. on a quarterly basis). When reviewing the WSP, new risks and control measures should be added to the WSP.
- **Module 11: Revise the WSP following an incident**
  The WSP should be reviewed after an incident occurs, and provides the WSP team an opportunity to reflect on the incident and the lessons learned from the incident. These lessons should feed back into the WSP, such that the WSP shows continual improvement with each revision.

5.2 Wastewater Risk Abatement Plan (W_2RAP)

A wastewater risk abatement plan (W_2RAP) is a risk-based assessment that aims to identify wastewater related risks, and to ensures that effective plans are put in place to reduce the impact of these risks, thus ensuring that wastewater is adequately "collected, treated and discharged or reused" (vd Merwe-Botha and Manus, 2011). Simplistically, the W_2RAP process could be considered like a WSP, but for wastewater. In South Africa, the W_2RAP process is a requirement of the DWS Green Drop Certification programme (vd Merwe-Botha and Manus, 2011). There are three essential components to the W_2RAP process including: (i) wastewater system assessment, (ii) risk assessment, and (iii) risk management. These components and their sub-components are briefly summarised below:

i.) Wastewater system assessment

- **Assemble the team to prepare the Wastewater Risk Abatement Plan (W_2RAP)**
  This requires a multi-disciplinary team with an understanding of the wastewater treatment systems, and who can develop and implement the W_2RAP. Typical members

may include engineers, wastewater quality specialists, wastewater treatment plant staff, decision-makers, etc.

- **Document and describe the system**

  This requires the team to collect and collate any information related to the wastewater system, and evaluate what the critical control points are in the system (i.e. identify where a problem will occur, from consumer (toilet) to the receiving environment). The team should also identify what could go wrong at each critical control point. A more comprehensive system description should include local climatic conditions.

- **Assess the existing or new system and compile a flow diagram**

  The assessment should be inclusive of all elements in the wastewater system, and a flow diagram should be developed. When assessing the system, the sensitivity of the system to contamination along the wastewater reticulation and treatment system should also be considered.

ii.) Risk Assessment

- **Undertake a hazard assessment and risk characterisation (and prioritisation) to identify and understand hazards**

  Hazard identification is required at each step of the wastewater reticulation and treatment system, so that adequate preventative measures can be identified and put in place. A risk assessment allows the determination of the impact of the risk on the system and to prioritise the risk accordingly. The risk can easily be determined using a risk matrix, which will assist the team to prioritise risks.

- **Identify control measures and develop preventative plans to control risks**

  Hazards identified require adequate control measures to ensure that impacts to the system are reduced if they occur. An important component of identifying control measures is to reassess the risk to determine the effectiveness of the control measures (i.e. has the risk been reduced after implementation of the control measure). Preventative maintenance plans should be developed for each control measure, and descriptions of the actions should be provided for the implementation.

iii.) Risk Management

- **Define monitoring of control measures – what limits define acceptable performance and how these are monitored**

  Monitoring of control measures is essential as it allows the operators to implement additional controls to reduce the impact of a hazard. Control measures may have defined operational limits for chemical, physical and microbial parameters.

- **Use credible technical information to validate that the control measures are effective in controlling the hazards**

  Control measures should be validated to ensure that they are effective and minimise the risk when a hazard occurs. This requires the team to evaluate technical information, wastewater quality data, equipment specification and evidence against the control measure performance. The validation process should consider literature and local standards/limits to ensure that the optimum results are achieved for the control measure.

- **Establish procedures to verify that the W$_2$RAP is working effectively and will meet the health-based targets**

Verification is the process of monitoring and analysis of treated effluent at various points in the treatment process, to ensure that the system is operating effectively. Analysis results should be compared to pre-defined standards for each parameter being measured.

- **Management procedures for wastewater treatment systems**
  Management procedures are defined actions to be taken when responding to an incident; to reduce the impact of the incident. These actions should be defined for likely incidents, and as far as possible for anticipated unlikely incidents. An example of a management procedure may include standard operating procedures, which guide staff personnel on what to do during 'normal' conditions and what to do during emergency conditions. Supporting programmes should also be considered when creating management procedures. Supporting programmes may be in the form of continued skills development and education, to ensure that plant personnel perform their tasks adequately.
- **Establish documentation and communication procedures.**
  The W_2RAP should be regularly updated with new information as and when it becomes available. The information also allows tracking the performance of system processes and assists to identify when replacement or maintenance of processes is required. The W_2RAP and associated wastewater quality monitoring data should be communicated to various stakeholders so as to ensure that when an incident occurs these stakeholders are aware of how the incident and implemented control measures may impact them.
- **Review of the W_2RAP**
  The W_2RAP should be reviewed following an incident, or if there has been a system change/upgrade. A W_2RAP review should be done to identify any gaps, but also to ensure that treated wastewater meets the required standards. Additional risks should be added to the W_2RAP during the review, and previously identified risks should be reviewed to check if they are still valid.

There is a strong link to the WSP and W_2RAP processes described above, as they have similar steps in common, however, they are specifically designed for use in water and wastewater systems respectively. There is also a strong emphasis on the risks to each type of system, and the need for effective control measures to reduce the impact of risks. There is also a need for the WSP processes and W_2RAP processes to include climate resilience, as the uncertainty of climate change may result in systems being under- and/or over-capacitated and unable to respond effectively (e.g. to an increased/reduced hydraulic load; increased concentration of contaminants, etc.).

5.3 Climate Resilient Water Safety Plans (CR-WSP)

The WSP process has evolved since its inception in 2009, and now also includes consideration of climate change and the need for climate resilience. The inclusion of climate resilience into the WSP process is to ensure continued sustainability of safe drinking water, under current and future climate conditions. Climate change is expected to introduce changes in temporal and spatial distribution of climate and weather-related events; as well as an increase in severe climate and weather-related events (such as floods, droughts, storms, etc.). This is expected to bring about challenges to water resources, as well as the ability of water utilities to provide adequate safe drinking water to consumers. Water scarce countries such as South Africa may be most affected as climate change will only worsen the current water scarcity issues (Schewe *et al.,* 2013). It is therefore essential that South African water utilities include climate resilience into their WSP processes to prepare for increased water scarcity.

The process of incorporating climate resilience builds on seven (7) of the traditional 11 WSP modules. Modules 1 to 5, 8 and 9 have been identified as those that need to be revised to include consideration of the impact of climate change. Numerous countries including Ethiopia, Nepal and Bangladesh have already developed and started to implement climate resilient WSPs. When incorporating climate resilience into these modules water utilities should consider:

(i) Which hazards and hazardous events are likely to worsen under the effects of climate change?
(ii) Are there emerging hazards and hazardous events that we have not previously considered?
(iii) What weather conditions are likely to cause them?

This will require the Water Services Institutions (WSIs) to source various datasets (e.g. rainfall, temperature), analyse and interpret the data, and importantly reach conclusions that allow appropriate action.

5.4 Climate Resilient Wastewater Risk Abatement Plans (CR-W_2RAP)

To-date, there has been no guidelines or manuals developed that address the concept of Climate Resilient Wastewater Risk Abatement Plans (CR-W_2RAP), and to the project teams' knowledge, formal development and implementation of a CR-W_2RAP process has not yet been done. In developing the CR-W_2RAP, the team aims to follow a similar approach to developing a CR-WSP, and the relevant sub-components of the W_2RAP will be amended to include climate resilience aspects. As previously noted, incorporating climate resilience into W_2RAP modules will require the WSI to source and interpret climate related datasets, and incorporate such findings into their CR-W_2RAP.

6. Methodology Developed to Draw Basic Climate Impact Conclusions

6.1 Accessing climate information

6.1.1 Availability, accessibility, and ease of use

Incorporating climate resilience into your WSP and W_2RAP processes requires an understanding of the historical climate, climate trends and climate projections (future scenarios). An understanding of this information and the impact climate change will have on your system will inform the required steps to become resilient. However, before resilience can be incorporated into your WSP and W_2RAP processes, it is necessary to consider the type of information needed for your system, and the availability, ease of access, and the ease of using that information to support WSP and W_2RAP. It is strongly advised that one first considers data and information that requires limited processing and has already been analysed and/or summarized by technical experts. By way of example, if your WTW or WWTW has limited technical capacity or resources, data/information could be gathered through local and expert stakeholders accounts (e.g. via focus group discussions or workshops). Climate reports such as synthesis reports or climate vulnerability assessments are good examples of reports that contain "already analysed and/or summarized" information. Climate reports typically contain qualitative/quantitative information and summaries/conclusions of relevance to your water and wastewater systems.

If your WTW or WWTW has moderate to high technical capacity or resources, other data sources such as interactive web-tools that provide access to "already analysed and/or summarized" data can be used with relative ease. In some cases, your WSP or W_2RAP team may have access to data sources not available elsewhere. By way of example, hourly inflow or outflow totals into the WTW or WWTW that are collected at the inlets and outlets, they can be analysed graphically with relative ease by your team.

If your WTW or WWTW has high technical capacity and resources that are able to analyse and interpret "raw" data/information using complicated and advanced technical skills/tools/model, data and information can be accessed from data portals. An example of this may be hydrological models that use various inputs such as rainfall, soil moisture, topography, and potential evapotranspiration to produce estimates of runoff or river flow, which can in turn be used to estimate the quantity and quality of water resources.

Regardless of your capacity and resources, WSP and W_2RAP teams are strongly encouraged to start simple (i.e. consider approach 1), and incrementally improve over time (i.e. consider approach 2 and approach 3).

6.1.2 Geographic scale

Typically, climate information may only be available at the local planning level if you have a very well-established monitoring network. Climate information accessed from climate reports, interactive web-tools or other sources may be available at various spatial scales. The spatial scale that you access data/information at, may vary depending on your system and is dependent on your available monitoring network (Figure 21).

- Local
- Sub-national
- National
- Transnational
- Continental
- Global

High resolution					Low Resolution
Local	Sub-National	National	Transnational	Continental	Global
Most appropriate at local planning level		Increased complexity of understanding local level problems with decreasing resolution		Least appropriate at local planning level	

Figure 21: *Appropriateness of data at various levels*

6.1.3 Identifying the time scale of data

Climate information can span various time scales such as historic scales (last 30 or more years), recent scales (last 10 years to present) or future scales (climate projections). Figure 22 describes these scales and the type of information available at each scale.

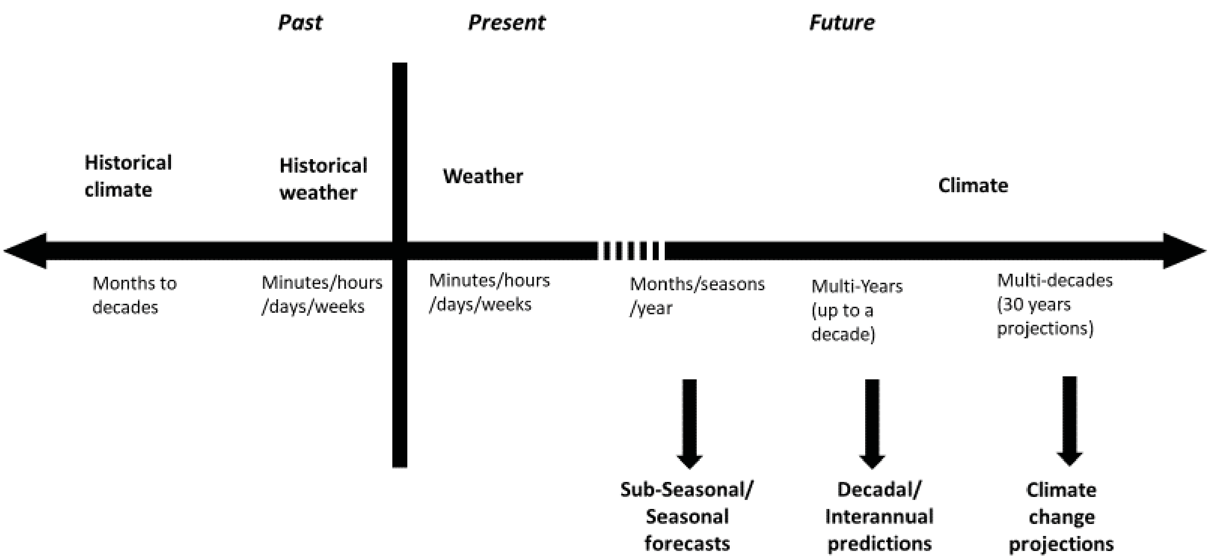


Figure 22: *Information accessible at different timescales (Soares et al., 2018)*

Analysis of historical information will provide you with historical patterns of climate variables (e.g. observed pattern of rainfall and temperature across the region, variability throughout the year, seasonal patterns). Additionally, the pattern of extremes such as heatwaves, droughts, high intensity rainfall events and flooding may also be observed/detected through analysis of historical data.

Moving to the right of the Figure 22 (i.e. the present to near future), weather monitoring and forecasting for periods of 1 day to several weeks or even seasons are covered. The terms seasonal (or sub-seasonal) considers longer periods such as months and up to a year. Seasonal forecasts can be useful in water resources planning, as this can inform decisions of whether water restrictions need to be implemented, and the extent to which they need to be implemented. Further along, climate predictions model future climate possibilities over time scales of multiple decades.

For the purposes of WSPs and W_2RAPs, recent and historical climate observations are likely to be very useful. Recent climate data/information describes the conditions that have been experienced in the recent past, which includes its pattern of variability and extremes. This type of information will inform decisions such as how to operate water storage infrastructure, or required mitigation measures, and provides an indication of the likely climate trend that could continue. Finally, climate forecasting and projections remain useful especially for longer term planning and are likely to be valuable to WSP or W_2RAP teams. Despite the uncertainties associated with climate projections, they still provide information as to how key climate variables may change. It may indicate to planners whether flooding will likely increase, or if dry period frequency and length will increase. However, a key challenge facing teams is that this information may not always be available.

WSP and W_2RAP teams need to consider which time scales are appropriate for planning purposes as it may vary depending on the local context, resources, and capacity. In those instances, whereby capacity and resources are low, the team may want to prioritize nearer-term information for shorter term planning (e.g. seasonal-year). However, where resources and capacity allow, the teams are encouraged to plan for future scenarios (i.e. 30-year scenarios) and therefore need corresponding longer-term information.

6.1.4 Data quality and completeness

WSP and W_2RAP teams should, where possible, give preference to those data sources where, at least some, data quality control has been undertaken. It is recommended that the teams consider those data sources that are trustworthy and reliable (e.g. national meteorological services or respected international agencies). WSP teams should also be aware that there may be monitoring gaps in the records. This could be due to faulty equipment, budgetary issues, or political issues; however, this data/information may still be useful.

6.2 Selecting climate information analysts or an analysis team

The current expertise of the WSP and W_2RAP teams should be reviewed and, where required, additional members that include technical climate specialists should be considered. The technical specialist will assist with climate data retrieval and analysis. The inclusion of technical specialists is covered in more detail in Section 7 'Incorporating Climate Information into Water Safety Planning into the WSP and Section 8 Incorporating Climate Information into W_2RAP'. The main aim of the extended/expanded team is to collect and analyse data in the various forms (interviews, reports, news media, graphs, tables, etc.) (Figure 23). Not all members of the expanded team (data analysts) need to be permanent members. Rather, they can be ad-hoc members and their contributions can be made on an as and when needed basis.

Figure 23: *WSP and W_2RAP teams engaging and assessing climate data*

6.3 Approaches to accessing data/information

The data/information sources found in **Appendix A** can be divided into three basic approaches, as follows:

- **Approach 1:** Working with stakeholders/expert groups to understand climate risks,
- **Approach 2:** Accessing existing climate reports (such as Climate Vulnerability Assessments (CVAs)),
- **Approach 3:** Using existing web-based tools to access/analyse historical and predicted climate related data (for example interactive web-portals that allow users to add and remove "layers" of climate information, such as FDMT and climatewizard.org)

As mentioned above, three distinct approaches are presented each describing how and where, to access and interpret climate information. When following these approaches, the WSP and W_2RAP teams may find that one approach does not meet all their needs due to information gaps, such limited stakeholder knowledge. **It is therefore strongly recommended that WSP and W_2RAP teams start simple with an approach that requires limited resources and capacity (e.g. approach 1) and progress to more sophisticated approaches as capacity/skills/experience/support permits**. The WSP and W_2RAP teams may also need to consider using a combination of the various approaches. For example, focus group meetings (Approach 1) can be informed/supplemented with review of existing climate information summaries (e.g. CVA or similar, Approach 2). This is in line with the WSP and W_2RAP approach, which promotes the concepts of flexibility and incremental improvement (Table 5).

It is important that you consider each of the three approaches before deciding which approach or combination of approaches suits your context the best. The team should, therefore, carefully study the climate resources information **(Appendix A).** Below you will find a basic selection form, to assist you with selecting the most appropriate approach. However, the team is encouraged to review all streams before making a final decision (Table 5).

NOTE: You are encouraged to start simple and as your CR-WSP and CR-W_2RAP develops and more detailed information is required, refer to other approaches. Information that is more detailed requires technical expertise that your WSP or W_2RAP team may not readily have.

Table 5: Approach selection form

Information type	Description	Target audience	Capacity/Resources required	Should we use this information?
Approach 1 – Stakeholders engagement	Information is in the form of stakeholder interviews	Generalists	Low capacity and required. Target audience only need a basic understanding of climate change and the effects of climate change. ***Ease of use: +***	Do you think you are able to use this approach to make conclusions such as changes in rainfall and temperature trends, changes in sea level, increases or decreases of floods and drought? If 'Yes' refer to section 6.3 of this guide for steps on how to conduct the process. If 'No' review, the other approaches on this assessment form and select one.
Approach 2 – Climate reports	Summarised information is typically contained in an existing climate report/s. Information is readily available within the report and readily analysed and provides information on climate impacts. retrieving information requires accessing the report/s for the area or region	Generalists	Requires some degree of knowledge of data/information analysis, as most outputs are in the forms of graphs/maps ***Ease of use: + +***	Do you think you are able to use this approach to make such as changes in rainfall and temperature trends, changes in sea level, increases or decreases of floods and drought, and climate projections? If 'Yes' refer to section 6.4 of this guide for steps on how to conduct the process. If 'No' review, the other approaches on this assessment form and select one.
Approach 3 – Interactive web-tools	Provides users with access to 'big' datasets and displays data in various formats such as maps and graphs. Requires at least a minimum level of technical skill for analysis.	Technical specialists	High level technical expertise required, with access to technology, to access and retrieve information ***Ease of use: + + +***	Do you think you are able to use this approach to make conclusions such as changes in rainfall and temperature trends, changes in sea level, increases or decreases of floods and drought, and climate projections? If 'Yes' refer to section 6.5 of this guide for steps on how to conduct the process. If 'No' review, the other approaches on this assessment form and select one.

Ease of use rating: + low capacity/resources with only general knowledge required; + + requires some degree of technical expertise to understand and interpret graphs and maps; + + + requires high level of technical expertise, access to technology, and ability to access and understand various type of information

6.3.1 Approach 1: Stakeholder engagement

Stakeholder engagement refers to information gathering from engaging with technical experts, locals and other institutions. During stakeholder engagements the teams are more likely to receive anecdotal accounts of when, for example, floods have occurred and the number of occurrences within a certain period, and the observed changes in frequency, severity and geographical range rather than scientifically reliable data. By way of example, you may find a local has recorded information on flooding events for the last 30 years.

> A good starting point when engaging stakeholders is to first engage the various WSP and W_2RAP team members, and their respective institutions. You might find that the WSP and W_2RAP team members or their institutions already have some of this knowledge readily available. After you have consulted your WSP or W_2RAP team, you may have already developed a clear understanding of the system, and what additional information is required and which stakeholders to approach.

This type of information has applications for water utilities of all capacities (more especially those with limited capacity to access and analyse raw datasets), and it can be considered as a starting point used to gain a broad understanding of the impacts of climate change within an area. Furthermore, many local people have an excellent understanding of their areas and may recall the occurrence of major climate events.

Type of information

The table below captures some examples of the types of information and the potential sources of information that may assist you in developing your WSP (Table 6).

Table 6: Examples of anecdotal information and possible sources

Type of information	Sources of information
Technical expert knowledge	Climatologists, hydrologists, Managers, decision makers, etc.
Local knowledge	Farmers, academics (e.g. climatologists, hydrologists), disaster managers, focus groups with local councillors, water user group representatives
Local institutions	Local weather bureau, department of water
Other?	

Processing information

The steps to follow when working with stakeholders, expert groups and are outlined below. The steps for this section are summarised in Table 7. Each step is covered in more detail after the table.

Table 7: *Summary of steps for stakeholder engagement*

Step	Description	Examples	Action
1. Focus group discussions	Focus group discussions to gather local knowledge of local climate and area	Discussions with water resource managers, experts, academics, locals, etc.	Arrange Focus group discussions special invitation or by placing a notice or advert in a newspaper, bulletin board or municipal website, etc.
2. Question the focus group	Ask the group questions about changes in local climate variable such as temperature, river flows, sea levels etc.	i. What is the historic pattern of surface temperature within the region? ii. How long do flows last? iii. How have sea levels varied in the past?	Prepare a list of questions to ask during Focus Group discussions. Appendix A provides examples of questions. Questions should be asked of temperature, rainfall, sea levels, etc.
3. Summarize climate information	Capture and summarize climate information in a table	i. Increased temperatures ii. Increased rainfall iii. Etc.	Complete 'Climate hazard' column of the climate information analysis summary table in Appendix B (refer to Table 1 for guidance). Add all the changes in climatic conditions to this column, this should be based on the Focus group discussions.
4. Identify threats	Identify threats that have occurred in your area, those threats that have worsened.	i. Flooding ii. Droughts iii. Landslides iv. Etc.	Develop a list of climate threats that are occur in your area.
5. When do threats occur	What weather/climate conditions do threats occur under, i.e. what conditions result in floods, droughts etc.	i. Flooding occurs during periods of high rainfall ii. Droughts occur during periods of low rainfall (usually over a few years) iii. Etc.	Associate the threats you have identified in Step 4 with the climate conditions under which they occur.
6. Site Visit	Do a site visit to determine which processes are likely to be affected by climate threats.	i. High rainfall can result in flooding at the inlet works ii. Droughts can result in high concentrations of contaminants	Do a site visit and ask questions of your team and plant staff as to what is likely to go wrong at each process. Complete the 'Climate threats' column, refer to Table 1 for guidance.
7. Threat impact	Identify, based on focus group discussions, the primary impact of each threat under the changes in climate conditions.	i. Primary impact of drought – reduced water for supply ii. Primary impact of erratic rainfall – reduced water for groundwater recharge	Complete 'Primary Impacts' of the column of the climate information analysis summary table in Appendix C (refer to Table 1 for guidance). Add all identified primary impacts to this column

		iii. Etc.	
8. Changes in geographical range of threats	Ask the stakeholders what their observations are on threats moving/expanding into different areas are, i.e. has a threat that was typically localised to a specific area been occurring in different areas.	i. The focus group may indicate that flooding is occurring in areas that previously never experienced floods. ii. Storm surge is more frequent in coastal areas	Based on your findings complete 'Impact on water supply and wastewater treatment systems' column of the climate information analysis summary table in Appendix C (refer to Table 1 for guidance). Add all identified impacts to this column.

Step 1 Arrange focus group discussions with relevant stakeholders such as technical experts, locals, and local institutions

- The purpose of the focus group meeting should be to gather local knowledge and understanding of the area. Therefore, there should be limited engagement with climate reports and raw data, unless required.
- Focus group meetings can be arranged by special invitation or by placing a notice or advert in a newspaper, bulletin board or municipal website with the agenda discussion/workshop.

Step 2 The stakeholders need to be interrogated to determine the effects of climate change in the area as observed by the interested and affected parties. The following questions could be used as a guide during your stakeholder engagements:

i. What is the historic pattern of surface temperature within the region?
ii. What are the seasonal temperature patterns? Have these changed?
iii. What is the trend of extreme temperature (both high and low temperatures)?
iv. What are seasonal precipitation patterns? Have these changed?
v. How variable are historical rainfalls?
vi. What is the trend of extreme precipitation?
vii. What is the trend of historic river flows within the region?
viii. What are the water levels of extreme peak flows?
ix. How long do flows last?
x. What is the history of flooding?
xi. What is the duration of flooding?
xii. How often do floods occur within the region?

xiii. How do water storage levels vary?

xiv. How long do low water levels persist?

xv. What is the history of drought in the region?

xvi. How do aquifer levels vary? (may be limited to areas that have a high dependence on groundwater)

xvii. How have sea levels varied in the past?

xviii. What are the projections for the future and how may this impact water supply, from catchment to consumer?

Step 3: Summarise the information in table.

Action

Based on your findings complete 'Climate hazard' column of the climate information analysis summary table (template provided in guideline document). Add all the changes in climatic conditions to this column.

Step 4. The types of threats related to the observed changes in climate conditions will be covered below. During your stakeholder engagements, you may note stakeholders indicate that under certain conditions certain threats occur. By way of example, floods are linked to increased rainfall and intensity, or heat stress is linked to abnormally high temperatures. Therefore, you should try to determine this during threat identification.

A generic list of typical threats experienced in South Africa has been developed. This list should be used as a starting point when identifying threats and is included in the accompanying guidance document.

Not all of these threats may be applicable to your area (for instance inland areas will not be affected by saline intrusion), and there may be other threats relevant to your situation that have not been listed. Therefore, the type of threats should be considered during the focus group discussions. The threat list should be expanded to include additional threats identified. This is a key step as, not all threats will occur in any one area, for instance inland areas are less susceptible to saline intrusion. Therefore, planning and resources can be effectively allocated to the relevant threats.

Step 5 Determine when a threat typically occurs.

- Ask the stakeholders what types of threats have occurred their area.
- Ask the stakeholders what type of weather conditions brought about these threats.
  - This requires that you to associate the identified threats with certain climate conditions (e.g. heat stress caused by high temperatures occurs in the hot/dry season)

Step 6 Site visit to determine susceptibility to threats.

- Based on the threats identified above, determine which threats are relevant to the different parts of the system

By way of example:

- The catchment area is susceptible to erosion and loss of riverbed depth, during periods of increased flows.
- The water treatment plant is susceptible to flooding and loss of treatment capacity, during periods of increased rainfall.

TIP: During your site visit, as you arrive at each of the various system components consider the following.
Ask questions of yourselves and of supplier staff, for example:

i. What could go wrong here?
ii. What steps are currently taken to stop that from happening?
iii. What evidence is there that those measures do (or do not) work?
iv. What is the impact on local water resources, if this component fails?
v. What is the effect on water supply if this component fails?

Action

Based on your findings complete 'Climate threat' of the column of the climate information analysis summary table in (template provided in guideline document). Add all identified climate threats to this column.

Step 7 You should identify, based on focus group discussions, the primary impact of each threat under the changes in climate conditions.

By way of example:

i. Primary impact of drought – reduced water for supply
ii. Primary impact of erratic rainfall – reduced water for groundwater recharge

Action

Based on your findings complete the 'Primary impact' column of the climate information analysis summary table in (template provided in guideline document). Add all identified primary impacts to this column.

This may require additional discussions with municipal/government officials to understand impacts of threats.

Step 8 Identify the changes in geographical range from local accounts and technical expert input.

- Ask the stakeholders what their observations are on threats moving/expanding into different areas are, i.e. has a threat that was typically localised to a specific area been occurring in different areas.

- Technical experts can provide you with a clear indication of past incidences and locations especially those who are involved in disaster or emergency relief (Figure 24).

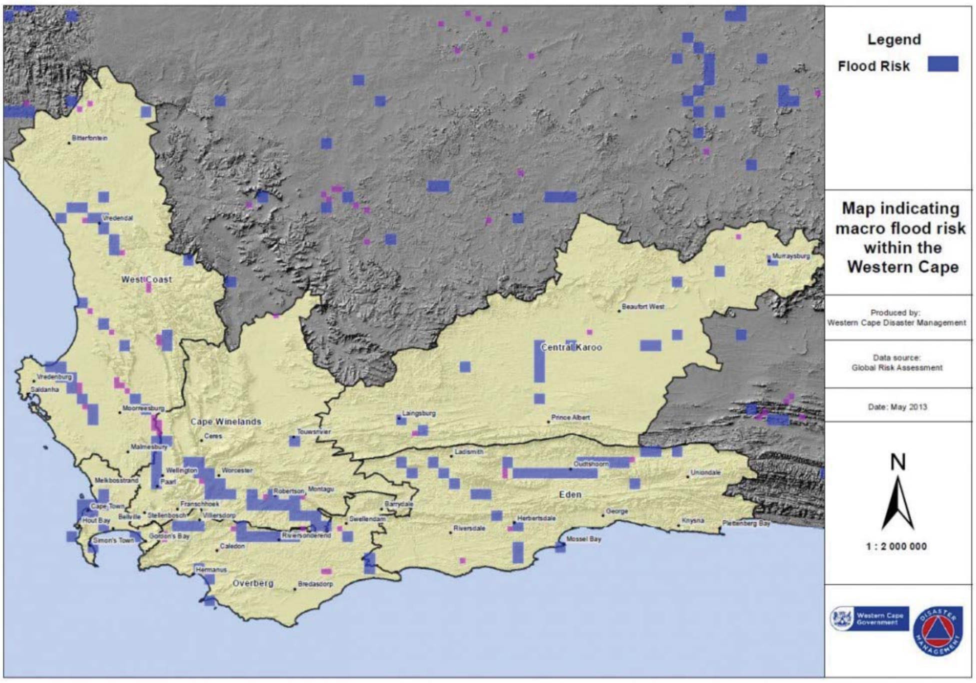


Figure 24: *Example of a disaster map indicating the areas affected by flooding in the Western Cape (Source: Western Cape govt, 2012).*

- Ask the stakeholders what the impact of the threat in the new area is.
  - A threat expanding into a new area/s may have a low impact at present, but may worsen over time, and therefore requires monitoring.

Action

Based on your findings complete 'Impact on water and wastewater treatment systems' column of the climate information analysis summary table in (template provided in guideline document). Add all identified impacts to this column.

Summarising stakeholders, expert groups information

The team should consider the following questions to summarise the information gathered when reviewing focus group accounts:

- What is the information indicating about medium- to long-term trends in rainfall and temperature?
- What is the information saying about climate threats and the occurrence of the various threats?
- What are the impacts of these threats, and is the impact increasing?
- What are the key information gaps and unknowns/uncertainties?
- Which WSP/W$_2$RAP steps should be amended to incorporate the findings from the report/s?
- Considering the information gathered from report/s, which hazards and hazardous events are highest priority? Make a list documenting the priority hazards and hazardous events.

6.3.2 *Approach 2: Accessing existing climate reports*

Climate reports are comprehensive assessments about the knowledge of climate change, its causes, and potential impacts. In South Africa, SAWS and DEA publish annual climate summary reports, and additional information on climate vulnerability can be found on the 'Lets respond toolkit'. Climate reports may include national level, regional level, or sometimes even local level reports. Climate reports such as Climate Vulnerability Assessments (CVAs) can be a very useful source of information to use, as the threats and impacts associated with climate change for a country or region are already collated into one document using qualitative/quantitative information sources. Although other types of climate reports exist (e.g. synthesis reports, impact and adaptation reports, mitigation reports, etc.), climate assessments, which include risk and vulnerability assessment reports, for South Africa referred to. Where they exist, CVAs for WASH and climate change should be used. Where resources permit, undertaking a climate change and WASH CVA can be highly useful to inform local-level water safety and wastewater risk abatement planning. These reports do not provide raw data; rather they provide information on climate vulnerability based on a completed analysis of raw data and focus group discussions. South African climate reports are easily sourced as they can be retrieved online, or directly from the relevant organization/institution that has completed the report (Refer to **Appendix A** for a list of climate reports and where to access them). The geographical range covered by threats are also mapped.

Outputs from a climate assessment report

Outputs from climate assessment reports inform water safety planning and wastewater risk abatement planning. A national or regional CVA could produce the following information that is useful for, among other uses, the WSP and W_2RAP:

- A detailed understanding of current climate change impacts as well as future risks, such as flooding, increased sea level rise, increase temperature, and saltwater intrusion that could impact wastewater treatment and water supply and safety and ultimately health.
- Qualitative or quantitative estimates, forecasts, and projections of changes to key parameters, such as precipitation, temperature and river flows, under climate change scenarios. Average values are useful as well as information on the extremes. These could include the number of hot days or intense precipitation.
- Information on the likelihood and magnitude of extreme weather events, such as storms, floods and droughts, in both the current and future scenarios.
- Implications for water resources in the region, such as the threats to existing sources and the need to identify new water sources.

CVA studies can range from simple review studies to complete integrated assessments. The information-sourced from such reports has applications for all WSP and W_2RAP teams (i.e. teams with both limited/low technical capacity and high technical capacity). Teams should study the report/s to identify and catalogue the types of threats that are relevant to your area.

Type of information

The following table captures some examples of the type of information and their description found in these qualitative reports that may assist utilities in preparing for climate resilience (Table 8).

Table 8: Examples of information found in a climate vulnerability report

Type of information	Description
Climate information	The differences in climatic regions for an area/region of focus
Geographical range of threats	Maps indicating flood-prone zones, drought-prone zones, saline intrusion zones, etc.
Frequency change	Changes in frequency of floods, droughts, stream flow change, etc.
Meteorological changes	Changes in long-term temperature, long-term rainfall, and the natural disaster associated with these changes' typhoons, etc.
List of climate related threats	Fires, floods, droughts, storm surge, erosion, etc.
Focus group perceptions on natural disasters	The observations of climate change made by local community members
Other?	

Processing Information

The steps to follow when processing the information found in the qualitative reports are outlined below. The steps for this section are summarised in Table 9. Each step is covered in more detail after the table.

Table 9: Summary of steps for assessing climate reports

Step	Description	Examples	Action
1. Retrieve your climate assessment report	Retrieve climate assessment report/s for South Africa, and where available for your province or local or neighbouring area.	Examples include reviewing most recent: i. Climate change risk and vulnerability assessments (e.g. for a province, district or for function – e.g. rural human settlements ii. Annual state of climate summary for South Africa iii. Etc.	Refer to the resources list for South Africa for climate assessment reports links to access each report, Appendix A
2. Review your Climate assessment report	Review the climate assessment report to determine how historical climate has changed over time. Ask questions of the information, to determine changes in local climate variable such as temperature, river flows, sea levels, etc.	i. What do the graphs/tables indicate about the historic pattern of surface temperature within the region? ii. What do the graphs/tables indicate about how long do flows last? iii. What do the graphs/tables indicate about how have sea levels varied in the past?	Prepare a list of questions to ask of the information contained in the climate assessment report. Appendix A provides examples of questions. Questions should be asked of temperature, rainfall, sea levels, etc.
3. Summarise climate information	Capture and summarise climate information in a table	i. Increased temperatures ii. Increased Rainfall iii. Decreased river flows iv. Etc.	Complete 'Climate hazard' column of the climate information analysis summary table in Appendix B (refer to Table 1 for guidance). Add all the changes in climatic conditions to this column, this should be based on the Climate assessment.
4. Identify threats	During review of the climate assessment report, identify which threats typically occur in your area/region	i. Flooding ii. Droughts iii. Landslides iv. Etc.	Develop a list of climate threats that are occur in your area. Use the climate assessment report to identify these typical threats.
5. When do threats occur	What weather/climate conditions do threats occur under, i.e. what conditions result in floods, droughts, etc.	i. Flooding occurs during periods of high rainfall ii. Droughts occur during periods of low rainfall (usually over a few years) iii. Etc.	Associate the threats you have identified in Step 4 with the climate conditions under which they occur. By way of example, droughts in the Western Cape are caused during periods of reduced rainfall and increases in temperatures typically brought about by El Nino conditions.

Step	Description	Examples	Action
6. Site Visit	Do a site visit to determine which processes are likely to be affected by climate threats	i. High rainfall can result in flooding at the inlet works ii. Droughts can result in high concentrations of contaminants	Do a site visit and ask questions of your team and plant staff as to what is likely to go wrong at each process. Complete the 'Climate threats' column, refer to Table 1 for guidance.
7. Threat impact	Identify, the primary impact of each threat under the changes in climate conditions	i. Primary impact of drought – reduced water for supply ii. Primary impact of erratic rainfall – reduced water for groundwater recharge iii. Etc.	Complete 'Primary impacts' of the column of the climate information analysis summary table in Appendix C (refer to Table 1 for guidance). Add all identified primary impacts to this column. Examples can be easily found in the CSIR Climate Risk and Vulnerability Assessment Report (2017)
8. Changes in geographical range of threats	Review your climate assessment report and identify which threats are moving/expanding into different areas are, i.e. has a threat that was typically localised to a specific area been occurring in different areas. Use projection maps to determine which areas will be affected by your identified threats in the future	i. The climate assessment reports may indicate that flooding that flooding is occurring in areas that previously never experienced floods, or that flooding will expand to other areas in future. ii. Storm surge is more frequent in coastal areas, and the area affected will increase in future.	Based on your findings complete 'Impact on water supply and wastewater treatment systems' column of the climate information analysis summary table in Appendix C (refer to Table 1 for guidance). Add all identified impacts to this column.

Step 1 Retrieve climate assessment report/s for South Africa, and where available for your province or local or neighbouring area.

- Most climate summaries developed in South Africa are available online and can be readily downloaded or obtained directly from the organization/institution that developed the report. Key examples of existing CVAs (or similar) are presented **Appendix A**.

Step 2 You need to review the climate assessment report to determine how historical climate has changed over time (By way of example, this information is easily found in the "*SAWS Annual state of climate at a provincial scale*" reports). You should analyse the various graphs and maps to determine if there are changes in climate variables. When reviewing the climate assessment reports ask the following questions of the information:

i. What is the historic pattern of surface temperature within the region?

ii. What is the trend of extreme temperature (both high and low temperatures)?
iii. How is temperature projected to changes?
iv. What are seasonal precipitation patterns? Have these changed?
v. How variable is historical precipitation?
vi. What is the trend of extreme precipitation?
vii. How is precipitation projected changed?
viii. What is the trend of historic river flows within the region?
ix. What are the water levels of extreme peak flows?
x. How long do flows last?
xi. How is the pattern of river flows projected to change?
xii. What is the history of flooding?
xiii. What is the duration of flooding?
xiv. How often, do floods occur within the region?
xv. How is the pattern of flooding projected to change?
xvi. How do water storage levels vary?
xvii. How long do low water levels persist?
xviii. What is the history of drought in the region?
xix. How is the pattern of droughts expected to change?
xx. How do aquifer levels vary? (may be limited to areas that have a high dependence of groundwater)
xxi. How are these likely to change under changing precipitation patterns?
xxii. How have sea levels varied in the past?
xxiii. What are the projections of seas level rise?
xxiv. What are the projections for the future and how may this impact water supply, from catchment to consumer?

The above questions can be relatively easily answered by reviewing the climate assessment reports. By way of example:

- The *Climate change risk and vulnerability assessment for rural human settlements* (2013), contains information on sea level rise, flooding, and droughts.
- The *SAWS – Annual state of climate reports* provide information on long-term rainfall at a provincial level.
- You will need to assess the long-term temperature and rainfall graphs found in the assessment reports.
  - By way of example Figure 25 indicates that temperatures over Southern Africa have been increasing since the 1970s. This has resulted in significantly warmer periods.

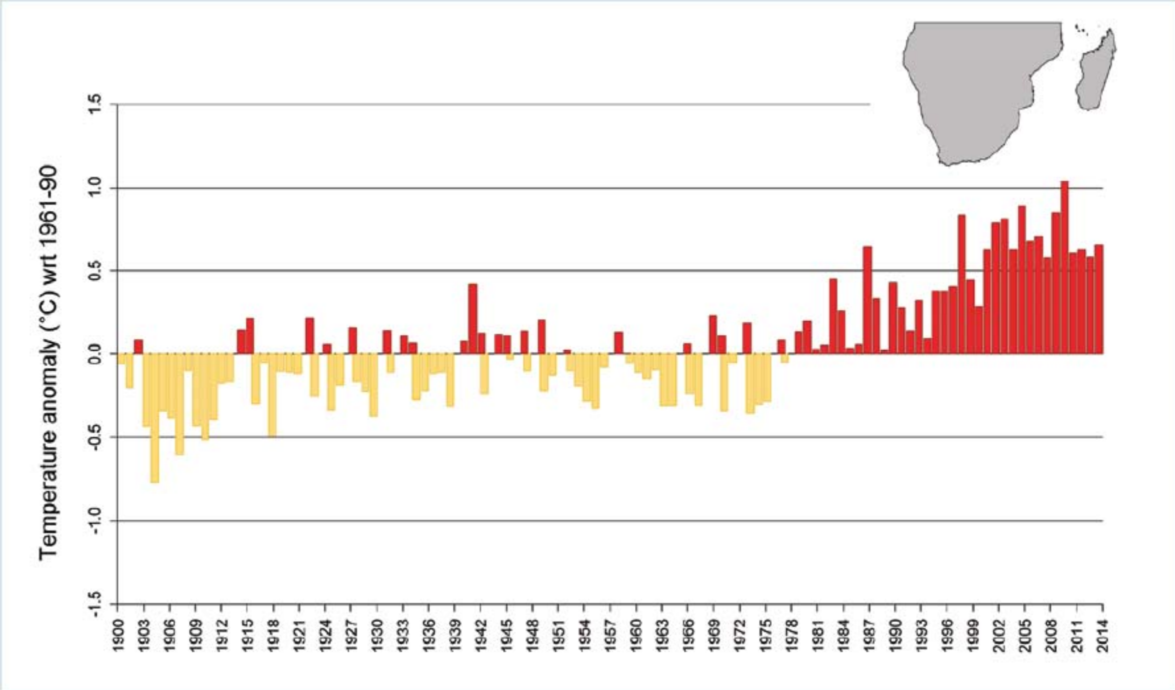


Figure 25: *Example of the type of graphs found in CVA reports (CSIR, 2017)*

Step 3 Summarise the information in table

Action

Based on your findings complete 'Climate hazard' column of the climate information analysis summary table in (template provided in guideline document). Add all the changes in climatic conditions to this column.

Step 4 Identify threats

During review of the climate assessment report, identify which threats typically occur in your area/region. Threats may be strongly linked to climate conditions experienced in an area (e.g. floods are linked to increased rainfall, or heat stress is linked to increased temperature). Therefore, consider the types of threats that may occur and the conditions under which they occur.

Examples of threats typical to South Africa can be found in:

- the *CSIR Climate Risk and Vulnerability Assessment Report* (2017).
- the *SAWS – Annual state of climate reports* (which provide information on major events that occurred in the last year at a provincial scale).

A generic list of threats has been developed, which includes typical threats experienced in South Africa (see guideline document)**.** You should consult this list (and relevant climate reports) to identify which of these threats are applicable to your area. This list should be used as a starting point when identifying threats.

Not all of these threats may be applicable to your area (for instance inland areas will not be affected by saline intrusion), and there may be other threats relevant to your situation. Therefore, the type of threats should be considered during literature review. The threat list should be expanded to include additional threats identified. This is a key step as, not all threats will occur in any one area, for instance inland areas are less susceptible to saline intrusion. Therefore, planning and resources can be effectively allocated to the relevant threats.

Action:

Based on your findings complete 'Climate threat' column of the climate information analysis summary table (template provided in guideline document). Add all identified climate threats to this column.

Step 5 Determine the conditions that cause a threat to occur
You need to associate the threats you identified in the previous step for certain climate conditions. By way of example, droughts in the Western Cape are caused during periods of reduced rainfall and increases in temperatures typically brought about by El Nino conditions (Figure 26). The *CSIR Climate Risk and Vulnerability Assessment Report* (2017) provides very good examples of the conditions that bring about floods, droughts, and veld fires.

Figure 26: *Droughts have resulted in low dam storage levels in Theewaterskloof, picture taken in January 2019*

Step 6 Site visit to determine susceptibility to threats

- Identify which threats are relevant to the different parts of the system.

    - System components may include grey (built, engineered) and green (natural) infrastructure. The importance of green infrastructure that may unknowingly already serve as control measures should not be ignored (e.g. indigenous vegetation found in catchments reduce the amount of sediment entering the dams).
- Based on the threats identified above, determine which threats are relevant to the different parts of the water and wastewater systems.

By way of example:

- The inlet works of the water/wastewater treatment works is susceptible to flooding and loss of treatment capacity during periods of increased rainfall and the ingress of stormwater.

When you arrive at each of the various system components consider the following questions of yourselves and of supplier staff, for example:

i. What could go wrong here?
ii. What steps are currently taken to stop that from happening?
iii. What evidence is there that those measures do (or do not) work?

Identify which parts of your system will be affected by a climate threat

When identifying which parts of your system are susceptible to a threat, you may find it useful to do a site visit or use a diagram of the system and mark which areas are likely to be impacted (Figure 27). This will provide you with a better understanding of which parts of the system are most vulnerable, and where resources should be allocated to implement additional control measures or amend/strengthen existing control measures. Points in the system that require prioritisation should be ranked using a numbering or colour coding system, to highlight the system components facing the highest risk. Updating your system diagram is covered in WSP module 2 and W$_2$RAP Step 2.

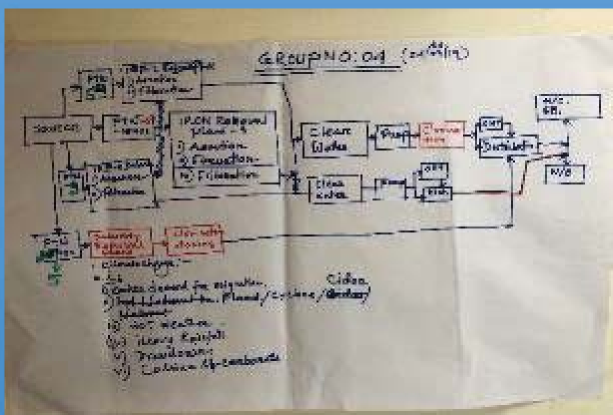


Figure 27: *A team doing a site visit to identify threats to their system. A diagram of the system being assessed.*

Step 7 Identify changes in impact

You should identify, based on your review of the climate assessment report, the primary impact of each threat under the changes in climate conditions.

By way of example:

i. Primary impact of below average rainfall – reduced water available for supply during dry months
ii. Primary impact of sinkholes – surface land damage

Additional information related to threats and their impacts can be found in the *CSIR Climate Risk and Vulnerability Assessment Report* (2017) (Figure 28).

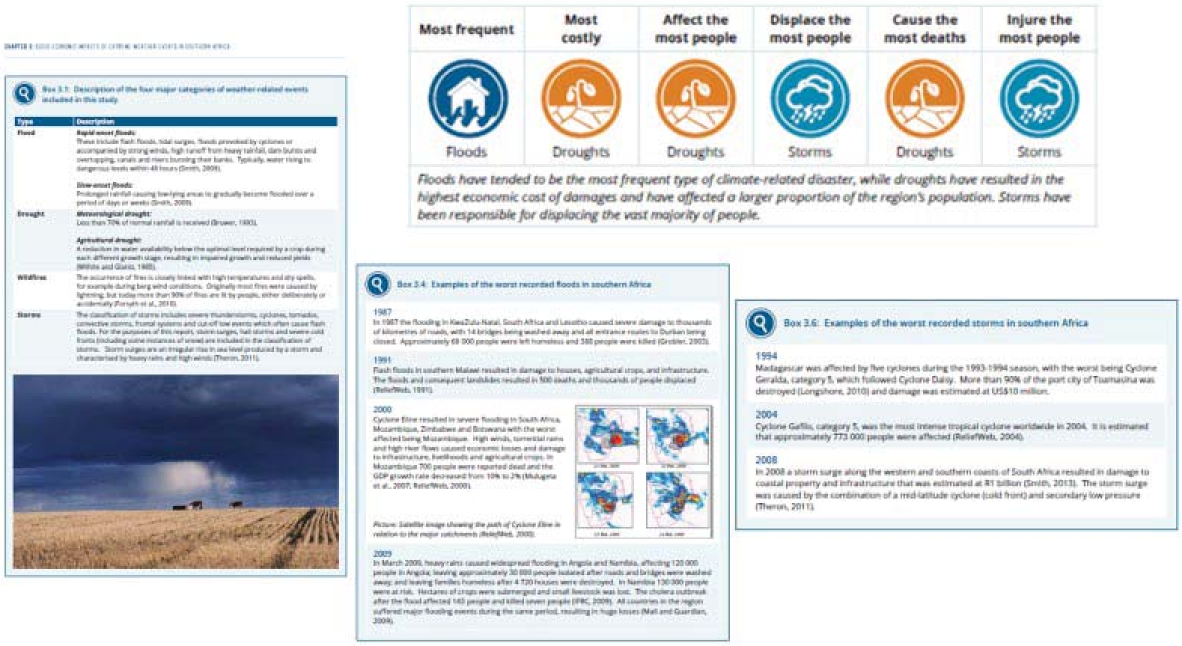


Figure 28: *Examples of threat and impact information from climate assessments (CSIR, 2017)*

Impacts may be strongly linked to past experiences of threats, which may be captured in the climate assessment reports. The losses and damage caused by threats, as well the intensity of threats (e.g. annual climate summaries may report on the threats that were experienced in an area or region). When reviewing, consider the following:

i. What is the impact on local water resources?
ii. What is the effect on water or wastewater treatment?

Action

Based on your findings complete the 'Primary impact' column of the climate information analysis summary table in (template provided in guideline document). Add all identified primary impacts to this column.

Step 8: Identify the change in geographical range of threats

- This can be done by using disaster maps to identify the areas affected by each threat. Climate vulnerability reports typically include maps that show the vulnerability of an area to a threat (at present as well as the expected future change) (Figure 29).

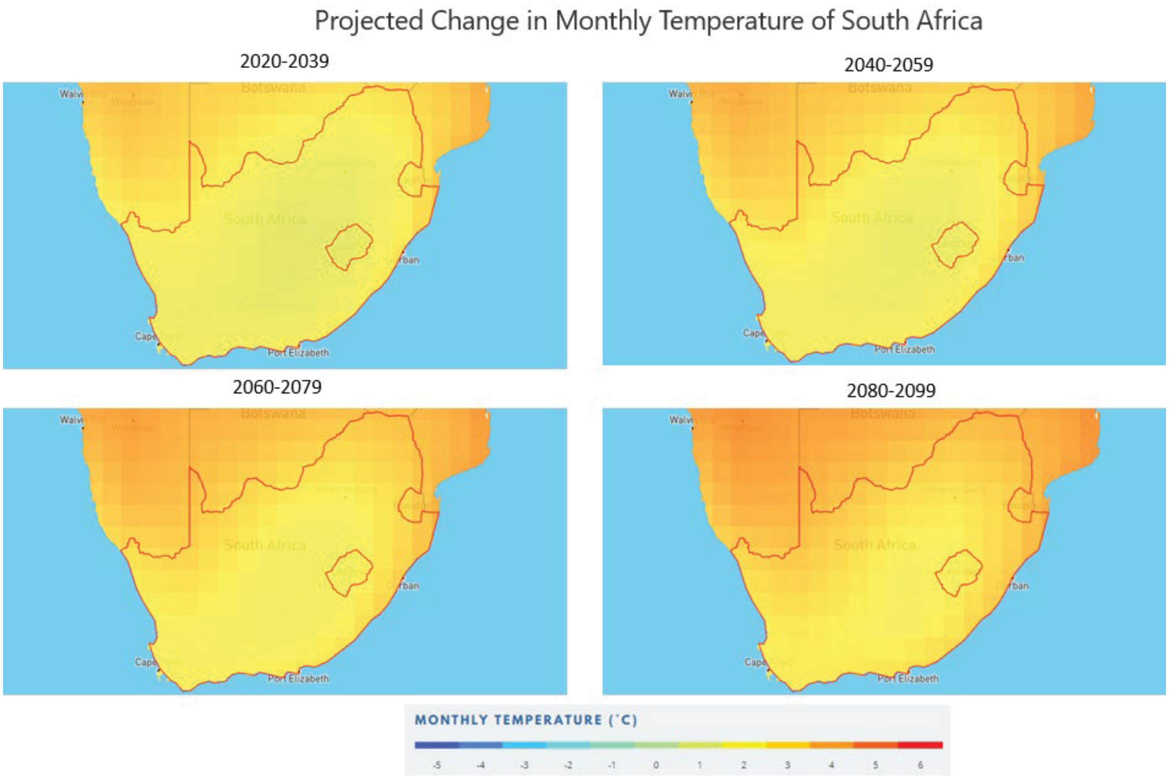


Figure 29: *Maps showing the exposure to temperature change over time for RCP8.5 (worldbank.org)*

- A threat expanding into a new area/s may have a low impact at present, but may worsen over time, and will require monitoring.
- Although the scale or resolution of the map may not be ideal, these maps can still provide a useful indication of typical threats.

> **Action**
>
> Based on your findings complete 'Impact on water supply and wastewater treatment systems' column of the climate information analysis summary table (template provided in guideline document). Add all identified impacts to this column.

Summarising climate information reports

The team should consider the following questions to summarise the information gathered when reviewing qualitative reports:

- What is the information indicating about medium- to long-term trends in rainfall and temperature?
- What is the information saying about climate threats and the occurrence of the various threats?
- What are the impacts of these threats, and is the impact increasing?
- What are the key information gaps and unknowns/uncertainties?
- Which WSP/W_2RAP steps should be amended to incorporate the findings from the report/s?

- Considering the information gathered from report/s, which hazards and hazardous events are highest priority? Make a list documenting the priority hazards and hazardous events.

6.3.3 Approach 3: Using existing web-based tools to access/analyse historical and predicted climate related data

Data retrieval and analysis can be done by accessing data from existing web-tools and databases. These databases can be found locally (i.e. national or even municipal monitoring services), or internationally (sources such as the World Bank). The analysis of these datasets is largely aimed at municipalities/water suppliers/water utilities that have technical specialists with the skills to operate such tools, analyse the data and interpret the outcomes (i.e. high technical capacity). The benefits of using this type of information:

- Provides you with a simple to use data/information interface to access and analyse 'big' data sets.
- You can translate data into meaningful outputs to support local-level water safety planning and wastewater risk abatement planning.
- It may address existing gaps in existing climate reports to support local level water safety planning (i.e. more detailed than CVAs, and local-level information gaps).
- Provides you with access to national meteorological and hydrological information.

Examples of resources that have data/information specific to South Africa can be found in **Appendix A**.

Type of information

The table below captures some examples of the types of information and their description that municipalities/water suppliers/water utilities can source (Table 10).

Table 10: Examples of information available to technical experts

Type of information	Description
Meteorological data	Rainfall, temperature, wind speed and direction
Hydrological and hydrogeological	River flow, groundwater levels, water chemistry, water quality, water storage levels, water temperature
Historical occurrences of events	Floods and drought history
Forecasting information	Representative Concentration pathways (RCP4.5; RCP8.5)
Ocean data	Sea levels, and sea level projections
Others?	

Processing information

The steps to follow when processing the information from existing web-based tools are outlined below. The steps for this section are summarised in Table 11. Each step is covered in more detail after the table.

__Table 11:__ Summary of steps to access and analyse data and information on web tools

Step	Description	Examples	Action
1. Identify your data needs	Typical datasets may include rainfall and temperature. However, additional datasets may be required such as sea level or river levels if your system is located near the ocean or a river.	Examples include: i. Department of Water and Sanitations hydrology and rainfall graphs and data ii. South African Weather Services (SAWS) station data iii. Etc.	Identify your dataset requirements for your area. This may not be the same for all areas, however basic datasets include rainfall and temperature.
2. Access data and information	Access the data and information from the relevant web tool/s, from the links in the data sources list, for 30 years and the climate forecast/projection data	Datasets available may include: i. Temperature ii. Precipitation iii. River flows iv. Groundwater v. Etc.	Refer to the resources list for South Africa for climate data and the links to access data and information (**Appendix A**).
3. Analyse long term graphs	Long-term graphs (i.e. 30 years or more) need to be analysed to determine the changes in climatic conditions over time. Graphs and maps should be analysed to determine the climatic conditions of an area/s (e.g. temperature maps could be used to indicate how the average temperatures have changed over time).	i. What do the graphs/tables indicate about the historic pattern of surface temperature within the region? ii. What do the graphs/tables indicate about how long do flows last? iii. What do the graphs/tables indicate about how have sea levels varied in the past? iv. Historical, current, and forecasting graphs/maps should be compared to evaluate how climate is likely to vary over time v. Etc.	Prepare a list of questions to ask of the data/ information when analysing the data and information found on web tools. Appendix A provides examples of questions. Questions should be asked of temperature, rainfall, seas levels, etc. Analyse graphs and maps to determine how local climate has changed, i.e. has temperature increased or has rainfall increased, etc.

Step	Description	Examples	Action
4. Summarise climate information	Capture and summarise climate information in a table.	i. Increased temperatures ii. Increased Rainfall iii. Decreased river flows iv. Etc.	Complete 'Climate hazard' column of the climate information analysis summary table. Add all the changes in climatic conditions to this column, this should be based on the data analysis.
5. Identify threats	During the data analysis, identify which threats typically occur in your area/region. You may need to access datasets that cover flooding, drought indices, etc.	i. Flooding ii. Droughts iii. Landslides iv. Etc.	Develop a list of climate threats that are occur in your area. Use generic lists to assist you in identifying which threats typically occur in your area.
6. When do threats occur	What weather/climate conditions do threats occur under, i.e. what conditions result in floods, droughts, etc.	i. Flooding occurs during periods of high rainfall ii. Droughts occur during periods of low rainfall (usually over a few years) iii. Etc.	Associate the threats you have identified in Step 4 with the climate conditions under which they occur. By way of example, droughts in the Western Cape are caused during periods of reduced rainfall and increases in temperatures typically brought about by El Nino conditions. You may need to pair some datasets such as dam levels with rainfall.
7. Site Visit	Do a site visit to determine which processes are likely to be affected by climate threats	i. High rainfall can result in flooding at the inlet works ii. Droughts can result in high concentrations of contaminants	Do a site visit and ask questions of your team and plant staff as to what is likely to go wrong at each process. Complete the 'Climate threats' column.
8. Threat impact	Identify, the primary impact of each threat under the changes in climate conditions	i. Primary impact of drought – reduced water for supply ii. Primary impact of erratic rainfall – reduced water for groundwater recharge iii. Etc.	Complete 'Primary impacts' of the column of the climate information analysis summary table. Add all identified primary impacts to this column. Examples can be easily found in the CSIR Climate Risk and Vulnerability Assessment Report (2017).
9. Changes in geographical range of threats	Review the data and identify which threats are moving/expanding into different areas are, i.e. has a threat that was typically localised to a	i. The data may indicate that flooding that flooding is occurring in areas that previously never experienced	Based on your findings complete 'Impact on water supply and wastewater treatment systems' column of the climate information analysis summary table. Add all identified impacts to this column.

Step	Description	Examples	Action
	specific area been occurring in different areas. Use projection maps and data to determine which areas will be affected by your identified threats in the future	floods, or that flooding will expand to other areas in future. ii. Storm surge is more frequent in coastal areas, and the area affected will increase in future. iii. Projection data will indicate the susceptibly of an area or region to a threat	

Step 1 Refer to the climate data sources list developed for South Africa and identify your minimum dataset requirements and the ideal format required for analysis for your area **(Appendix A)**.

- You need to carefully review each of the data sources and visit the websites for the web-tools in the list, before deciding which dataset best suits your needs.
- You may find that a combination of these datasets works best for you.

You should ensure that you are retrieving the correct datasets, as data/information are generally available in different formats, including:

i. Graphs
ii. Maps
iii. Station data (raw data) (Figure 30)

CAPE POINT
Climatology Period:1981 - 2010

Month	Precip	Rainy Days	Tmean	Tmax	Tmin
1	6.6	3	18.8	23.1	15.8
2	5.0	4	19.2	24.1	15.9
3	6.2	4	18.0	22.8	14.9
4	13.2	5	16.7	21.6	13.6
5	11.9	7	15.2	19.3	12.5
6	17.1	8	13.4	17.4	10.8
7	20.9	7	12.8	16.4	10.3
8	24.1	10	13.0	17.3	10.6
9	11.6	8	13.4	17.4	11.0
10	10.6	5	14.6	19.0	12.0
11	6.1	6	16.2	20.4	13.3
12	3.6	4	17.8	22.5	14.8

Figure 30: *Rainfall and temperature data in table format, this is downloadable and can be processed (African regional climate centre, 2014)*

Determine minimum data requirements

The minimum data requirements typically include temperature and rainfall data, as most climate change impacts can be linked to this type of data. However, you may need additional data as your system may be affected by changes in other climate variables such as river flows, sea levels, etc. Location/proximity to may also affect your data requirements.

By way of example: if your system is not located near the ocean, you will not need sea levels. However, if it is in a low-lying area you may need groundwater level data as a rise in the water table may flood your system.

The format of the data may vary depending on your requirements and technical skill. If your team has low technical skill then the best data formats would be in the form of graphs, maps, and tables (where applicable). This will reduce your need to analyse the data. However, if your team has high technical skills and you find that you need to do some modelling, then 'raw data' will be a better option, so that you can download, and copy it into your modelling application.

Pairing datasets

Some datasets may provide more insight into what the system is currently experiencing or has experienced in the past if paired with another dataset/s. Additionally, the conditions under which a particular threat is likely to occur may then also be determined. You should consider which datasets should be paired, when trying to assess the effects of climate change on weather variables and threats. For example, if you are concerned that fires occurrence may increase, the ideal datasets would be temperature, number of dry days, drought history.

Step 2 Access the data/information from the relevant web-based tool/s, from the links in the data sources list, for 30 years (or oldest record if less than 30 years available), and the climate forecast/projection data

- Datasets in **Appendix A** cover temperature, precipitation, river flows, groundwater, floods, and droughts
- Climate forecast/projection data and information indicate if, for example, temperature is likely to increase or decrease in the future.
- Which months are expected to be the hottest and driest, or coldest and wettest in the future?

Examples of these data sources include:

- SAWS,
- Climate Systems Analysis Group,
- African Regional Climate Centre, and
- DWS.
- HydroNet

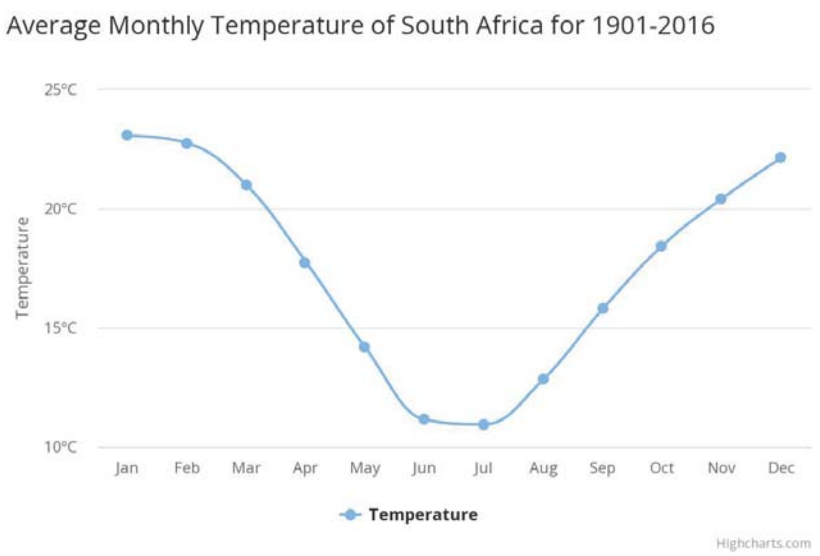
It should be noted that the data retrieved from SAWS or DWS may require some processing to develop graphs or maps. However, the data from these sources are at a station scale and therefore very useful to describe local conditions.

Step 3 Long-term graphs (i.e. 30 years or more) need to be analysed to determine the changes in climatic conditions over time.

- Graphs and maps should be analysed to determine the climatic conditions of an area/s (e.g. temperature maps could be used to indicate how the average temperatures have changed over time).
- Historical, current, and forecasting graphs/maps should be compared to evaluate how climate is likely to vary over time (Figure 31).

Analysing station data

Interactive web-tools provide information in the form of raw station data, which you may analyse using your own techniques or tools to suit your own needs. Station data (raw data) requires analysis by summarising data using descriptive statistics. Data analysis should be aimed at trying to determine the changes in historical trends of climate data, such as if there are notable increases or decreases in how long river flows last, or changes in average temperature, etc. Data should be plotted on graphs or maps for further analysis.



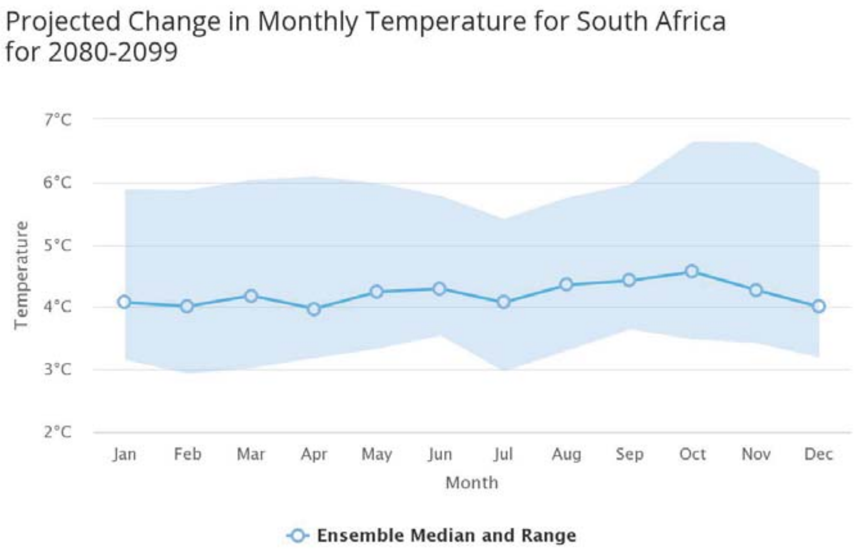


Figure 31: *South Africa temperature observations and projected changes in temperature for the period 2080-2099 for RCP8.5 climate scenario (Worldbank.org).*

Benefits of maps

Maps are a visual representation tool that can be used to highlight areas that are at most risk of a particular threat. Maps can be used as a tool to determine areas that require mitigation or other prevention measures, which leads to improved decision-making and local planning (Venik *et al.,* 2020). Maps also assist you in determining which areas are at risk of more than one threat, and which areas need to be targeted for additional mitigation measures.

The team needs to review the data available on the selected web-based tool to determine how historical climate has changed over time. You should analyse the various graphs and maps to determine if there are changes in climate variables. When reviewing the data and information on the web-based tools ask the following questions of the information:

i. What is the historic pattern of surface temperature within the region?
ii. What are the seasonal temperature patterns? Have these changed?
iii. What are the typical mean, maximum, and minimum temperatures? Have these changed over time and how have they changed?
iv. What is the trend of extreme temperature (both high and low temperatures)?
v. How is temperature projected to changes?
vi. What are seasonal precipitation patterns? Have these changed?
vii. How variable is historical precipitation?
viii. What is the trend of extreme precipitation?
ix. How has the projected precipitation changed?
x. What is the trend of historic river flows within the region?
xi. What are the water levels of extreme peak flows?
xii. How long do flows last?
xiii. How is the pattern of river flows projected to change?
xiv. What is the history of flooding?
xv. What is the duration of flooding?
xvi. How often, do floods occur within the region?
xvii. How is the pattern of flooding projected to change?
xviii. How do water storage levels vary?
xix. How long do low water levels persist?
xx. What is the history of drought in the region?
xxi. How is the pattern of droughts expected to change?
xxii. How do aquifer levels vary? (may be limited to areas that have a high dependence of groundwater)
xxiii. How are these likely to change under changing precipitation patterns?
xxiv. How have sea levels varied in the past?
xxv. What are the projections of seas level rise?
xxvi. What are the projections for the future and how may this impact water supply, from catchment to consumer?

Step 4: Summarise the information in table

Action

Based on your findings complete 'Climate hazard' column of the climate information analysis summary table in (template provided in guideline document). Add all the changes in climatic conditions to this column.

Step 5: Identify threats

Types of threat related to the observed changes in climate conditions will be covered below. During your analysis of the data/information, consider the threats that typically occur in your area/region. Threats may be strongly linked to climate conditions experienced in an area, e.g. floods are linked to increased rainfall or heat stress is linked to increased temperature, etc. Therefore, consider the types of threats that may occur under and the conditions under which they occur.

A generic list of threats has been developed, which includes typical threats experienced in South Africa. You should consult this list to identify which of these threats are applicable to your area.

Not all of these threats may be applicable to your area (for instance inland areas will not be affected by saline intrusion), and therefore the type of threats should be considered during the focus group discussions and literature review. The threat list should be expanded to include additional threats identified. This is a key step as, not all threats will occur in any one area, for instance inland areas are less susceptible to saline intrusion. Therefore, planning and resources can be effectively allocated to

During threat identification, you should consider the types of threats that are likely to worsen under climate change.

Step 6 Determine when a threat typically occurs.

- This step requires you to associate a threat with certain climate conditions (Increased rainfall, etc.)
  - e.g. Flooding in Gauteng occurs when there are periods of persistent rainfall, whereas droughts in the Eastern Cape are the result of several wet seasons of below average rainfall

Step 7 Site visit to determine susceptibility to threats.

- Identify which threats are relevant to the different parts of the system. The system components may include green and grey infrastructure.

By way of example:

Rivers may be susceptible to erosion; or coastal areas may be affected by salt-water intrusion.

TIP: When you arrive at each of the various system components consider the following
Ask questions of yourselves and of supplier staff, for example:

i. What could go wrong here?

ii. What steps are currently taken to stop that from happening?

Action

Based on your findings complete column the 'Climate threat' column of the climate information analysis summary table in (template provided in guideline document). Add all identified threats to this column.

Step 8 Identify changes in impact

You should determine, based on your data analysis, the primary impact of each threat under the changes in climate conditions. This may be strongly linked to changes in intensity of climatic variables.

By way of example:

- Due to increases in average temperature, occurrences of drought may increase, and new threats may arise in the form of heat stress on the human population.

> **Action**
>
> Based on your findings complete column 'Primary impact' column of the climate information analysis summary table in (template provided in guideline document). Add all identified primary impacts to this column

You should also identify which threats are expected to worsen in the future, by using projection data/information. Consider the following and how these will be affected under climate change:

i. What is the impact on local water resources and water quality?
ii. What is the effect on water and wastewater treatment processes?

Step 9 Identify the change in geographical range. Maps should be used to identify the changes in susceptibility of an area to extreme conditions

- Historical maps will indicate which areas are exposed to threats.
- Projection maps may indicate which areas are likely to be exposed to threats in the future.

A good source of historical maps and projection maps is the World Bank Group's Climate Change Knowledge Portal.

> **Action**
>
> Based on your findings complete columns 'Impact on water supply and wastewater treatment systems' column of the climate information analysis summary table in (template provided in guideline document). Add all identified threats to this column.

Summarising data retrieved from web-based tools

The team should consider the following questions to summarise the information gathered analysing data.

- What is the information indicating about medium- to long-term trends in rainfall and temperature?
- What is the information saying about climate threats and the occurrence of the various threats?
- What are the impacts of these threats, and is the impact increasing?
- What are the key information gaps and unknowns/uncertainties?
- Which WSP/W$_2$RAP steps should be amended to incorporate the findings from the report/s?
- Considering the information gathered from report/s, which hazards and hazardous events are highest priority? Make a list documenting the priority hazards and hazardous events.

6.4 Additional sources of information

The type of data/information accessible and available as described in the above three approaches will assist audiences with low technical (generalists) to high technical expertise (experts). However, you may find that there are gaps and that the data/information does not meet your internal needs. Therefore, you may be required to generate some of your own data/information. Such information can be collected through:

- Observed climate and environmental data (temperatures, precipitation, river flows) from your own monitoring stations

- Processed climate and environmental data (in the form of indices)
- Climate modelling (e.g. climate projection, hydrological projections)

However, development of the above can only be done at a high level of technical expertise and resources. Additionally, meaningful trends may take a long time to develop (at least 10 years) (i.e. these are not short-term actions). In the early stages, it will be challenging to analyse the data with the purpose of identifying trends, or identifying what changes are likely to occur under the effect of climate change. Therefore, this activity should not be taken lightly, and only done where significant data gaps occur which limit your ability to make climate data related conclusions. Examples of the variables that can be monitored are presented in Table 12:

Table 12: Examples of variables that could be monitored

Type of information	Description
Meteorological data	Rainfall, temperature, wind speed and direction (gauges)
Hydrological and hydrogeological	River flow, groundwater levels, water chemistry, water quality (flow meter, piezometer, pH meter, etc.)
Landuse	Water use (flow meter)
Soil moisture	Water content contained in soils (soil moisture probe)
Water quality	Laboratories
Other?	

These are the type of information that can be accessed using the other approaches, however it may be more localised to your specific area (i.e. station data). As it may not be possible for you to setup monitoring stations for all climate variables, the selected location of the monitoring point should be representative of the wider area of investigation.

Data collected from monitoring stations should be manipulated and summarised using descriptive statistics, and data should be plotted on graphs or maps. Examples of required statistics are listed below:

- time series plots
- spatial datasets (maps)
- mean
- median
- frequency
- minimum
- maximum
- range
- variance
- standard deviation

It should be noted that using analytical or decision support tools for manipulating data or model outputs could achieve the outputs in the form of the above descriptive statistics. The information should be interrogated to gain an understanding of the types of threats, the impact of the threats, and the geographic areas that may be affected by the threat.

6.5 Summarising climate information

The information gathered through the previous steps can be used to develop a climate summary and conclusions. A climate summary provides a brief overview of climate conditions and climatic variables for an area, climate trends and observed changes (in some cases more than 30 years), and climate projections. The information is displayed in the form of tables, graphs, and maps and provides readers with a list of conditions and threats that are likely to worsen.

This information can be included in the main body of the WSP and W_2RAP, or in an annex, with the key conclusions presented in the system description. Your completed summary table should be attached to the climate summary. This is so that reader of the climate summary has a clear understanding of the impacts that climate change will have on their system.

Example of a climate summary

By way of example, a climate summary was developed for Witzenberg municipality, which highlights the effects of current and future effects of climate change (Figure 32).

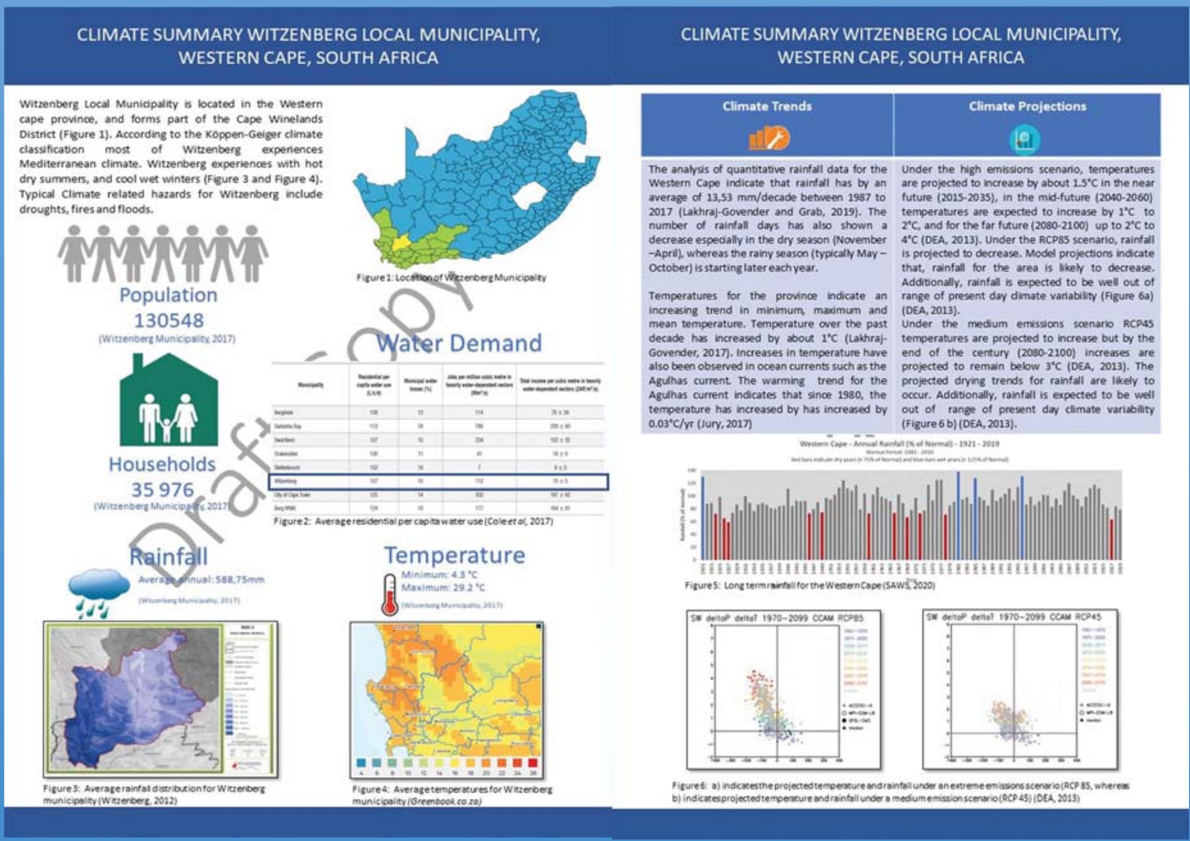


Figure 32: Climate summary for Witzenberg Municipality, Western Cape

6.6 How can limitations of knowledge and data be overcome?

When trying to assess your information needs and requirements, you may come across various obstacles. Information may come with limitations, and the information may not suit your needs. Limitations may include (but not limited to) the following:

- Information covers a regional or national scale, but not does not cover a local scale (i.e. your municipal boundary),
- You may get information from two different ends of the spectrum for example, some locals within an area may indicate that rainfall is increasing, whereas others indicate that rainfall is decreasing,
- Incomplete records/missing values (i.e. data may be missing for an entire season in a particular year),
- Only a short data record may be available and meaningful conclusions cannot be drawn,
- Staff may not be willing to share information,
- Web-tools may require a fee to access the information,
- Information can vary in quality and format.

Addressing these limitations in information may, in some cases, require you to consider elements of other approaches to verify your findings. If, for instance, you receive conflicting responses from stakeholders regarding changes in rainfall over time, you can use a graph found in a climate assessment report or from a web-tool to verify what is happening. Information limitations should not result in no action on your part; rather it should be the start of further investigation or you establish your own information database to fill gaps in information. Limitations and gaps should be well documented in the WSP/W$_2$RAP and included in the management and operational procedures section. You should not immediately attempt each of the above approaches when developing a CR-WSP or CR-W$_2$RAP. Rather you should start simple, and incrementally increase the detail of your data/information requirements as and when the need arises or when you gain more skills and experience with the process.

7. Incorporating Climate Information into Water Safety Planning

7.1 Modules, and how to incorporate findings into your WSP

The purpose of this section is to provide municipalities/water suppliers/water utilities with guidance on amending the 7 WSP modules that are impacted on by climate change. This section is in no way meant to replace the WHO/IWA WSP manual (2009) or the WHO CR-WSP manual (2017), and water utilities are encouraged to consult both guides when preparing their WSP and CR-WSP. Modules requiring amendment include:

- Module 1. Assemble the team
- Module 2. Describe the water supply system
- Module 3. Identify hazards and hazardous events and assess the risks
- Module 4. Determine and validate control measures, reassess, and prioritize the risks
- Module 5. Develop, implement, and maintain an improvement/upgrade plan
- Module 8. Prepare management procedures
- Module 9. Develop supporting programmes.

> "For those modules not covered in this document, it is expected that appropriate consideration of climate-related issues will follow from explicit consideration of climate issues in the modules addressed in this document, with no additional guidance necessary for these modules. For example, additional control measures required to manage climate-related risks are explicitly addressed in this document (part of module 5). When WSP teams go on to define control measure monitoring plans in module 6, it is expected that climate-related controls will be considered alongside all other controls without any additional guidance required."
>
> (WHO, 2017)

The following scenario will be referred to throughout this section to demonstrate how each step in the WSP should be amended and how the climate information summary table should be completed. This colour box indicates how the WSP step should be amended.

Scenario:

Hydroville water treatment works (WTW) is in Hydroland. The WTW is responsible for treating and distributing water to all residents of Hydroland. In recent years, the provision of water of an adequate quantity and quality has proved especially challenging. Hydroland is prone to droughts, and incoming water is generally of a lower quality during drought periods. Additionally, when rainfall occurs during the drought period, it is typically high intensity and short duration which results in flooding at the WTW. Flooding at the WTW typically results in process failures due to infrastructure damage, over capacity issues, ineffective treatment, and poor product quality due to ingress of floodwaters. The works has been studying climate assessment reports and have realised that under the influence of climate change; high intensity rainfall of a short duration is likely to increase. A recent review of the WSP has indicated that the WSP does not consider the impact of climate change and there are no plans in place to address climate change. Additionally, the current WSP team does not have the technical skills required to incorporate climate change considerations into the WSP. Urgent Action is required to prevent total collapse of the WTW.

During the review of the Climate vulnerability assessment the WSP team started to fill in the climate information summary table as below (Table 13):

Table 13: The WSP team has started to identify effects climate may have on their system.

Climate hazard	Climate threat	Impacts	Impact on water supply system
Increased high intensity and short duration rainfall events			

Based on the review of the CVA, the WSP could complete the column one of the climate information summary table. For the team to add more information, a site visit is required (Step 2: System assessment).

Module 1: Assemble the team

Establishment of an experienced, qualified, dedicated multidisciplinary team is a prerequisite to securing the technical expertise needed to develop a WSP. The team will be responsible for the development and ongoing implementation of the WSP. In terms of climate resilience, the WSP team should include sector professionals that understand climate information, water system knowledge, authority figures and supporting members.

Typical WSP team members

- Technical Director
- Water Engineers and Technicians
- Water Network and Distribution personnel
- Water Works Superintendents and Senior Process Controllers

- Human Resources Departments
- Financial Department
- Catchment Management
- Water Monitoring and Laboratories (if in-house)
- National Departments (DWS, DEA, etc.)
- Water Service Providers
- Public Health specialists
- Disaster reduction specialists
- Local people with a knowledge of the local climate and climate threats
- Managers, ward leaders and decision makers
- Water utility personnel with knowledge of drinking water related issues
- Water utility personnel with knowledge of natural water resources
- Experts on disaster and risk reduction and identification
- Other key role players

Inclusion of sector professionals to address climate change.

The Hydroville WSP team is very well established and includes members that are involved in various levels of water treatment and distribution. However, after reviewing their WSP, they realised that additional members are required to incorporate climate change considerations. The additional required members must have technical skill and knowledge related to the accessing and analysis of climate related information. The technical experts need only be ad-hoc WSP team members. Hydroville WSP team has identified the following technical experts:

- Climatologists and meteorologists (local weather services)
- Hydrologists and geohydrologists
- Geographical Information System Scientists
- Oceanographers
- Others?

The WSP should consider what other technical members are required on the WSP team.

Identify key team members (internal and external) and assign roles and responsibilities and secure commitment.

The role of specialist and non-specialist team members should be defined when analysing climate related information:

- Team members must perform data analysis and tasks according to their expertise (i.e. climatologists must review climate graphs and maps, hydrologists must review hydrological graphs).

- Specialists are required to identify relevant data and information sets, and setup monitoring stations (only where necessary).
- Non-specialists on the team should focus on reviewing general sections such as the effects of climate change on people or infrastructure. Where possible give specialists access to data/information.
- The roles of each team member should be clearly defined as follows (Table 14).

Table 14: Example of defined roles for each team member

Name	*Job title*	*Organization*	*Role of the WSP Team*	*Contact information*
Ms. X	Manager operations	Hydroville utility	WSP team leader	Tel.: 4543 1234
Mr. Y	Water quality & risk specialist	Hydroville utility	Water quality risk management	Tel.: 3454 1234
Ms. W	Catchment liaison officer	Hydroville catchment authority	Catchment user liaison	Tel.: 5443 1234
Mr. C	Professor of climate sciences	Hydroville College	Auxiliary Member	Tel.: 3544 1234

Module 2. Describe the water supply system

It is the responsibility of the WSP team to describe the water supply system. The description should include relevant documentation such as an updated flow diagram of the water treatment works. A more comprehensive description includes relevant data such as average flow at various points, water quality and climate of the area in the description. A climate summary can be useful to describe the climate of your area. The WSP team members that form part of the municipalities/water suppliers/water utility, should have access to this documentation and data. The system description should be updated to incorporate, climate resilience with the following considerations:

- Include climate trends – use graphs and maps (Figure 33); such info can also be presented in an annexure, with key conclusions in the main body of the WSP.
- Include flow diagrams describing water flow and treatment unit processes water goes through from catchment to consumer.
- Other supporting information should also be included such as:
    - Source water quality
    - Catchment land use
    - Water treatment, storage, and distribution details
    - Water uses and users
    - Resources available for the system
    - Details in wastewater/stormwater/sanitation management
    - Current water quality being supplied
    - Water quality standards or objectives.

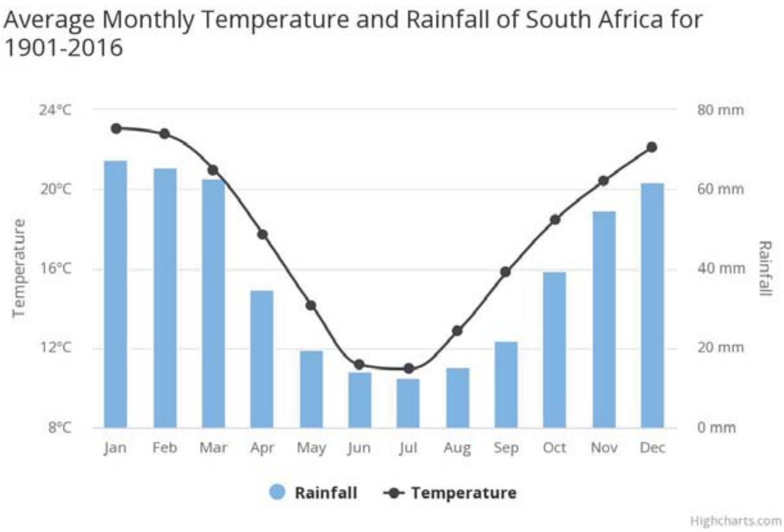


Figure 33: Example of climate data (Worldbank.org.)

- You should consider climate related information for current and predicted conditions, including key information in the system description that is required for subsequent hazard identification and risk assessment
  - Climate information (e.g. historical v. projected rainfall data, temperature, etc.),
  - Sea-level rise; inundation/flooding zones,
  - River flows,
  - Aquifer recharge rates, yield vs. demand,
  - Water quality challenges,
  - Alternative water sources,
  - Catchment land-use,
  - New development,
  - Population growth,
  - Urbanisation

This information should be captured in a system diagram, which can be overlaid with key climate information. Where a water treatment plant is present, a separate and more detailed schematic of the facility should also be included.

Including Groundwater in the description

Water utilities should include groundwater information in their descriptions. In the future groundwater may become an important water resource, especially in areas likely to experience prolonged drought. Additionally, the potential release of contaminants from groundwater may also become a problem, in areas that use onsite sanitation and are prone to flooding. Groundwater information should include aquifer type/s, borehole yield, geology and soil characteristics, and water quality. It is therefore necessary for water utilities to not only understand how water flows through their system, but also how water flows through the hydrological cycle.

Updating system description

The Hydroville WSP team reviewed their system description and realised that it does not include the local climate conditions or flood prone areas at the WTW. Following the review of the climate information the WSP team updated their system description. The WSP team have updated their system diagram to include current climate and climate change considerations. The new system diagram was updated to include the following (Figure 36):

- Annual rainfall
- Predicted change in annual rainfall by 2030
- Delineated areas that flood during high intensity short duration rainfall and future flood zones
- Potential future water source
- Impact on of flooding on drinking water supplies

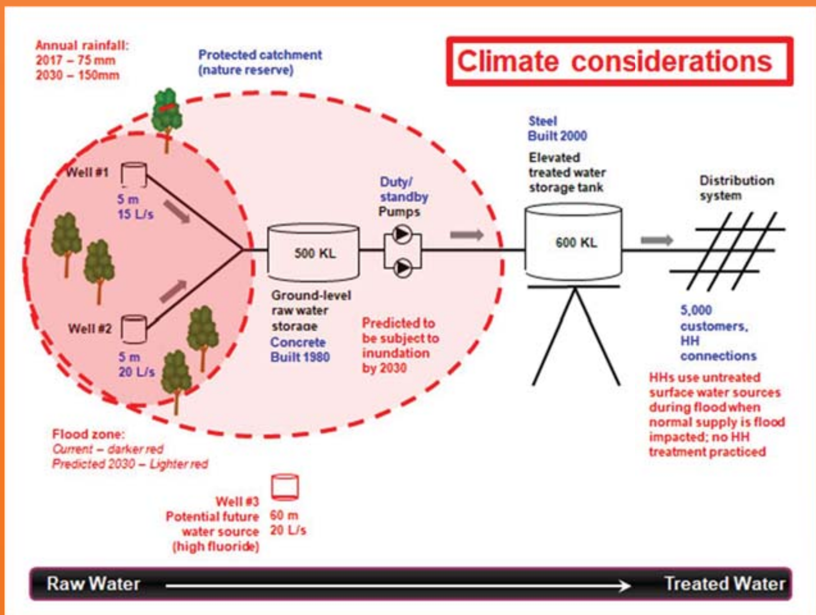


***Figure 34:** System description of a water supply system from catchment to consumer; relevant climate information is presented in red (WHO, 2019)*

After review and update of the system description, the WSP team was able to update the Climate information summary table. The WSP team realised that high intensity short duration would result in increased water availability at the inlet works (Table 15).

Table 15: Updated climate information summary table.

Climate hazard	Climate threat	Impacts	Impact on water supply system
Increased high intensity and short duration rainfall events	Increased water availability at the inlet of the WTW		

The works will update the climate summary table after the site visit (Step 4: System Assessment (Risk Analysis, Prioritization).

Developing a climate summary

To gain an understanding of the current and projected climate conditions for Hydroville, a climate summary was prepared. The 'Climate Data for resources list for South Africa' table was consulted to identify the relevant climate information, and where to source them (**Appendix A:** Climate data sources list for South Africa). The climate summary was developed by accessing and reviewing existing climate related literature and web tools (like approaches two and three described above). Examples of information include the following:

- Climate assessment reports
- Knowledge portals and websites that include various climate related information

The climate summary provided an indication as to the current climate of Hydroville such as temperature maximums and minimums and rainfall amounts, climate trends (i.e. has temperature increased or decreased, etc.). The hazards that are typically experienced in Polokwane were covered, as well the change in exposure to these hazards. Climate related disasters identified for Hydroville include the following:

- Flood risk
- Increased runoff

A climate summary table was developed based on the findings of the climate summary. The climate summary table provides an indication as to what the impact of changes and temperature are likely to have on the system based on climate projections (Table 16).

Table 16: Completed climate summary information table

	Climate threat	Primary impact	Impact on water supply systems
Increased rainfall	Increased water entering system	Flooding	Failure of treatment infrastructure due to capacity exceedance
	Increased water infiltration	Raised water tables	Contaminated groundwater due to water tables in areas with unlined pit latrines
	Increased water entering system	Increased surface runoff	Increased pathogen and sediment loading
	Increased water entering system	Flooding	Contaminated surface water entering groundwater through wells

Module 3. Identify hazards and hazardous events and assess the risk

This requires you to do a system assessment to identify what could go wrong and where it could go wrong, at each part of the water supply chain.

According to WSP terminology, a hazard is any biological, chemical, physical, or radiological agent that has the potential to cause harm to the system or consumers. The site visit may highlight the hazards that are likely to occur in the system, and the source/s of the hazard. Hazardous events are the mechanism whereby an agent (biological, chemical, physical, or radiological) is introduced into the system. Hazardous events can be described as follows:

X happens (to the water supply) because of Y

X = What can happen to the water supply

Y = How it can happen (i.e. cause)

Examples:

- Source water becomes faecally contaminated (**X**) because of discharge of untreated domestic waste from households (**Y**)
- Water in the pipe network becomes contaminated (**X**) because of unsanitary pipeline repair practices (**Y**)
- Water is over- or under-dosed with chlorine (**X**) because of insufficient operator training (**Y**)

To be climate resilient, additional hazards need to be considered (e.g. quantity). These considerations should include the impact of climate change at each part of the system (catchment to consumer). The risk associated with each hazard and hazardous event, should be calculated for new risks, and re-calculated to determine impacts of climate change. Below is a list of considerations for identifying climate related hazards and hazardous events, and assessing the risk:

- Complete a site visit – Prepare a list of generic questions such as: what would happen if the inlet works were flooded?
- Differentiate between climate related hazards/hazardous events, and non-climate related hazards/hazardous events – not all hazards will be affected by climate change.

Hazards and hazardous events require prioritisation, as the degree of attention and effort required for each risk may vary. Risk is determined based on the product of likelihood and severity. This will better assist you in determining which risks are more important and which are less important. A simple example of a risk matrix and risk scores are presented in Table 17 and Table 18.

Table 17: Example of a risk matrix

	Severity				
Likelihood	Insignificant 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
Almost Certain 5	5	10	15	20	25
Likely 4	4	8	12	16	20
Moderate 3	3	6	9	12	15
Unlikely 2	2	4	6	8	10
Rare 1	1	2	3	4	5

Table 18: WSP Risk score description

Score	Risk profile	
0-10	Low	These systems operate with minor deficiencies. Usually the systems met the water quality parameters specified by the appropriate guidelines (SANS 241)
11-20	Moderate	These are system with deficiencies which individually or combined pose a moderate risk to the quality of water and human health. These systems would not generally require immediate action, but the deficiencies could be more easily to avoid future problems
21-25	High	These are systems with major deficiencies which individually or combined pose a high risk to the quality of water and may lead to potential health and safety or environmental concerns. Once systems are classified under this category, immediate corrective action is required to minimise or eliminate deficiencies.

Data and information limitations should be considered as a hazard/hazardous event and should be captured as such in the WSP or W_2RAP. This becomes especially important if you identify that for, e.g. increases or decreases in temperature are a climate hazard, but you are unable to source the relevant temperature for your area/system.

Using a questionnaire to identify hazards and hazardous events at the WTW

As part of South Africa's Blue Drop programme a comprehensive questionnaire has been developed that can be used to assess each of the process steps within your system. The questionnaire covers multiple aspects such as appearance of the works, primary mains, reservoirs, boosting stations, and disinfection but to name a few. The questionnaire can be used to assess a water treatment works with any combination of processes (Figure 37).

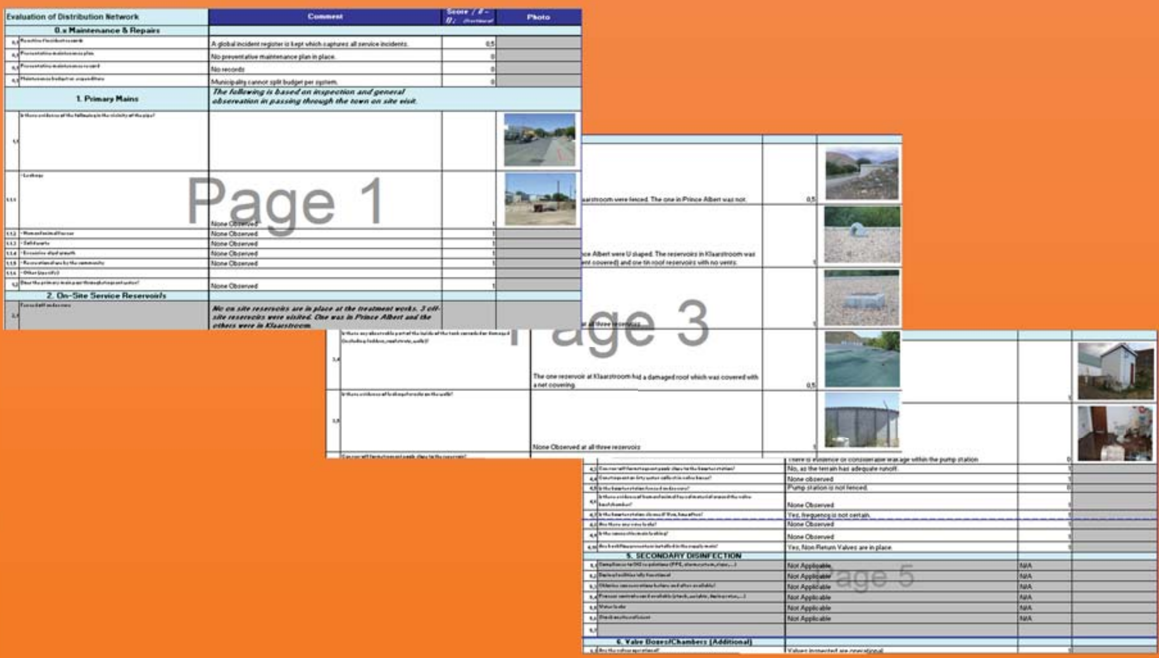


Figure 35: *Example of Blue drop site inspection questionnaire.*

However, the questionnaire does not cover questions that seek to understand the impacts of climate change on the system. Therefore, when trying to incorporate climate resilience into your WSP you need to develop a list of generic questions that can be asked at each of the process. During the site visit additional questions must be added to the list, as and when they arise. Table 19 provides you the list of generic questions that can be added to the site inspection questionnaire.

Table 19: Example a data collection tool.

Water treatment works inspection form		
1	How is this process affected by changes in atmospheric temperature? i.e. What impact do low/high temperatures have on this process	Y/N
2	How is this process affected by changes in flow? i.e. an increase in flow and a decrease in flow	Y/N
3	How is this process affected by rainfall, do spillages occur?	Y/N
4	Is the infrastructure capable of periods of overcapacity brought about by periods of high rainfall?	Y/N
5	How is this process affected by increased wastewater temperatures?	Y/N

Refer to Step 2 in each of the Approaches for additional questions.

Module 4. Determine and validate control measures, reassess, and prioritize the risks

Existing and potentially new/additional control measures should be identified during the site visit and risk identification process. Under the influence of climate change, existing control measures may no longer be effective, and an assessment thereof should be conducted to understand if new or additional control measures should be implemented. Control measures should be validated through regular monitoring, and after an incident occurs. If control measures are not effective, new control measures should be identified and implemented. The risk associated with each hazard and hazardous event should be calculated for new risks and re-calculated for existing risks to determine impacts of climate change. Below is a list of considerations for identifying climate related hazards and hazardous events and assessing the risk:

- Are my current control measures still effective or, do we need new control measures or, do we only need to upscale/modify our current control measures?
- Are these control measures effective under the influence of climate change?
- What new control measures are required?
- Can control measures be implemented quickly or do we require a long period for implementation?
- Do we need to develop new SOPs, contingency plans, training programmes and emergency procedures for climate resilient control measures?
    - 2 step risk assessment – what is the risk per hazard/hazardous event before climate change impacts
    - What is the risk per hazard/hazardous event after considering climate change impacts (has it changed and how)? Which hazards/hazardous events are affected?
- Include your list of climate threats in this section
    - Develop hazard and hazardous events for each threat
    - Consider the risk scores for each hazard and hazardous event
- Conclusions drawn from the CVA or data analysis should be used to amend the risk scores.

Risk assessments are best done in groups by consensus, as this eliminates potential bias if completed by an individual.

Table 20 and Table 21 can be used to determine the risk of a hazard and hazardous event, before and after considering the impacts of climate change.

Table 20: Assessment of risk before climate change consideration

Effectiveness of control measures before climate change consideration																		
			Risk if there were no controls in place				**Are controls effective?**					**Risk with controls in place**				**Additional control needed?**		
Process Step	**Hazardous Event**	**Hazard Type**	**Likelihood**	**Consequence**	**Risk score**	**Risk level**	**Existing control measures**	**Yes**	**No**	**Somewhat**	**Validation notes** *(basis of effectiveness assessment)*	**Likelihood**	**Consequence**	**Risk score**	**Risk level**	**Yes**	**No**	**If yes, proposed controls** *(to be further detailed in improvement plan)*
Inlet	Increased water availability at the WTW due to high intensity short duration rainfall	Phys	3	5	15	M	Reduce flow of raw water, during rain events	✓			Monitoring of flow at the inlet works	3	1	3	L		✓	---

Table 21: Assessment of risk after climate change consideration, the control measure implemented before climate change is no longer effective, and a new control measure is required.

Effectiveness of control measures after climate change consideration																		
			Risk if there were no controls in place				**Are controls effective?**					**Risk with controls in place**				**Additional control needed?**		
Process Step	**Hazardous Event**	**Hazard Type**	**Likelihood**	**Consequence**	**Risk score**	**Risk level**	**Existing control measures**	**Yes**	**No**	**Somewhat**	**Validation notes** *(basis of effectiveness assessment)*	**Likelihood**	**Consequence**	**Risk score**	**Risk level**	**Yes**	**No**	**If yes, proposed controls** *(to be further detailed in improvement plan)*
Inlet	Increased water availability at the WTW due to high intensity short duration rainfall	Phys	3	5	15	M	Reduce flow of raw water, during rain events		✓		Due to increased flood occurrence and increased periods, flooding still occurs	3	5	15	M	✓		Long-term: Increase capacity of WTW Short-term: build temporary balancing dam and divert excess flow

Module 5. Develop, implement, and maintain an incremental improvement/upgrade plan

An improvement/upgrade plan is required where additional or long-term control measures are required, for all significant risks that require strategic and future considerations. In some cases, a significant amount of funds and time is required before control measures are fully implemented. Therefore, actions should be geared towards incrementally implementing control measures (i.e. what is required for phase 1, what is required for phase 2, etc.). This requires the water utility, through investigation, to also consider and implement low/no cost control measures in the short-term, while the necessary funds are made available for long-term control measures to be implemented. Long-term control measures typically require significant time and funding before they can be fully implemented and should be conducted in phases or stages to allow for more funding to become available. The improvement/upgrade plan should be implemented such that the measures put in place are effective under future climate conditions/scenarios.

Using short-term and long-term control measures

Sometimes a stepwise or incremental approach to full implementation of an optimal solution is needed due to resource constraints. Short-term control measures can be defined as those actions that can be implemented immediately with proven effectiveness, at a low cost to the utility, however, may only be effective for a short period (e.g. within 5 years) before long-term action is required. These may only be effective under current climate conditions.

Long-term control measures can be defined as those actions that require implementation over a long period (e.g. 5 years to be fully implemented), and large financial resources, but may be effective for an extended period (30 or more years).

Considering the above, municipalities/water suppliers/water utilities may need to implement both short-term and long-term control measures. Short-term control measures should be implemented as interim actions, while long-term control measures are implemented incrementally and over a period (Table 22).

Table 22: Example of incremental control measure implementation

	What improvement is needed?	*What is the priority level for the improvement? (H/M/L)*	*Who is responsible for completion of the improvement?*	*How much is it estimated to cost?*	*Planned start date?*	*Planned finish date?*	*What is the status?*
1	Build temporary balancing dam	High	Mr. Y	R 100,000	August 2020	December 2020	Not started
2	Increase WTW capacity to cope with increased periods of increased flows	High	Ms X	R 100,000,000	June 2021	June 2027	Not started

Module 8. Prepare management procedures

Management procedures should be developed that define the actions required when the system is running optimally and/or when an incident occurs. These actions should be documented as each process is routinely monitored or corrected during an incident. More experienced staff/team members should oversee the documentation process. Management procedures can be broken down into four basic aspects including:

- Management – These require actions to be implemented when the system is operating optimally (i.e. normal/routine activities), and actions required when a deviation in normal operations occurs (i.e. corrective actions) or in emergencies.
- Documentation – Provides information on the drinking water system and programmes to upgrade the system for improved water delivery. Plans and related reports for operational monitoring and verification of the WSP effectiveness. These records are essential as they provide auditors with an indication of the adequacy of the WSP, in relation to the adherence to operational standards.
- Communication methods/protocol – This is the process whereby an incident is communicated within the water utility and is escalated to the relevant responsible person to carry out the required corrective actions. In some instances, the public may need to be notified of an incident, and information should be made available to them. The platforms for communication should also be highlighted.
- Authorisation Audits – Audits should consider the impact of climate change; this can be done during the site visit component of the Audit. Questions should be developed that aims to understand how processes are being modified/upgraded to ensure climate resilience. This may require additional training for auditors to understand the effects of climate change on WTW processes, such that they can determine if the works intended modification/upgrade plans address climate change and make the appropriate recommendations.
- Process Audits – Process audits need to consider the performance of a various processes under the influence of climate change. The application of climate change to the process audit, may inform where new technologies need to be implemented and which technologies should be retired. It should be noted that not all processes will be impacted by climate change, the processes likely to be affected are those that utilise micro-organisms as part of treatment.
- Update/modify and develop SOPs – Under the effect of climate change, existing Standard Operating Procedures (SOPs) and management procedures may no longer be effective. It will therefore require the updating or modifying of existing SOPs and management procedures. In some cases, new SOPs have to be developed for new hazards and hazardous events. SOPs need to consider the impact of climate change on the system and the on hazard and hazardous events. SOPs also need to include/account for climate-related emergencies/disasters and pre-emptive actions required when disasters are predicted/forecast
- COVID-19 considerations – The impact of COVID-19 is well documented in news media, as well the temporary business closure when staff were exposed to the virus. Management procedures must be developed for these emergency conditions, especially if your system must continue operating. The plan should be detailed such to ensure business continuity after an emergency/virus exposure happens, and how long after exposure to an incident business may resume (and staff may return). Different incidents may have different down times and contingency plans must be developed to ensure business resumes as soon as possible. This may

include having internal contingency plans, as well as your service providers (such as chemical suppliers) having similar plans. In the case of your system you may need to operate on a rotational basis and ensure that staff from each rotation do not encounter each other.

Module 9. Develop supporting programmes

Support programmes are those programmes that improve the skills and knowledge of water utility staff or of local people. These skills and knowledge require further development especially under the effects of climate change, and where new control measures are put in place.

- Supporting programmes should aim to address the impacts disasters and hazards/hazardous events may have on the water supply system. Examples include (Figure 36):
    - Climate resilience-based training for process controllers/operators
    - Awareness programmes aimed at consumers
    - Equipment calibration and maintenance training
    - Laboratory quality control
    - Research programmes such as water supply system assessment to support increased operational & water efficiency
    - Capacity building programmes such as flood/drought event management & planning.

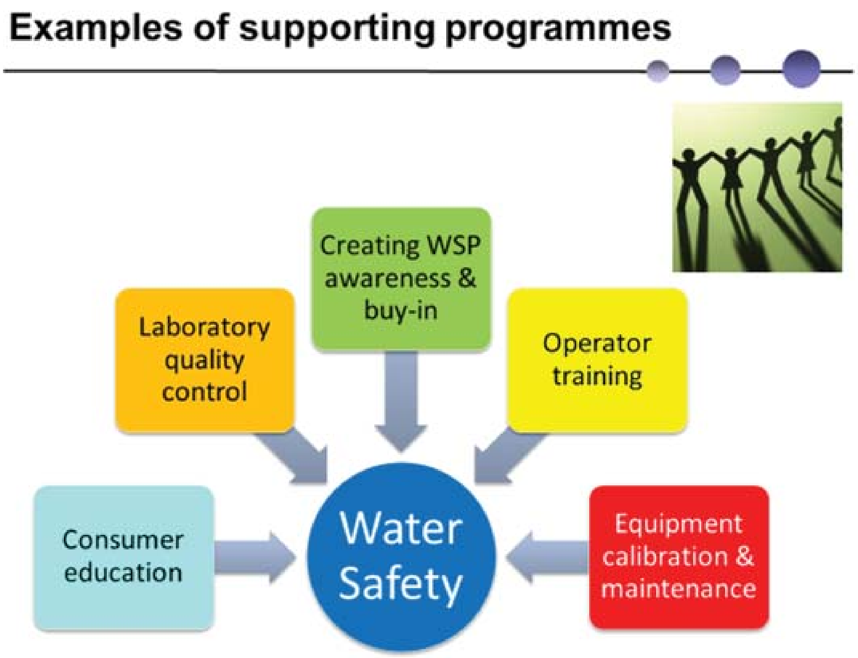


Figure 36: *Supporting programmes feed into the WSP*

8. Incorporating Climate Information into Wastewater Risk Abatement Planning

8.1 Steps, and how to incorporate findings into your W_2RAP

The purpose of this section is to provide municipalities/ wastewater treatment plants/water utilities with guidance on amending the seven W_2RAP modules that are impacted on by climate change. This section is in no way meant to replace the W_2RAP guideline (2011), and water utilities are encouraged to use the guideline when developing their W_2RAP. Steps requiring amendment include:

- Step 1. Assemble a team to develop the W_2RAP
- Step 2. Document and describe the system
- Step 3. Assess the existing or proposed system
- Step 4. Hazard assessment and risk characterisation
- Step 5. Identify hazards, control measures and preventative actions/validation
- Step 8. Management procedures for wastewater treatment systems
- Step 9. Documentation and communication

The scenario below will be referred to throughout this section to demonstrate how each step in the W_2RAP should be amended and how the climate information summary table should be completed. This colour box indicates how the W_2RAP step should be amended.

Scenario:

Sewerville wastewater treatment works (WWTW) is in Sewerland. The WWTW is responsible for treating wastewater received from all Sewerland. In recent years, the treating of wastewater to meet the requirements as per their water use Authorisation (WUA) has become increasingly challenging. The location of the WWTW has experienced above average temperatures in recent years. The increased temperatures have resulted in ineffective treatment, poor final effluent quality due to decreased biological activity associated with increased temperatures. The works has been studying climate assessment reports and have realised that under the influence of climate change; temperatures are likely to continue increasing. A recent review of the W_2RAP has indicated that the W_2RAP does not consider the impact of climate change and there are no plans in place to address climate change. Additionally, the current W_2RAP team does not have the technical skills required to incorporate climate change considerations into the W_2RAP. Urgent Action is required to prevent failure of treatment processes at the WWTW.

During the review of the Climate vulnerability assessment the W_2RAP team started filling in the climate information summary table as below (Table 23):

Table 23: The WSP team has started to identify effects climate may have on their system.

Climate hazard	Climate threat	Impacts	Impact on wastewater system
Increased high temperatures			

Based on the review of the CVA, the W_2RAP team could complete the column one of the climate information summary table. For the team to add more information, a site visit is required (Step 4: hazard assessment and risk characterisation).

Step 1. Assemble a team to develop the W_2RAP

This requires a multi-disciplinary team with an understanding of the wastewater treatment systems. The team member should typically be comprised of members that are involved in various stages of the wastewater value chain. The team will be responsible for developing and implementing the W_2RAP. In terms of climate resilience, the W_2RAP team should include sector professionals that understand climate information, wastewater system knowledge, authority figures and supporting members.

Typical W_2RAP team members:

- Technical Director
- Water Engineers and Technicians
- Water Network and Distribution personnel
- Water Works Superintendents and Senior Process Controllers
- Human Resources Departments
- Financial Department
- Catchment Management

- Water Monitoring and Laboratories (if in-house)
- National departments (DWS, DEA, etc.)
- Water Service Providers
- Public Health specialists
- Disaster reduction specialists
- Local people with a knowledge of the local climate and climate threats
- Managers, ward leaders and decision makers
- Water utility personnel with knowledge of drinking water related issues
- Water utility personnel with knowledge of natural water resources
- Experts on disaster and risk reduction and identification
- Other key role players

Inclusion of sector professionals to address climate change

The Sewerville W_2RAP team is very well established and includes members that are involved in various levels of wastewater treatment. However, after the review of their W_2RAP they realised that additional members are required to incorporate climate change considerations. The outstanding required members must have technical skill and knowledge related to the accessing and analysis of climate related information. The technical experts need only be ad-hoc W_2RAP team members. Sewerville W_2RAP team has identified the following technical experts:

- Climatologists and meteorologists (local weather services)
- Hydrologists and geohydrologists
- Geographical Information System Scientists
- Oceanographers
- Research Institution/Centres – Universities, NGO research entities, etc.
- Municipal Energy Champions / Managers
- Change Managers
- Others?

The WSP should consider what other technical members are required on the WSP team.

Identify key team members (internal and external) and assign roles and responsibilities and secure commitment.

The role of specialist and non-specialist team members when analysing climate related information should be defined

- Team members must perform data analysis and tasks according to their expertise (i.e. climatologists must review climate graphs and maps, hydrologists must review hydrological graphs, etc.).
- Specialists are required to identify relevant data and information sets, and setup monitoring stations (only where necessary).
- Non-specialists on the team should focus on reviewing general sections such as the effects of climate change on people or infrastructure. Where possible give specialists access to data/information.
- The roles of each team member should be clearly defined as follows (Table 24)

Table 24: Example of defined roles for each team member

Name	*Job title*	*Organization*	*Role of the W_2RAP Team*	*Contact information*
Ms. X	Manager operations	Sewerville utility	W_2RAP team leader	Tel.: 1245 3343
Mr. Y	Wastewater quality & risk specialist	Sewerville utility	Wastewater quality risk management	Tel.: 3421 3494
Ms. W	WMA liaison officer	Sewerville catchment authority	WMA representative	Tel.: 1894 5773
Mr. C	Professor of climate sciences	Sewerville College	Auxiliary Member	Tel.: 1544 3577

We are moving into an environment where energy efficiency, renewable energy and its impact on climate change and resilience need to be managed – so we need an integrated approach (wastewater treatment plus energy) and competencies if we are to achieve climate change adaptation, resilience and mitigation from a wastewater perspective.

Step 2. Document and describe the system

The W_2RAP team must have or develop a comprehensive understanding of the wastewater system. This includes, understanding the range and magnitude of hazards, as well as the current capabilities of the current processes to manage or mitigate the hazards. This requires the team to collect and collate any information related to the wastewater system and evaluate what the critical control points are in the system (i.e. identify where a problem will occur, from consumer (toilet) to the receiving environment). The team should also identify what could go wrong at each critical control point. A more comprehensive system description should include local climatic conditions. A climate summary can be useful to describe the climate of your area.

- Include climate trends – use graphs and maps such info can also be presented in an annexure, with key conclusions in the main body of the W_2RAP and include the following (Figure 37).
  - Rainfall (both catchment and receiving body)
  - Temperature
  - Inflow to the works

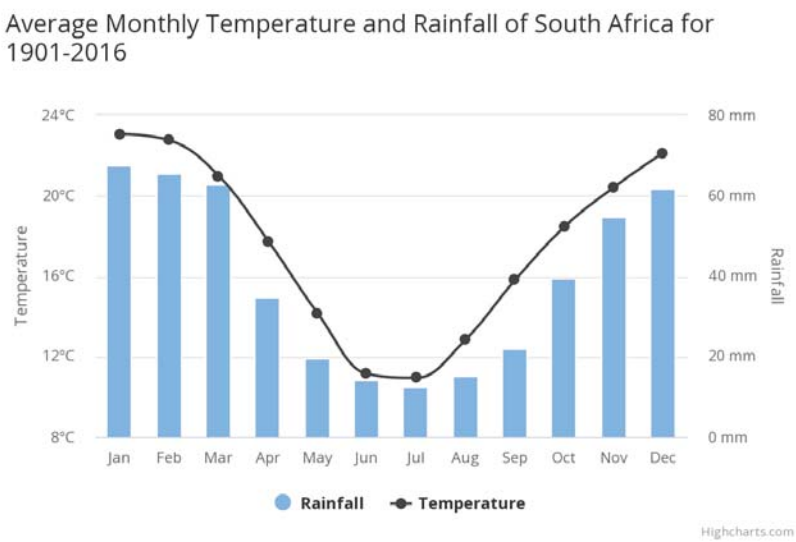


Figure 37: *Average monthly temperature and rainfall for South Africa (Worldbank.org.)*

Include flow diagrams describing wastewater flow and treatment unit processes wastewater goes through from consumer to catchment. Below are the various processes and aspects that can be used to describe each.

Catchment/ drainage area

- Average Dry Weather Flow and Peak Wet Weather Flow to treatment plant
- Rainfall events: frequency, duration, and volume
- Peak Factor design of plant versus exceedance of peak factor (impact on how plants are designed – we no longer can design for the standard peak factor of 1.8-2.1)
- Maps and catchment layout plans and drainage maps
- Water quality objectives of the receiving water resource
- Restrictions on effluent quality limits within the catchment (Water Quality Objectives)
- Effluent quality compliance of dry weather versus wet weather conditions (a key risk if wet weather brings higher non-compliance)
- Trend analysis in wastewater flow and strength
    - E.g. Western Cape – we see flow reduction of up to 40%, but organic loading increased – this changes the capability of the plant to meet effluent quality specs – ultimately having to be identified as a risk, with mitigation measures translating to redesign or refurbishment of certain process units.
    - E.g. in KwaZulu-Natal – floods – we see flushes of high flow, low organic loading – need for balancing peak flows, and higher return flows to be applied to keep bugs in the basins, i.e. sludge age (operational mitigation and infrastructure refurb).

Collection and reticulation

- Gravity and pump systems
- Age, capacity and condition of main collectors and pumping mains
- Industrial / domestic sources
- Population profile: current and future population served and service profiles (quantity and quality)
- Water Balances
- Extraneous water ingress (stormwater, groundwater) to sewer network

Treatment facility

- Capacity and plant classification
- Age, upgrade history
- Technology, process units
- Sludge management
- Authorisation and legal requirements
- Plans to upgrade – short to long-term
- Facilities to become redundant
- Buildings, structures, and landscaping
- Stormwater capture and management at plant
- Design shortfalls or bottlenecks as identified from Process Audits. Depending on drought or floods engineers need to change their design specifications and considerations – e.g. design for a higher

or lower PF, design more or lesser structure for bypassing inlet works and balancing of peak stormwater events, design for higher or lesser hydraulic or organic capacity, etc.

Influent quantity and quality

- Typical inflow
- Typical outflow
- Expected/projected inflow and outflow under climate change impacted conditions
    - All WWTW should know their climate change conditions and have some baseline stats, to enable them to link to key indicators such as peak wet weather flows, peak flows, storm water ingress, and effluent quality impact. WWTW need to be able to identify risks against a baseline of plant specific data and climate change projected impacts in their drainage/regional area.

Receiving environment and end users

- Discharge to water body
- Reuse and reclamation (including irrigation and reuse water for potable and industrial class water).

This information should be captured in a system diagram, which can be overlaid with key climate information. Where a wastewater treatment plant is present, a separate and more detailed schematic of the facility should also be included (refer to the box below on ‘Updating the system description’).

Updating system description

The Sewerville W$_2$RAP team reviewed their system description and realised that it does not include the local climate conditions or the processes that are impacted by increased temperatures. Following the review of the climate information the W$_2$RAP team updated their system description. The W$_2$RAP team have updated their system diagram to include current climate and climate change considerations. The new system diagram was updated to include the following (Figure 38):

- Annual temperature
- Predicted change in annual temperature by 2030
- Delineated areas that the processes that are currently affected by changes in temperature and other areas that are likely to be affected
- Areas that may be impacted by poorly treated effluent

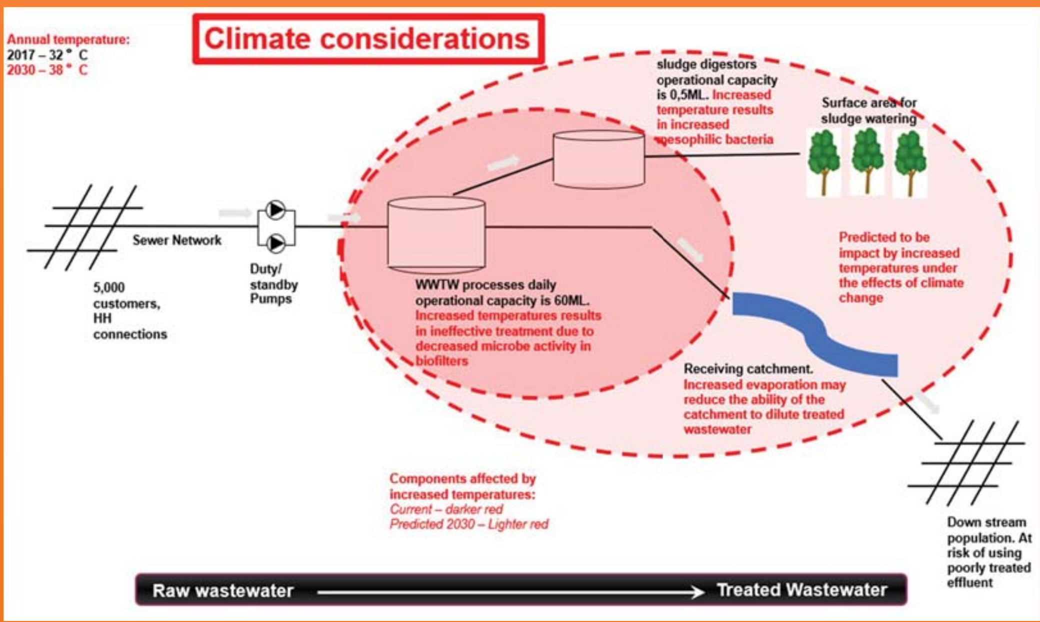


Figure 38: *System description of a wastewater treatment system across the sanitation value chain; relevant climate information is presented in red.*

After review and update of the system description, the W$_2$RAP team was able to update the Climate information summary table. The W$_2$RAP team realised that high intensity short duration would result in increased water availability at the inlet works (Table 25).

Table 25: Updated climate information summary table.

Climate hazard	Climate threat	Impacts	Impact on wastewater system
Increased high temperatures	Increased number of warm days		

The works will update the climate summary table after the site visit (Step 4: System Assessment (Risk Analysis, Prioritization).

Step 3. Assess the existing or new system and compile a flow diagram

The assessment should be inclusive of all elements in the wastewater system, and a flow diagram should be developed. When assessing the system, the sensitivity of the system to contamination along the wastewater reticulation and treatment system should also be considered. Components that require assessing are presented in Figure 39.

Component of wastewater system	Information to consider in assessing component of wastewater treatment system
Catchment	Geology (presence of dykes, sill & faults), topography and soil conditions
	Meteorology and weather patterns (regional climate, rainfall data, temperature data, wind data, evaporation and extreme weather)
	General catchment and river health
	Wildlife & natural vegetation
	Competing water uses
	Nature and intensity of development and land use and zoning, flood lines
	Other activities in the catchment that potentially release contaminants into source water (settlements without sanitation, religious ceremonies, mining)
	Planned future activities
	Sensitive landscapes and site of archaeological interest
	Industrial activity (types of industries, type of waste purification and by whom)
Surface water (inland and coastal)	Description of water body type (e.g. river, reservoir, dam, deep/shallow sea)
	Flow and reliability of source water
	Water constituents (physical, chemical, microbial)
	Presence of wetlands and other protection
	Surface water use (domestic, industrial, agricultural, recreational or natural environment)
	Water authorities and water users
Groundwater	Confined or unconfined aquifer
	Aquifer hydrogeology
	Presence and position of boreholes within a 1000 m radius of system
	Yield of boreholes
	Groundwater use
	Groundwater quality (pH, conductivity & nitrate)
Collector systems	% of area unsewered
	Manner of service (pit latrines, bucket system, conservancy tanks, septic tanks and French drains)

Treatment	% of area severed or to be sewered
	Type of network in place or to be installed (standard or small bore systems)
	Location of sewers (midblock or standard)
	Protection (e.g. covers, enclosures, access)
	Nature of sewerage
	Domestic component (existing and projected)
	Industrial component (daily volumes / expected volume to be treated, type of industrial waste[mainly organic, organic / inorganic, heavy metals, mixture], potential problem constituent received from industries)
	Stormwater, ground water and/or potable water ingress or influx
	Hydraulic & organic loading
	Seasonal variations
	Peak dry and wet weather flow factors
	A history of equipment malfunctions
	Maintenance schedules and frequency
	List of suppliers for critical equipment and parts
	Treatment processes (including optional processes)
	Method of disposal of screenings, sludge, supernatant liquid, methane gas, etc.
	Wastewater treatment chemicals used
	Treatment efficiencies (chemical, physical, microbiological)
	Disinfection of pathogens
	Disinfectant residual / contact time
	Disinfection other – details of use, period of application and intensity
	Equipment design
	Monitoring equipment and automation
	Availability of standby / spare equipment (mechanical, electrical)
	Final effluent and sludge disposal (methodology, quantities, norms and standards applicable)
	Water Balance

Figure 39: *Components and information for assessing wastewater treatment systems (vd Merwe-Botha and Manus, 2011)*

Using climate data/information with operational monitoring

The processes occurring in a the WWTWs are subsequently affected by climate change; temperature impacts the biological processes (increased mesophilic activity), more extreme weather events will lead to more untreated sewer overflows, increased flooding, over capacity but to name a few. Climate data and information must be used conjunction with operational monitoring, compliance monitoring, catchment monitoring, industrial monitoring and in some cases air quality monitoring to determine the impact of climate change on processes. Temperature can affect operational limits of activated sludge (MLSS and DO), types of organisms that are present in reactor, and sludge treatment (may be beneficial if temperature increases). Floods may impact collection systems, treatment plant, and discharge point. Floods may result in overcapacity at various point in the system. Droughts may on the catchment if final effluent is of a poor quality. Droughts may also impact on quality and quantity of effluent reaching the plant (Day Zero scenario with water shortages leading to less flushing of toilets).

It should be noted that wastewater treatment contributes to climate change through the release of greenhouse gases (GHGs) Carbon Dioxide (CO_2) from aerobic (oxidation processes), methane (CH4) from anaerobic processes (3-19% of global anthropogenic methane emissions), and nitrous oxide (N2O) (3% of N_2O emissions from all sources) associated with nitrification/denitrification processes. Therefore, additional control measures may be required to reduce these emissions, such as reuse of biogas for energy production to offset the contribution of WWTW to climate change.

Step 4. Undertake a hazard assessment and risk characterisation (and prioritisation) to identify and understand hazards

Hazard identification is required at each step of the wastewater reticulation and treatment system, so that adequate preventative measures can be identified and put in place. A risk assessment allows you to determine, what could go wrong and where it could go wrong at each part of the wastewater value chain, and the risk on the system and to prioritise the risk accordingly. However, to be climate resilient hazards considerations that consider the impact of changes in inflow quantity and temperature, etc. need to be included. These considerations should be carried at for each part of the value chain (consumer to catchment). The risk associated with each hazard and hazardous event, should be calculated for new risks, and re-calculated to determine impacts of climate change. The risk can easily be determined using a risk matrix, which will assist the team to prioritise risks. The W_2RAP needs to take into consideration and include the following key risk assessments.

- Authorisation Audits
- Process Audits
- Sludge Classification and Management Plans
- Sanitation Masterplans – including sewer network inspection reports and planned upgrades to deal with increase in population size
- Biomonitoring and toxicology
- Extraneous water infiltration/ingress management plan

Climate Change/Hazard needs to be included as a Root Cause and risks associated with such must be clearly identified. Remember that critical control points need to be identified through this process as well will need to be connected/indicated in the solid and liquid stream of the process.

Below is a list of considerations for identifying climate related hazards and hazardous events, and assessing the risk:

- Complete a site visit – Prepare a list of generic questions such as: what would happen if the inlet works were flooded?
- Differentiate between climate related hazards/hazardous events, and non-climate related hazards/hazardous events – not all hazards will be affected by climate change.

The site visit may highlight the hazards that are likely to occur in the system, and the source/s of the hazard. Hazardous events are the mechanism whereby an agent (biological, chemical, physical, or radiological) is introduced into the system. Hazardous events can be described as follows:

X happens (to the sanitation system or environment) because of Y

X = What can happen at the process

Y = How it can happen (i.e. cause)

Example:

- Catchment becomes faecally contaminated (**X**) because of discharge of poorly treated wastewater release from the WWTW (**Y**)
- Effluent is over- or under-dosed with chlorine (**X**) because of insufficient operator training (**Y**)

Hazards and hazardous events require prioritisation, as the degree of attention and effort required for each risk may vary. Risk is determined based on the product of likelihood and severity. This will better assist you in determining which risks are more important and which are less important. A simple example of a risk matrix and risk scores are presented in Table 26 and Table 27.

Data and information limitations should be considered as a hazard/hazardous event and should be captured as such in the WSP or W_2RAP. This becomes especially important if you identify that for, e.g. increases or decrease in temperature are a climate hazard, but you are unable to source the relevant temperature for your area/system.

Table 26: *Example of a risk matrix*

	Severity				
Likelihood	Insignificant 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
Almost Certain 5	5	10	15	20	25
Likely 4	4	8	12	16	20
Moderate 3	3	6	9	12	15
Unlikely 2	2	4	6	8	10
Rare 1	1	2	3	4	5

__Table 27:__ W_2RAP Risk score description (vd Merwe-Botha and Manus)

Score	Risk profile	
0-10	Low	These are systems that operate with minor deficiency and usually meet the effluent quality specifications set by the Department of Water Affairs. It is unlikely that this level of risk is harmful to the health of people and the environment. Aesthetically and/or physical non-compliance can be expected for short periods.
11-20	Moderate	These are systems with deficiencies which individually or combined pose a medium risk to the quality of the receiving environment and health. These systems would not generally require immediate action but the deficiencies should be rectified to avoid future problems and associated cost to rectify once in HIGH risk. Aesthetically and/or physically non-compliance can be expected over a medium term. Medium term impact on infrastructure and partial failure of the wastewater treatment plant and disinfection process is likely.
21-25	High	These are systems with deficiencies which individually or combined pose a high risk to the quality of the receiving environment and health, and may lead to potential health, safety and environmental concerns. Once a system (or part of a system) is classified under this category, immediate corrective action is required to arrest or eliminate the deficiency. High impact on the health of people and the environment and/or significant damage to infrastructure can be expected. Total failure of the collector, treatment and disinfection facility is likely.

After the site visit, the W_2RAP team realised that increased temperatures have an impact on the operating capacities of various processes. Wastewater that has above normal operating capacities compromises the system to deliver and treat water at its design capacity. Temperature is likely to continue increasing over time and the effect of which is likely to expand/impact to other areas of the WWTW, and action is required (Table 28).

Table 28: Updated climate summary to include the impacts of the climate threat

Climate hazard	Climate threat	Impacts	Impact on wastewater system
Increased high temperatures	Increased number of warm days	Increase in wastewater temperatures	Reduced operating capacity of various processes within the wastewater system

Using a questionnaire to identify hazards and hazardous events at the WWTW

As part of South Africa's Green Drop programme a comprehensive list of questions has been developed. The questionnaire covers multiple aspects such as appearance of the works, wastewater treatment processes, disinfection, chemical dosing, and sludge treatment processes. The questionnaire can be used to assess a wastewater treatment works with any combination of processes (Figure 40).

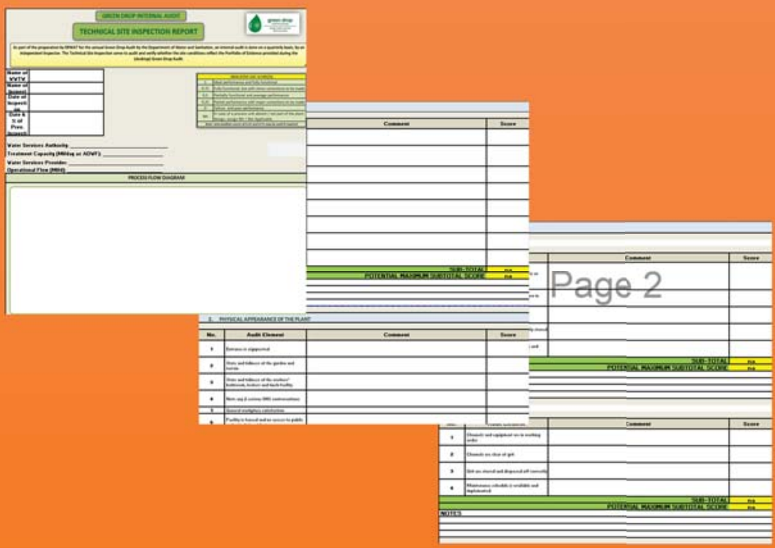


Figure 40: *Example of Green drop site inspection questionnaire.*

However, the questionnaire does not cover questions that seek to understand the impacts of climate change on the system. Therefore, when trying to incorporate climate resilience into your W_2RAP you need to develop a list of generic questions that can be asked at each of the process units. During the site visit additional questions must be added to the list, as and when they arise. Table 29 provides you the list of generic question that can be added to the site inspection questionnaire.

Table 29: Example a data collection tool.

Wastewater treatment works inspection form		
1	How is this process affected by changes in atmospheric temperature? i.e. What impact do low/high temperatures have on this process	Y/N
2	How is this process affected by changes in flow? i.e. an increase in flow and a decrease in flow	Y/N
3	How is this process affected by rainfall, do spillages occur?	Y/N
4	Is the infrastructure capable of periods of overcapacity brought about by periods of high rainfall?	Y/N
5	How is this process affected by increased wastewater temperatures?	Y/N

Refer to Step 2 in each of the Approaches for additional questions.

Step 5. Identify hazards, control measures & preventative actions

Hazards identified require adequate control measures to ensure that impacts to the system are reduced if they occur. An important component of identifying control measures is to reassess the risk to determine the effectiveness of the control measures (i.e. has the risk been reduced after implementation of the control measure). Preventative maintenance plans should be developed for each control measure, and descriptions of the actions should be provided for the implementation.

Climate change may change the risk of existing hazards and hazardous event but may also introduce new hazards and hazardous event the risk of which need to be determined. During the site visit the existing control measures must be identified. Control measures need to be assessed as under the influence of climate change; they may become ineffective. An assessment thereof must be conducted, and new/additional control measures should be implemented. The risk associated with each hazard and hazardous event, should be calculated for new risks, and re-calculated to determine impacts of climate change for hazard and hazardous event. Below is a list of considerations for identifying climate related hazards and hazardous events and assessing the risk:

- Are my current control measures still effective or, do we need new control measures or, do we only need to upscale/modify our current control measures?
- Are these control measures effective under the influence of climate change?
- What new control measures are required?
- Can control measures be implemented quickly or do we require a long period for implementation?
- Do we need to develop new SOPs, contingency plans, training programmes and emergency procedures for climate resilient control measures?
    - 2 step risk assessment – what is the risk per hazard/hazardous event before climate change impacts
    - What is the risk per hazard/hazardous event after considering climate change impacts (has it changed and how)? Which hazards/hazardous events are affected?
- Include your list of climate threats in this section
    - Develop hazard and hazardous events for each threat
    - Consider the risk scores for each hazard and hazardous event
- Conclusions drawn from climate assessments or data analysis should be used to amend the risk scores

Table 30 and Table 31 can be used to determine the risk of a hazard and hazardous event, before and after climate change consideration.

Table 30: Assessment of risk before climate change consideration

Effectiveness control measures before climate change consideration																		
			Risk if there were no controls in place				Are controls effective?					Risk with controls in place				Additional control needed?		
Process Step	Hazardous Event	Hazard Type	Likelihood	Consequence	Risk score	Risk level	Existing control measures	Yes	No	Somewhat	Validation notes *(basis of effectiveness assessment)*	Likelihood	Consequence	Risk score	Risk level	Yes	No	If yes, proposed controls *(to be further detailed in improvement plan)*
Pumping Stations	Micro-organisms in biofilters die off, due to increased atmospheric and wastewater temperatures	Phys	3	5	15	M	Require industry to reduce wastewater temperatures before release into the system	✓			Monitoring of temperatures Monitoring of temperatures across the system	3	2	6	L		✓	---

Table 31: Assessment of risk after climate change consideration, the control implemented before climate change is no longer valid under the influence of climate change and a new control measure is required.

Effectiveness control measures after climate change consideration																		
			Risk if there were no controls in place				Are controls effective?					Risk with controls in place				Additional control needed?		
Process Step	Hazardous Event	Hazard Type	Likelihood	Consequence	Risk score	Risk level	Existing control measures	Yes	No	Somewhat	Validation notes *(basis of effectiveness assessment)*	Likelihood	Consequence	Risk score	Risk level	Yes	No	If yes, proposed controls *(to be further detailed in improvement plan)*
Pumping Stations	Micro-organisms in biofilters die off, due to increased atmospheric and wastewater temperatures	Phys	3	5	15	M	Require industry to reduce wastewater temperatures before release into the system		✓		Monitoring of temperatures across the system	3	5	15	M	✓		Long-term: Implement processes that are less temperature sensitive Short-term: Reduce wastewater temperatures

Using short-term and long-term control measures

In some cases, you may find it necessary to implement control measures in the short-term, to abate risks while a long-term risk is being implemented in stages. Short-term control measures can be defined as those actions that can be implemented immediately with proven effectiveness, at a low cost to the utility, however, may only be effective for a short period (e.g. within 5 years) before long-term action is required. These may only be effective under current climate conditions.

Long-term control measures can be defined as those actions that require implementation over a long period (e.g. 5 years to be fully implemented), and large financial resources, but may be effective for an extended period (30 or more years).

Considering the above, municipalities/WWTW may need to implement both short-term and long-term control measures. Short-term control measures should be implemented as interim actions, while long-term control measures are implemented incrementally and over a period (Table 32).

Table 32: Example of incremental control measure implementation

	What improvement is needed?	What is the priority level for the improvement? (H/M/L)	Who is responsible for completion of the improvement?	How much is it estimated to cost?	Planned start date?	Planned finish date?	What is the status?
1	Build temporary balancing dam	High	Mr. Y	R 100,000	August 2020	December 2020	Not started
2	Increase WWTW capacity to cope with increased periods of increased flows	High	Ms X	R 100,000,000	June 2021	June 2027	Not started

Step 8. Management procedures for wastewater treatment systems

Management procedures are defined actions to be taken when responding to an incident; to reduce the impact of the incident. These actions should be defined for likely incidents, and as far as possible for anticipated unlikely incidents. An example of a management procedure may include standard operating procedures, which guide staff personnel on what to do during 'normal' conditions and what to do during emergency conditions. Supporting programmes should also be considered when creating management procedures. Supporting programmes may be in the form of continued skills development and education, to ensure that plant personnel perform their tasks adequately.

- Management – These require actions to be implemented when the system is operating optimally, i.e. normal activities, and actions required when there is a deviation in normal operations occurs, i.e. corrective actions.
- Documentation – Provides information on the wastewater system and programmes to upgrade the system for improved water delivery. Plans and related reports for operational monitoring and verification of the W_2RAP effectiveness. These records are essential as they provide auditors with an indication of the adequacy of the W_2RAP, in relation to the adherence to operational standards.
- Communication methods/protocol – This is a process whereby an incident is communicated within the water utility and is escalated to the relevant responsible person to carry out the required control measures. In some instances, the public may need to be notified of an incident, and information should be made available to them. The platforms for communication should also be highlighted.
- Operational Monitoring – These should be prepared based on water quality standards, either set by a local authority or within your institution.
- Update/modify and develop SOPs – Under the effect of climate change, existing Standard Operating Procedures (SOPs) and management procedures may no longer be effective. It will therefore require the updating or modifying of existing SOPs and management procedures. In some cases, new SOPs have to be developed for new hazards and hazardous events. SOPs need to consider the impact of climate change on the system and the on hazard and hazardous events. SOPs also need to include/account for climate-related emergencies/disasters and pre-emptive actions required when disasters are predicted/forecast.
- Authorisation Audits – Audits should consider the impact of climate change; this can be done during the site visit component of the Audit. Questions should be developed that aims to understand how processes are being modified/upgraded to ensure climate resilience. This may require additional training for auditors to understand the effects of climate change on WWTW processes, such that they can determine if the works intended modification/upgrade plans address climate change and make the appropriate recommendations.
- Process Audits – Process audits need to consider the performance of a various processes under the influence of climate change. The application of climate change to the process audit, may inform where new technologies need to be implemented and which technologies should be

retired. It should be noted that not all processes will be impacted by climate change, the processes likely to be affected are those that utilise micro-organisms as part of treatment.

- Sludge classification and management plans – Sludge is particularly susceptible to changes in temperature. Changes in temperature can result in conditions that are suitable for micro-organisms that thrive at higher temperatures. This will have an impact of the sludge classification and the use of the sludge. Sludge management plans must be updated to reflect the treatment, usage and application of sludge.
- Sanitation Master Plans – Sanitation Master Plans need to be updated to include the impact of climate change. The Master Plan should denote those areas that are susceptible to climate change and the types of climate threats. This will assist that the best sanitation technologies are implemented and the correct locations for implementation of various technologies.
- COVID-19 considerations – The impact of COVID-19 is well documented in news media, as well the temporary business closure when staff were exposed to the virus. Management procedures must be developed for these emergency conditions, especially if your system must continue operating. The plan should be detailed such to ensure business continuity after an emergency/virus exposure happens, and how long after exposure to an incident business may resume (and staff may return). Different incidents may have different down times and contingency plans must be developed to ensure business resumes as soon as possible. This may include having internal contingency plans, as well as your service providers (such as chemical suppliers) having similar plans. In the case of your system you may need to operate on a rotational basis and ensure that staff from each rotation do not encounter each other.

Step 9. Establish documentation and communication procedures

The W_2RAP should be regularly updated with new information as and when it becomes available. The information also allows tracking the performance of system processes and assists to identify when replacement or maintenance of processes is required. The W_2RAP and associated wastewater quality monitoring data should be communicated to various stakeholders to ensure that when an incident occurs these stakeholders are aware of how the incident and implemented control measures may impact them.

9. Testing and Refinement of Methodology through piloting at 3 selected Municipalities

9.1 Site Selection

The three provinces selected for this study include the Western Cape, KwaZulu-Natal, and Limpopo. The Western Cape Province was selected as, the province that experienced one of the worst hydrological droughts in recent history. The hydrological drought led to an extreme water shortage and restrictions on consumption. KwaZulu-Natal province was selected as the province experienced recent flooding, towards the end of 2019. Limpopo province was selected as it has transboundary municipalities that share the Limpopo River with neighbouring countries, and the province itself is also prone to the effects of climate change (i.e. both flooding and droughts experienced). Municipalities were shortlisted and selected based on the following criteria:

- Previously developed a water safety plan (WSP) and wastewater risk abatement plan (W_2RAP),
- Willingness to participate in project,
- Have been recently affected by either drought, flood or the geographic location (transboundary municipality),
- Accessibility/availability of climate related information / data,
- Site accessibility under COVID-19 restrictions, and
- Observing unprecedented impacts of climate change.

Considering the above, the following three (3) municipalities were selected (Figure 41).

- Witzenberg Local Municipality in the Western Cape
- Uthukela District Municipality in KwaZulu-Natal
- Lephalale Local Municipality in Limpopo Province

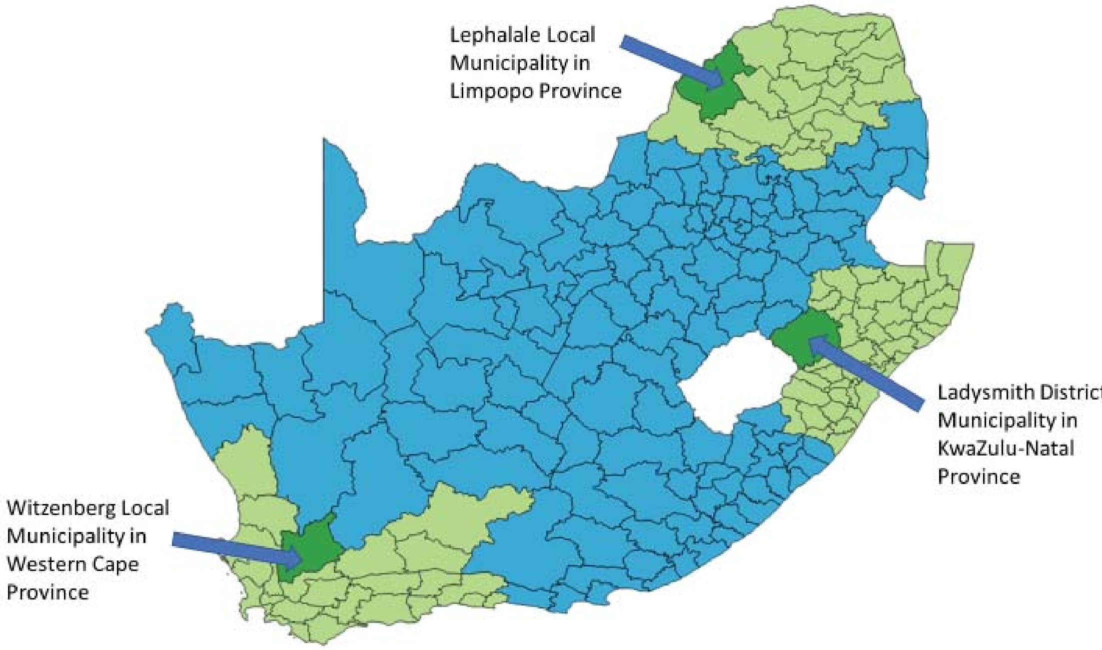


***Figure 41**: Location of the selected three municipalities*

For each of the selected municipalities, one (1) water supply system and one (1) wastewater system were selected for piloting. The aim of the pilot was not to develop a new WSP or W_2RAP, but rather to guide and assist each municipality to enhance and improve their current WSP and W_2RAP by understanding climate change impacts (both present and future) on their systems, such that they could start planning improvements to make their water and wastewater systems more resilient. As part of the pilot, the project team would assist municipalities to identify and incorporate climate related hazards and hazardous events into their plans, such that they can determine the efficacy of existing control measures, and where required identify and implement new climate resilient control measures. Understanding the process and actions required to update WSPs/W_2RAPs for climate resilience will:

1. Enable the municipalities to do similar for other water and wastewater systems within their municipality, and
2. Empower the municipality to be more confident to review and update their WSPs/W_2RAPs to address any new and emerging threats (e.g. COVID-19, cyber terrorism).

Considering the above, and in consultation with the municipality and their needs, the following systems were selected for piloting (Table 33).

Table 33: *Selected water and wastewater systems*

Municipality	Water Supply System	Wastewater System
Witzenberg Population: 130 548 Households: 35 976	Tulbagh Location: 33° 17’ 09’’ S, 19° 09’ 09’’ E Source water: Moordenaarskloof River Tierhokskloof River Schalkenbosch Dam Skilpadrug River Klein Berg River Technology type: Sand Filtration	Ceres Location: 33 23’ 03.29’’ S, 19 19’ 14.70’’ E Wastewater sources: Industrial Domestic Treatment type: Activated Sludge
Uthukela Population: 706 589 Households: 161 788	Ladysmith Location: 28° 33’ 8.15’’ S, 29° 44’ 58.28’’ E Source water: Klip River Spioenkop Dam Technology type: Slow Filtration	Ladysmith Location: 28° 33’ 8.15’’ S, 29° 44’ 58.28’’ E Wastewater sources: Industrial Domestic Treatment type: Biofiltration
Lephalale Population: 140 240 Households: 43 002	Zeeland Location: 23°45'35.1"S 27°37'23.2"E Source Water: Mokolo Dam Technology type: Sand Filtration	Paarl Location: 23°43'08.9"S 27°41'45.0"E Wastewater sources: Domestic Industrial Treatment type: Activated Sludge

9.2 Review of municipal WSP and W_2RAP

The three municipalities were requested to provide the project team with their most recent WSP and W_2RAP for review (Figure 42). All WSP modules and W_2RAP steps were reviewed to determine if they are current, comprehensive, and if there are any gaps. The review process indicated that the WSP for Ladysmith (Uthukela) was out of date, whereas both Tulbagh (Witzenberg) and Zeeland (Lephalale) WSPs were up to date. The W_2RAPs for both Ladysmith and Paarl (Lephalale) wastewater systems were both out of date, whereas the W_2RAP for Ceres (Witzenberg) was up to date. Additionally, the review indicated that not all anticipated risks were previously assessed for each of the three municipalities. These include: internal departmental risks, health and safety risks, financial risks, staff risks and operational risks.

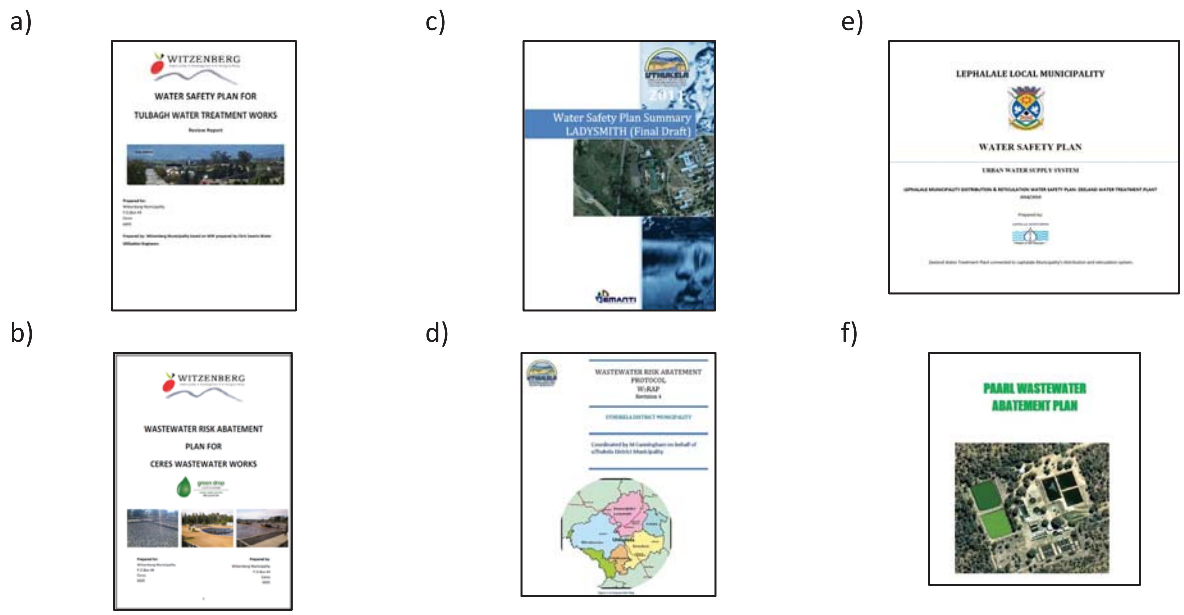


Figure 42: *The most recent WSPs and W₂RAP S for Witzenberg, Uthukela and Lephalale. a) Tulbagh WSP, b) Ceres W₂RAP, c) Ladysmith, d) Ladysmith W₂RAP, e) Zeeland WSP, f) Paarl W₂RAP.*

9.3 Testing and refinement of incorporating climate resilience into the Water Safety Plan and Wastewater Risk Abatement Plan

9.3.1 Climate resilient water safety plan and climate resilient wastewater risk abatement plan training

Upon arrival at each of the municipalities, an opening meeting was held with appropriate municipal staff. The meeting provided an overview of the project, the purpose of the site visit, and presented some initial findings based on the review of provided municipal documents. A brief climate resilient WSP and W_2RAP training session was conducted to prepare for the site assessment (Figure 43). The climate resilient WSP and W_2RAP training session covered the following topics:

- Refresher on WSP and W_2RAP process
- Weather and climate change,
- Potential climate change impacts to water supply and wastewater systems,
- Accessing, analysing and interpreting climate related information,
- Integrating climate information into the WSP and W_2RAP process

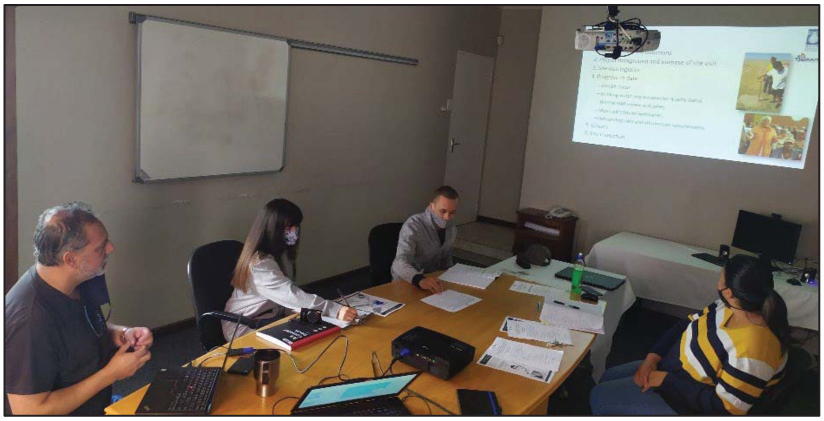


***Figure 43:** Opening meeting CR-WSP and CR-W$_2$RAP training sesion at Witzenberg Local Municipality*

The purpose of the training was to prepare the municipality to assist the project team in identifying those parts of the water supply and wastewater systems that are already affected by climate related threats such as floods and droughts, and to consider and identify those parts that are likely to be affected by future climate change impacts and the possible variation in the extent/coverage of these climate related threats. During the opening meetings, each municipality was presented with a draft climate summary for their municipality. The climate summary provides an overview of the current average climate conditions, long term climate trends and climate projections. The climate summary also includes a table that highlights the main climate threats identified for the area (e.g. increased temperature), and how the water and wastewater systems may be affected by the climate threats. These climate summaries are provided in **Appendix B**.

From the opening meeting, the following summarized feedback is noted (Table 34):

***Table 34:** Municipality feedback from Workshops and site visits*

	Witzenberg	Uthukela	Lephalale
Feedback from Opening Meeting and training session	1. The opening meeting allowed the municipality to ask for assistance on other issues including assistance on the energy audits, Process audits and sludge disposal methods. 2. The municipality found the session useful and allowed them to understand how climate change may impact their system.	1. The Municipality found the sessions interesting and insightful, especially as not all members present were familiar with the concept of water safety planning.	1. Indicated that the training session was insightful, and covered some interesting learning regarding climate change.

	Witzenberg	Uthukela	Lephalale
Feedback on Climate summary	1. The municipality found the climate summary very useful and were able to use the climate threats section to identify the threats pertinent to their area. 2. The municipality thinks that they will be able to use it in other processes or documents developed by the municipality.	1. The municipality found the climate summary useful for the processes, and easy to understand. The municipality indicated that the climate summary highlights the importance of climate change and the involvement and responsibility of every Government department.	1. The municipality found the climate summary useful.
Feedback on site visit and closing meeting	1. The municipality agreed with the findings made during the site visit, and highlighted additional climate threats.	1. The municipality highlighted that the main challenge with implementation of the findings include budgetary constraints and the willingness of council to participate in the process. 2. To address the above the municipality indicated that there is need to present an in-depth managerial climate change workshop to council and update WSP and W_2RAP as a “living” document.	1. The municipality engaged in the discussions and were able to provide the project teams with insights as to how they are already being affected by climate change.

9.3.2 Site inspection and identification of climate threats

Following the opening meeting, the project team and municipal team conducted joint site assessments. For the water supply systems, this included site inspection from source (catchment) to consumer (tap), while for wastewater this included site inspection from consumer (containment) to source (effluent discharge to the environment/catchment). During the site inspection, municipal officials were asked to comment on any climate threats that had previously occurred in their systems/area, and the impact thereof to their system. The project team also noted possible additional climate threats to the systems (based on literature review and data analysis) and indicated these to the municipality. A brief overview of the site inspections is noted in the sections that follow.

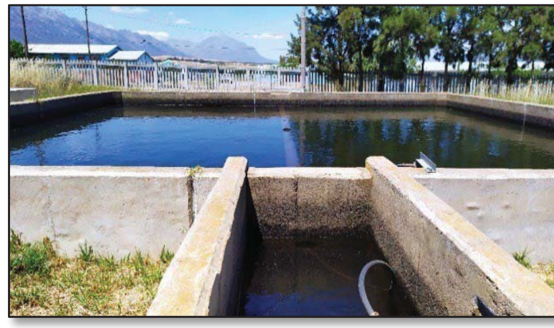
Witzenberg

The site inspection included a review of the following water supply and wastewater system components (Figure 44 and Figure 45):

Tulbagh Water Supply System

a)

b)



c)

d)

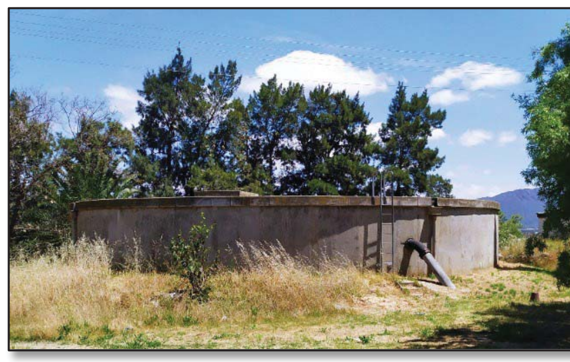


Figure 44: *Components of the Tulbagh water supply inspected during the site visit. The components include a) the source water, b) the water treatment works, c) the onsite laboratory and d) the reservoir.*

Ceres Wastewater System

a)

b)

c) d)

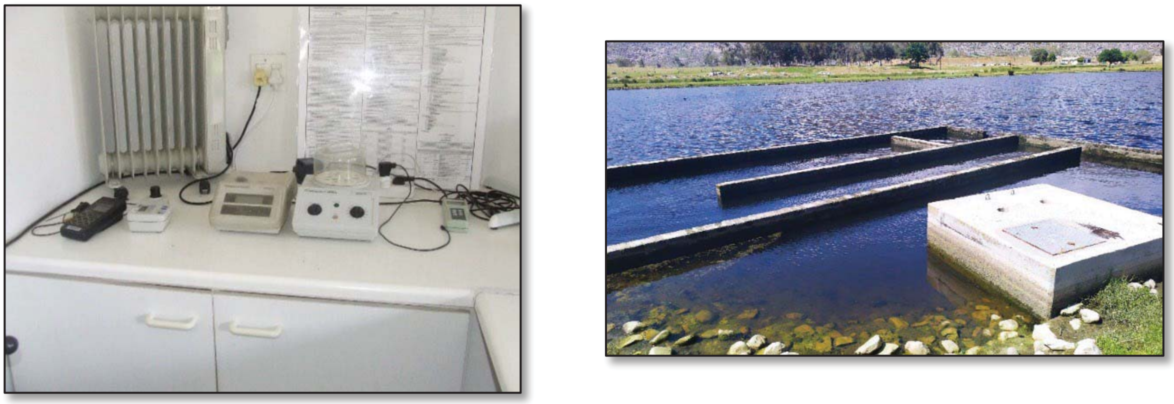


Figure 45: *Components of the Tulbagh wastewater system inspected during the site visit. The components include a) the pump stations, b) the wastewater treatment works, c) the onsite laboratory and d) the discharge point.*

The threats noted by the municipality and the project team are presented as follows (Table 35).

Table 35: *List of climate threats observed during the Witzenberg site visit*

Municipality	Climate threat
Witzenberg	Flooding
	Droughts
	Erosion
	Infrastructure damage (flood related)
	Sediment ingress (flood related)
	Heat stress
	Cold stress
	Fire

The climate threats in Witzenberg occur and affect all parts of the municipality, however at varying scales throughout the municipality. Examples of climate threats identified during the site inspection are presented in Figure 46.

a) b) c)

Figure 46: *Examples of climate threats identified at Witzenberg. In the above figure a) indicates high instances of erosion in the catchment area, b) indicates high amount of vegetation near the source water which could be fire risk (especially in drier years), and c) indicates the sludge lagoon at the Ceres WWTW that is at risk of flooding and can affect the nearby informal settlement*

Uthukela

The site inspection included a review of the following water supply and wastewater system components (Figure 47 and Figure 48):

Ladysmith Water Supply System

a)

b)

c)

d)

e)

Figure 47: *Components of the Ladysmith water supply inspected during the site visit. The components include a) the source water, b) the water treatment works, c) the onsite laboratory d) the reservoir and e) pump stations*

Ladysmith Wastewater System

a)

b)

c)

Figure 48: *Components of the Ladysmith wastewater system inspected during the site visit. The components include a) the pump stations, b) the wastewater treatment works, and c) the discharge point.*

The threats noted by the municipality and the project team are presented as follows (Table 36).

Table 36: *List of climate threats observed during the Uthukela site visit*

Municipality	Climate threat
Uthukela	Flood
	Fire
	Heat stress
	Cold stress
	Drought
	Dam siltation
	Infrastructure damage (flood related)

During the Uthukela site visit, both climate related and non-climate related threats were identified. Many of these threats are related to poor infrastructure maintenance and are likely to worsen under the effect of climate change if they are not timeously addressed. Examples of climate related threats identified during the site inspection are provided in Figure 49.

a) b) c)

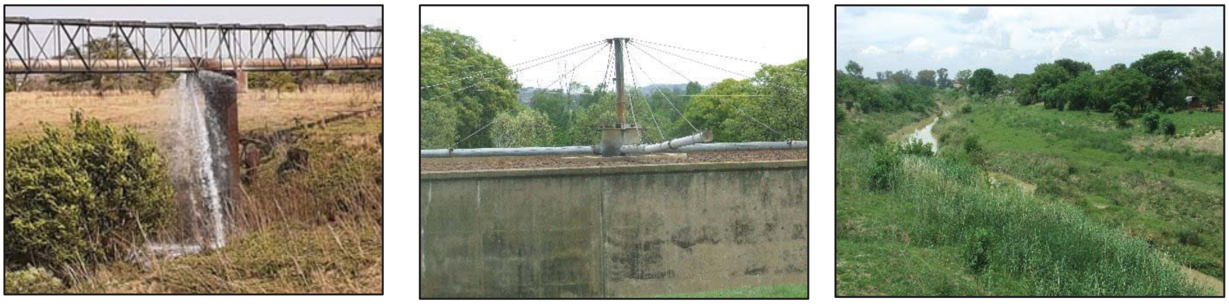


__Figure 49:__ Examples of components within Uthukela that are likely to be impacted by climate threats. In the above figure a) indicates a pipe burst due to poor infrastructure condition, this is likely to worsen during periods of high flows; b) indicates that flows into works negatively impacting on microbiological treatment efficiency of biofilters; c) flows into the works based on drought and impacts need to be managed

Lephalale

The site inspection included a review of the following water supply and wastewater system components (Figure 50 and Figure 51):

Zeeland Water Supply System

a) b) c)

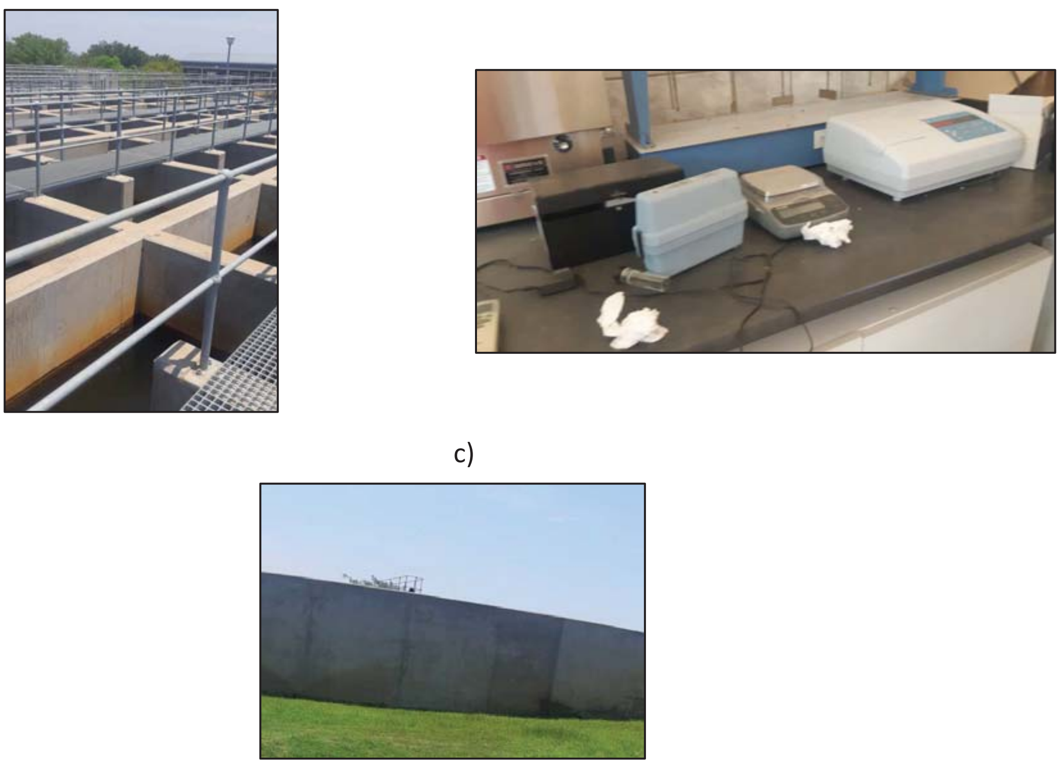


__Figure 50:__ Components of the Lephalale water supply inspected during the site visit. The components include a) the water treatment works, b) onsite laboratory, c) the reservoirs

Paarl Wastewater System

a)

b)

c)

Figure 51: *Components of the Lephalale wastewater system inspected during the site visit. The components include a) the pump stations, b) the wastewater treatment works, c) the discharge point.*

The threats noted by the municipality and the project team are presented as follows (Table 37).

Table 37: *List of climate threats observed during the Lephalale site visit*

Municipality	Climate threat
Lephalale	Drought
	Flood
	Earthquakes
	Heat stress
	Infrastructure damage (flood related)

During the Lephalale site visit, both climate related and non-climate related threats were identified. Key threats are related to water supply, as it was observed that in some instances one (1) borehole can serve up to nine (9) villages. This can pose a serious problem especially during periods of drought, which the area is becoming susceptible to. Examples of climate related threats identified during the site inspection are provided in Figure 52.

a) b) c)

__Figure 52:__ Examples of infrastructure components within Lephalale that are likely to be impacted by climate threats. In the above figure a) indicates one of the boreholes supplying several towns – with no alternative water supply; b) indicates pump stations are likely to fail due to increased temperatures and lack of adequate cooling; c) indicates that the WWTW are over capacity, and during periods of high rainfall are likely result in failure of the works to treat wastewater effectively.

9.3.3 Access to Weather and Climate Data

In terms of climate monitoring, Witzenberg Municipality has a weather a station in place at the Ceres WWTW. The weather station monitors various parameters including temperature, rainfall, wind speed and direction, air pressure, and humidity on an hourly basis (Figure 53). However, the data record is only for a relatively short period starting from 2014 up to 2020 (i.e. ~6 years).

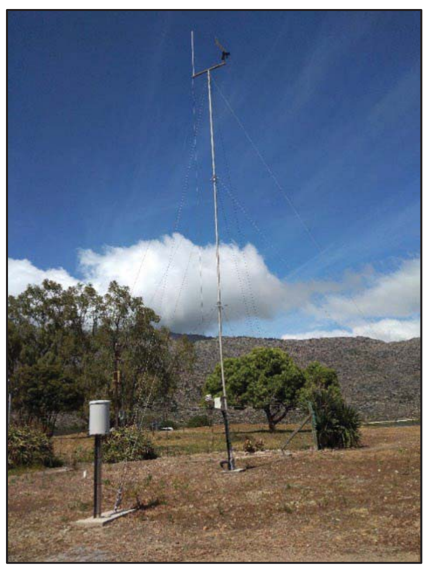


__Figure 53:__ Weather station in Witzenberg that monitors multiple climate and weather variables.

Both Lephalale and Uthukela indicated that though they are not monitoring climate, the information can be retrieved from various institutions such as SAWS, Eskom, and SANBI on request.

9.4 *Incorporating Climate Resilience into the Water Safety Plan and Wastewater Risk Abatement Plan*

9.4.1 Climate change resiliency requirements per WSP module and W_2RAP step as observed during the workshop and site inspections (per municipality)

As part of the piloting, various modules/steps of the WSP and W_2RAP were workshopped with the 3 municipalities to help them with incorporating climate impacts into their WSP/W_2RAP processes. The focus of the workshops was on ensuring:

1. Municipalities have an appropriate team that considers climate change related expertise.
2. System descriptions contain climate related information current and projected rainfall and temperatures, areas affected by flood and drought, etc.
3. Risk assessments consider both climate and non-climate related hazards and hazardous events.
4. Existing control measures remain effective for both current and new hazards/hazardous events.
5. Any additional required control measures are identified for capturing within an improvement.

Main findings from this process are summarised in the sections that follow.

WSP/W$_2$RAP team requirements

Establishment of an experienced, qualified, dedicated multidisciplinary team is a prerequisite to securing the technical expertise needed to develop a WSP/W$_2$RAP. The team will be responsible for the development and ongoing implementation of the WSP/W$_2$RAP. In terms of climate resilience, the WSP and W$_2$RAP teams should include sector professionals that understand climate information, water system knowledge, authority figures and supporting members. A comparison of team member requirements indicates that there is a common trend, with each of the municipalities indicating the need for national departments, parastatals and specialists such as hydrologists. During the workshops with the municipalities, the need for the following additional team members was identified (Table 38 and Table 39):

Table 38: *Water Safety Plan team requirements for each of the three municipalities*

	Witzenberg (Tulbagh)	Uthukela (Ladysmith)	Lephalale (Zeeland)
Module 1: Assemble the WSP Team	1. Consultant roster in place to appoint engineer, hydrologist, geologist. 2. Climate scientist from SAWS to assist with climate forecasting 3. Witzenberg Environmental Dept. representative 4. Dept. of Water and Sanitation representative 5. Tulbagh Water Association representative	1. Area engineers, hydrologists. 2. Uthukela Environmentalist 3. Members of KZN Wildlife (EZEMVELO) 4. WSP General Manager 5. Dept. of Water and Sanitation representative 6. SAWS representative 7. SANBI representative 8. Umgeni Water representative 9. Academics: UKZN, CSIR 10. Dept. of Environment, Forestry & Fisheries (Climate Section) representative 11. Provincial Dept. of Economic Development, Tourism and Environment Affairs (Climate section) representative 12. COGTA/MISA representative	1. Exxaro O&M team representative 2. Chief Financial Officer 3. Corporate Services representative 4. Executive Director Technical Services 5. Environmental Health Practitioner 6. Dept. Water and Sanitation representative 7. Catchment management agencies 8. Mine's representative (Simandlale) 9. Eskom representative 10. Water user's representative 11. Climatologists (SALGA) 12. Economists 13. Adaptation specialists 14. Strategic and emergency planners 15. Local and regional government representative

Table 39: Wastewater Risk Abatement Plan team requirements for each of the three municipalities

	Witzenberg (Ceres)	Uthukela (Ladysmith)	Lephalale (Paarl)
Step 1: **Assemble a team to develop the W_2RAP**	1. Consultant roster in place to appoint engineer, hydrologist, geologist. 2. Climate scientist from SAWS to assist with climate forecasting 3. Witzenberg Environmental Dept. representative 4. Dept. of Water and Sanitation representative 5. Tulbagh water association representative	1. Area engineers, hydrologists. 2. Uthukela Environmentalist 3. Members of KZN Wildlife (EZEMVELO) 4. Dept. of Water and Sanitation representative 5. SAWS representative – climate information 6. SANBI representative 7. Umgeni Water representative 8. Academics: UKZN, CSIR 9. Dept. of Environment, Forestry & Fisheries (Climate Section) (National) representative 10. Provincial Dept. of Economic Development, Tourism and Environment Affairs (Climate section) representative 11. COGTA/MISA representative (explore level of involvement)	1. Exxaro operation and maintenance team representative 2. Chief Financial Officer 3. Corporate Services representative 4. Executive Director Technical Services 5. Environmental Health Practitioner 6. Dept. Water and Sanitation representative 7. Catchment management agencies 8. Mine's representative (Simandlale) 9. Eskom representative 10. Councillors 11. Climatologists (SALGA), Hydrologists (DWS) 12. Economists (cost/benefit analysis) 13. Adaptation specialists 14. Strategic and emergency planners 15. Sanitation safety planning teams 16. Local and regional government with varied expertise in drinking water issues, natural resource management, Integrated Water Resource Management (IWRM) and Disaster Recovery (DR) specialists

System description requirements

It is the responsibility of the WSP/W_2RAP team to describe the system and to update the system as changes/upgrades are made. Relevant documentation should be included as part of the description such as, updated flow diagram of the water treatment works/ wastewater treatment works or other information that could be used as a portfolio of evidence. A more comprehensive description includes relevant data such as:

- Average flow at various points within the treatment process
- Climate of the area
- Source water quality and quantity (including seasonal variations)
- Catchment land use
- Water treatment, storage and distribution details
- Water uses and users (including any household treatment)
- Human and financial resources available for the system
- Details on wastewater/stormwater/sanitation management
- Current water quality being supplied
- Water quality standards or objectives

During the workshop with the municipalities, the following is required to include climate resilience into the WSP and W_2RAP (Table 40 and Table 41):

Table 40: CR-WSP system requirements for each of the three municipalities

	Witzenberg (Tulbagh)	Uthukela (Ladysmith)	Lephalale (Zeeland)
Module 2: Describe the water supply system	1. Rainfall data and forecasting/predictions (up to 2050) 2. Temperature data and forecasting/predictions 3. Drought considerations – availability of water and period of availability 4. Wind data and information 5. Evaporation information 6. Changes to areas affected by climate related threats/impacts (e.g. flood zones)	1. Groundwater levels (yields) 2. Source quality 3. River flow / dam levels 4. Understanding the Ecological Water 5. Requirements (EWR) set by DWS and the implications thereof 6. Precipitation data 7. Evaporation data 8. Historical information: areas prone to/affected by floods and droughts – frequency of such events 9. Ecological infrastructure and their status 10. Spatial / land use information	1. Climate information 2. River flows, aquifer recharge rates 3. Yield vs. demand 4. Water quality challenges 5. Alternative water sources 6. Catchment land-use, development, population, urbanization 7. Population projections

Table 41: CR-W$_2$RAP system requirements for each of the three municipalities

	Witzenberg (Ceres)	Uthukela (Ladysmith)	Lephalale (Paarl)
Step 2: Document and describe the system	1. Rainfall data and forecasting/predictions (at up to 2050) 2. Temperature data and forecasting/predictions 3. Drought considerations – availability of water and period of availability 4. Wind data and information 5. Evaporation information	1. Groundwater levels (yields) 2. Catchment quality 3. River flow 3. Understanding the Resource Quality Objectives (RQOs) set by DWS and the implications thereof 4. Precipitation data 5. Historical information: areas prone to/affected by floods and droughts – frequency of such events	1. Climate information 2. River flows, aquifer recharge rates 3. Yield vs. demand 4. Final effluent quality challenges 5. Catchment land-use, development, population, urbanization 6. Population projections

	Witzenberg (Ceres)	Uthukela (Ladysmith)	Lephalale (Paarl)
	6. Changes in areas affected by climate related threats/impacts (Flood zones)	6. Ecological infrastructure and their status 7. Spatial / land use information	

Observed climate related hazards and hazardous events and risk assessment

This requires the WSP/W$_2$RAP team to do a system assessment to identify: i) what could go wrong, and ii) where it could go wrong, at each part of the water supply chain and sanitation value chain. The site visit highlighted the climate threats that are likely to affect each of the three selected water and wastewater systems. Despite the location differences between the municipalities, there is a commonality between the type of threats experienced by each of the municipalities. Each municipality is prone to flooding, droughts, and heat stress related issues. However, the severity and frequency of these events may vary between locations.

Below are the findings based on the site visit and the workshop sessions with the municipalities (Table 42 and Table 43).

Table 42: *Identified climate related threats to the water systems of the municipalities*

	Witzenberg (Tulbagh)	Uthukela (Ladysmith)	Lephalale (Zeeland)
Module 3: Identify hazards and hazardous events	1. Flood zones (areas affected by river flooding) 2. Decrease in rainfall resulting in reduced water availability, storage quantity and quality in both surface water and groundwater (Ceres Dam was 10% full in 2015) 3. Increases in temperature (impact on water) (heat stress) 4. Risk of fire hazards in source water area/s	1. Areas prone to floods and droughts (current and future) – risks to water sources/abstraction points 2. Temperature increases – area experiences extremely high temperatures in summer months 3. Impaired water quality (less rainfall) – compounded if WWTW is discharging poor quality effluent to the environment. 4. Increased rainfall – can lead to increased ingress of stormwater –	1. Droughts 2. No alternative water sources 3. Flooding can result in reduced access to the WTW 4. Risk of earthquakes 5. Currently experiencing increased temperatures 6. Lack of rain

	Witzenberg (Tulbagh)	Uthukela (Ladysmith)	Lephalale (Zeeland)
	5. Cold stress (due to extreme cold conditions) 6. Increased rainfall results in flooding in the distribution system especially in low lying areas and is compounded by stormwater ingress 7. Increased wind speeds resulting in water quality challenges due to sediment loading in source waters 8. Fires damage to treatment system components and water resources components (damage to groundwater line) 9. High soil erosion in catchment area	reduces capacity of infrastructure to cope with events – resulting in overflows / back-flooding, infrastructure and equipment can be compromised/damaged 5. Increased rainfall – erosion – can expose infrastructure (e.g. pipelines), increased litter/debris washed into rivers – can create blockages at abstraction points and/or also clogged pipes.	

Table 43: *Identified climate related threats to the wastewater systems of the municipalities*

	Witzenberg (Ceres)	Uthukela (Ladysmith)	Lephalale (Paarl)
Step 3: **Hazard Assessment and Risk Determination**	1. Flood zones (areas affected by river flooding, sludge lagoons near informal settlements) 2. Increases in temperature (impact on water) (heat stress) 3. Risk of fire hazards in source water area/s 4. Cold stress (Witzenberg specifically due to extreme cold conditions)	1. Areas prone to floods and droughts (current and future) – risks to water sources/abstraction points 2. Temperature increases – area does extreme very high temperature in summer months) 3. Impaired water quality (less rainfall) – compounded if WWTW is discharging poor quality effluent.	1. Droughts 2. Flooding can result in reduced access to the WWTW 3. Risk of earthquakes 4. Currently experiencing increased temperatures 5. Existing pipe network infrastructure cannot handle excessive load/capacity 6. Plant exceeding its capacity

	Witzenberg (Ceres)	Uthukela (Ladysmith)	Lephalale (Paarl)
	5. Increased rainfall results in flooding in the distribution system especially in low lying areas and is compounded by storm water ingress 6. Increased wind speeds resulting in water quality challenges due to sediment loading in wastewater treatment processes 7. Fires damage to treatment	4. Increased rainfall – can lead to increased ingress of stormwater – reduces capacity of infrastructure to cope with events – resulting in overflows / back-flooding, infrastructure and equipment can be compromised/damaged 5. Increased rainfall – erosion – can exposed infrastructure, increased litter/debris pipes.	

In addition to the climate related threats events noted above (which are used to define hazards/hazardous events), the project team also identified several non-climate related hazards/hazardous events. Details thereof are contained in **Appendix C**. Municipalities have been encouraged to expand their current risk assessment to also consider these hazards/hazardous events.

Identify control measures, validate control measures, reassess, and reprioritize the risks

Existing and potentially new/additional control measures were identified during the workshop session. Under the influence of climate change, existing control measures may no longer be effective, and a reassessment thereof is necessary to understand if new or additional control measures should be implemented. Climate resilient control measures need to be applicable under current climate as well as future climate scenarios and may require implementation of both short-term and long-term control measures. In discussion with the municipalities some control measures have already been developed (e.g. Witzenberg's Drought Management Plan). Below are the control measures identified for the climate threats (Table 44 and Table 45).

Table 44: *Control measures applicable to the water system in each of the three municipalities*

	Witzenberg (Tulbagh)	Uthukela (Ladysmith)	Lephalale (Zeeland)
Module 4: Determine and Validate Control Measures, Reassess and Prioritize the Risks	1. Consider best practice (consider Greenbook mitigation measures) 2. Drought level indicators 3. Develop flood hazard disaster management plan 4. Role of environmental institutions (e.g. Cape Nature) 5. Have a drought management plan in place	1. Assess current state of infrastructure – is it in an acceptable standard, if not need to bring it to an acceptable level and then build in climate resilience 2. Risk Assessment Tool and Matrix to support decision making 3. District Climate Adaptation and Resilience Plan 4. Improving/investing in health of green/ecological infrastructure 5. Updated operating procedures 6. Consider other water source options to supplement existing sources	1. Train staff on climate change and climate change related control measures 2. Develop additional water resources, and promote conservative water usage during periods of low water availability 3. Improve drainage on access roads to Zeeland WTW 4. Review and develop new by-laws to consider climate change aspects

Table 45: *Control measures applicable to the wastewater system in each of the three municipalities*

	Witzenberg (Ceres)	Uthukela (Ladysmith)	Lephalale (Paarl)
Step 4: Identify hazards, control measures & preventative actions	1. Consider best practice (consider Greenbook mitigation measures) 2. Drought level indicators in terms of control measures 3. Develop flood hazard disaster management plan 4. Role of environmental institutions (e.g. Cape Nature) 5. Consider flood hazard plan	1. Assess current state of infrastructure – is it acceptable, if not need to bring it to an acceptable level and then build in climate resilience 2. Risk Assessment Tool and Matrix to support decision making 3. District Climate Adaptation and Resilience Plan 4. Improving/investing in health of green/ecological infrastructure	1. Train staff on climate change and climate change related control measures 2. Improve drainage on access roads to Paarl WWTW 3. Review and develop new by-laws to consider climate change

		5. Updated operating procedures	

Develop, implement, and maintain an improvement/upgrade plan

An improvement/upgrade plan is required where additional control measures are required. This also includes long-term control measures for all significant risks that require strategic and future climate impact considerations. The municipality needs to consider escalating actions contained in WSP/W_2RAP related improvement plans to their Master Plans, 5-year capital budgets and/or Water Services Development Plans. This will promote incremental improvement within their systems and creates a targeted goal for when the improvements need to be completed and implemented. This process may require the WSI to consider implementation of low/no cost control measures in the short-term, while the necessary funds are sourced/made available for longer-term control measures. The improvement/upgrade plan should be implemented such that the measures put in place are effective under both current and future climate conditions/scenarios. The following are the improvement actions highlighted by each of the municipalities (Table 46 and Table 47).

Table 46: *The improvements highlighted by the municipalities for their respective water systems to become climate resilient*

	Witzenberg (Tulbagh)	Uthukela (Ladysmith)	Lephalale (Zeeland)
Module 5: Develop, Implement and Maintain an Improvement / Upgrade Plan	1. Improvements captured in the 5-year capital budget plan or contained in operations and maintenance budget 2. High risk assets added to the capital budget as taken from the Asset Management Plan (AMP) 3. Inputs into WSDP are taken from the master plan	1. Included in Water and Sanitation Master Plan (cascaded to WSDP, other plans & KPIs of Business Units and responsible persons 2. Identify timeframe, responsibilities, and budget 3. Monitoring and Evaluation (Plan, Do, Check, Act)	1. Train staff on operating equipment and climate related control measures 2. Replace aging infrastructure with infrastructure that can cope with increased capacity 3. Improve access to infrastructure during flooding 4. Improve water quality monitoring 5. Develop appropriate SOPs

Table 47: The improvements highlighted by the municipalities for their respective wastewater systems to become climate resilient

	Witzenberg (Ceres)	Uthukela (Ladysmith)	Lephalale (Paarl)
Step 5 Monitoring of control measures and wastewater quality	1. Improvements captured in the 5-year capital budget plan or contained in operations and maintenance budget 2. High risks assets added to the capital budget as taken from the AMP 3. Inputs into WSDP are taken from the master plan	1. Included in Water and Sanitation Master Plan (cascaded to WSDP, other plans & KPIs of Business Units and persons' responsible 2. Identify timeframe, responsibilities, and budget 3. Monitoring and Evaluation (Plan, Do, Check, Act concept)	1. Train staff on operating equipment and climate related control measures 2. Replace aging infrastructure with infrastructure that can cope with increased capacity 3. Improve access to infrastructure during flooding 4. Improve water quality monitoring 5. Develop SOPs 6. Enforcement of by-laws

A summary of the findings and recommendations were compiled into a short report for each of the municipalities. The report provides an initial assessment of the current WSP and W_2RAP documents, a snapshot of the current and projected climate and associated impacts, recommends the WSP/W_2RAP and CR-WSP and CR-W_2RAP team requirements, and finally provides a suggested risk assessment that should be incorporated into an amended and updated WSP and W_2RAP. These reports are contained in **Appendix C**.

10. Catchment Management Agency (CMA)/Water Management Area (WMA) Workshops

10.1 CMA/WMA Workshop Design and Methodology

With the rising infections related to the COVID-19 second wave and remaining lockdown restrictions (i.e. restrictions on travel and large business workshops), the team held brief discussions with some of the key stakeholders, and indications were that these workshops should be held remotely (virtually, instead of face-to-face). To ensure that online workshops would be effective and appropriate, the team engaged with the (3) targeted CMAs/WMAs and associated pilot municipalities to gauge their ability and willingness to participating in an online workshop. This included consideration of:

- Participation (e.g. who will be participating, anticipated numbers)
    - Feedback indicated that between 5 to 10 people could be anticipated for each of the 3 CMA/WMA workshops.

- ICT to ensure staff can participate (e.g. do staff have appropriate internet connectivity, hardware, software to participate)
    - Participants indicated that internet connectivity should not be problematic.
    - Participants noted that they are comfortable using Microsoft Teams for the workshops.

- Workshop format and duration (e.g. what materials and style will work best)
    - Participants noted that ½ day workshops (starting at 9 am and ending at 1 pm) would be suitable.

- Post workshop requirements (e.g. presentations)
    - Participants indicated a need for:
        - Presentation slides, and
        - Recording of the workshop (to potentially share with others).

The workshop design therefore incorporated the following:

- Use of Microsoft Teams (presentations, discussions, exercises, Q&A), and Google Forms (attendance register and feedback evaluation).
- Blend of theoretical understanding and practical components, including best practice and case study examples.
- To keep the participants involved and engaged the approach includes the opportunity for participants to engage and interact on a regular basis (~every 15 minutes), via questions/discussions, mini-exercises, and dedicated question and answer sessions. These components are completed by the participants during the workshop.
- The workshop is recorded and can therefore be shared with other colleagues or stakeholders who were unable to attend.

Considering this, the following workshop programme was noted:

Time	Activity
09:00-09:20	Welcome and Introductions
09:20-09:30	Workshop overview
09:30-10:00	Understanding key concepts • Climate change and variability • How may this impact our water and wastewater/sanitation systems? • How best to manage current and predicted risks? • Risk management approaches for climate resilient systems
10:00-10:30	How to source and interpret climate information
10:30-10:45	Discussion/Q&A
10:45-11:00	*Comfort break*
11:00-11:30	How do I include this into my WSP (and W_2RAP)?
11:30-12:00	Municipal perspective – sharing experiences and lessons learnt from piloting
12:00-12:30	Discussion: • Need for and usefulness of the approach? Are there any challenges with the approach/methodology? Do you have any suggested/required improvements? • How can we mobilise support from CMAs/WMAs? How can we improve information/data sharing and integrated planning at a catchment level?
12:30-13:00	Wrap up and way forward
13:00	*Workshop closure*

10.2 CMA/WMA Workshops and Outcomes

Three (3) online CMA/WMA workshops were held as follows:

- 16th February 2021: Pongola-Umzimkulu Proto-CMA and related pilot municipality, Uthukela District Municipality (and including eThekwini Metropolitan Municipality)
- 17th February 2021: Limpopo and related pilot municipality, Lephalale Local Municipality
- 18th February 2021: Breede-Gouritz CMA and related pilot municipality, Witzenberg Local Municipality

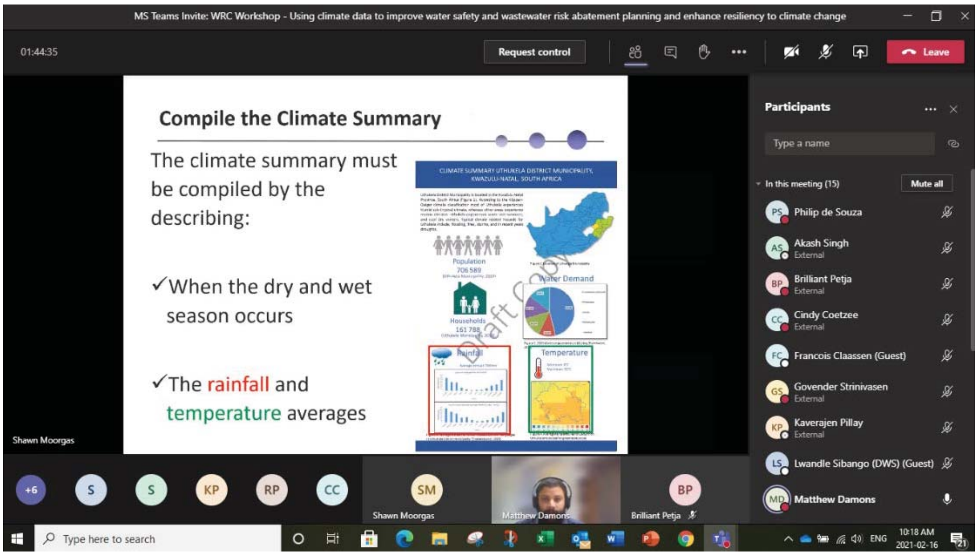


Figure 54: *Pongola-Umzimkulu Proto-CMA workshop held 16th February 2021*

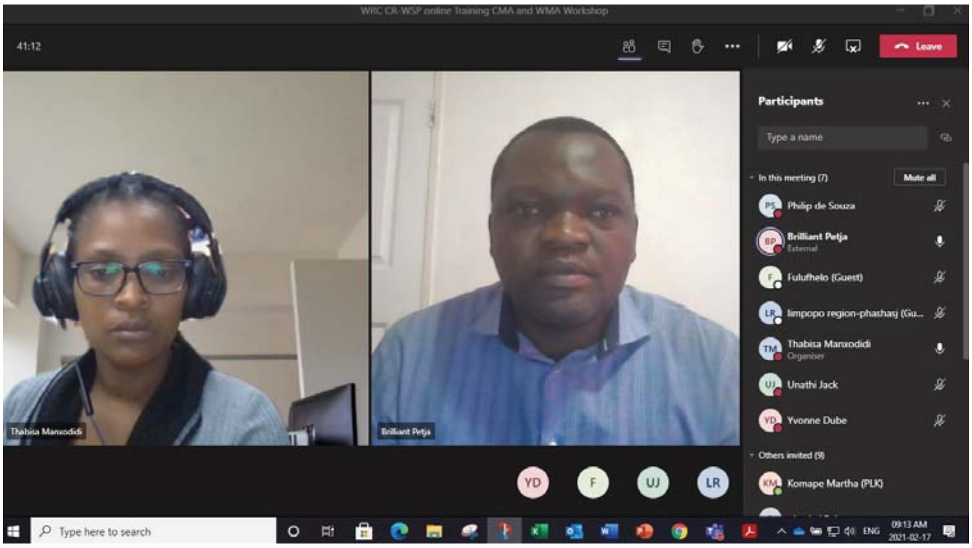


Figure 55: *Limpopo WMA workshop held 17th February 2021*

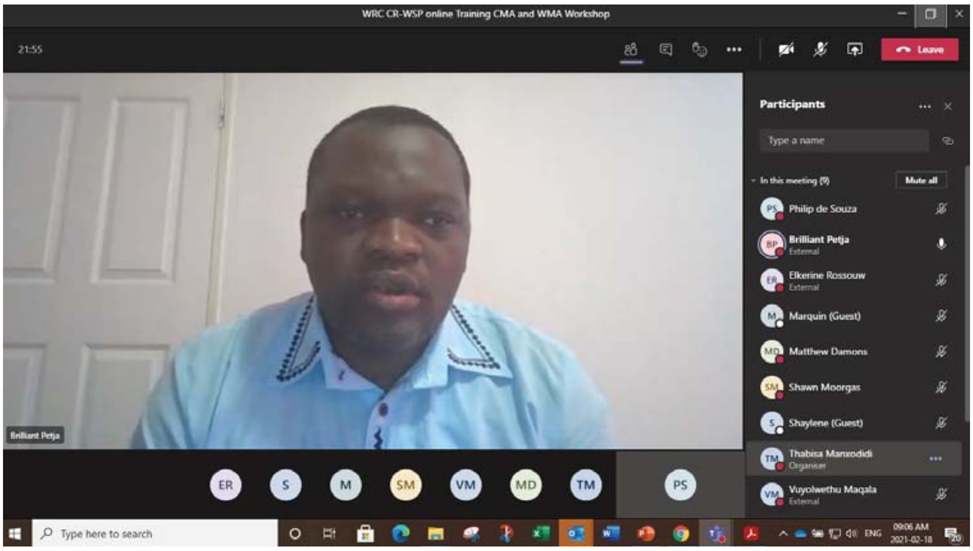


Figure 56: *Breede-Gouritz CMA workshop held 18th February 2021*

The following discussions were held during the workshop to understand participant knowledge and experience:

- **Do you have any climate change related experience?**
    - Both CMA/WMA and municipal participants indicated basic knowledge and experience.

- **Have you previously been involved in the implementation of a WSP/W$_2$RAP?**
    - Most municipal participants indicated experience with implementation of WSP/W$_2$RAP.
    - Some CMA/WMA staff in Limpopo and the Western Cape had limited exposure and understanding of WSP/W$_2$RAP, and additional time was spent to explain WSP/W$_2$RAP basics.

- **Have climate reports / assessments previously developed been for your area?**
    - Participants indicated that they were aware of some reports produced by the Department of Environmental Affairs.
        - Series of reports on monitoring of climate change, risks, and adaptation of and the implications of climate change for different sectors such as forestry, agriculture, food security, water resources sectors.
    - Some municipalities have developed climate change impact related reports.
        - eThekwini – The reports were developed by multiple departments and is very broad. It plans for over the next 15-20 years. Has section on the effects of climate change on sludge management, wastewater treatment works and sanitation and water resources, etc. but will be unpacked in the future.
        - Climate change impact related reports have also been developed for Witzenberg.
    - The Breede-Gouritz CMA and SANBI have developed wetland and climate change reports for catchment. These are accessible on the BGCMA website and available to the public.

- **Do you have access to / currently use web-based tools to store and access climate information?**
    - Pongola and Breede Gouritz CMA uses a web-based system, called HydroNET (https://www.hydronet.co.za/) and therefore they have access to historical weather data (e.g. rainfall, temperature) and some forecasting. They can see locations of all rainfall stations and can access station/gauge data for quaternary catchments, tertiary, or secondary catchment. They use the information and data internally and do not share this information with municipalities. If there are requests to share data/information, they would need to request permission from SAWS.
    - Limpopo WMA participants were not aware of HydroNET.
    - Municipalities indicated that access to historical data and forecasting would be useful.

- **Do you collect your own climate data from a weather station (or similar)?**
    - Not many participants noted that they collected their own weather/climate data.
        - Uthukela indicated that they do not have a weather station data close to their municipality (Harrismith is the closest source), and they do not have climate information readily available.

        - eThekwini noted that their Coastal and Stormwater Department have stations/gauges and data is accessible for planning purposes. Rainfall data is routinely collected at treatment facilities, but not always reliable.
        - Witzenberg indicated that have access to rainfall and temperature data collected by SAWS at a weather station at their treatment facility in Ceres.

- **Based on your experience and observations, how have climate related impacts changed?**
    - The following aspects were noted by participants:
        - It affects both quality and quantity.
        - Increase in occurrence of floods.
        - Water quality contamination in estuaries, changes in patterns of natural occurrences of estuaries.
        - Prevalence of waterborne diseases increased flooding and climate change impacts. By way of example, sewage works were not operational during the 2016 floods in the Vryheid area. The population was exposed to contaminated sewerage. It appears there is a lack of preparedness in dealing with such events. Improved planning is required to mitigate climate change impacts.
        - Malfunctioning of WWTWs has effects on surface water resources, compliance of WWTWs during flooding/heavy rainfall – During 2014/2015 drought in KwaZulu-Natal had increased levels of microbial concentrations during water analysis.
        - Agriculture sector has changed to adapt to changing climate. For example, farmers are requesting more information and access to climate data and looking at alternative water usage and storage to adapt. Also considering alternative crops.
        - Currently have Level 1 water restrictions in Tulbagh and are considering implementing Level 2 water restrictions soon – need to proactively manage your water resources.
        - Observed changes in water use in catchment by farmers and the municipality, including (i) adapting to rainfall schedules, (ii) changes to irrigation use, (iii) crops changed to suit weather (e.g. changing vineyards to olives or later bearing fruit trees), (iv) increase in the number of applications for water irrigation and storage, and (v) water availability percentage has changed over the years, mainly reduced in summer.
        - Dropping dam levels/reduced flow.
        - Complaints from users such as the farmers.
        - Decline in groundwater table.
        - Dry sampling points – reduced sampling.
        - Shortage/unavailability of water downstream due to activities carried out upstream – which already has reduced flow.
        - Although the province has received a lot of rains recently, the dams are not filling up as expected.

- **During recent floods/droughts/storms did you have a plan in place?**
    - *Flood*
        - Uthukela noted that they have a functional Incident Management Protocol.

- eThekwini noted that they have Disaster Management Plans in place. They also have reporting and incident plans in place at the WWTW to mitigate heavy rainfall and discharge of poor-quality effluent.
- Limpopo WMA noted that they have a Disaster Management Plan in place and are now developing a Drought Management Plan. They have a team in place to respond when there are floods. However, there is currently no team for droughts. Inter-departmental communications and response plans are put in place when they become aware of an expected emergency. This includes sharing of information and educational videos and any relevant materials to respond to the emergency. There is a Joint Operating Committee to respond to emergencies. This includes various other departments, not just DWS. Investigations on the cause of issues experienced at the resources (e.g. delays in filling up the dams, water unavailability) are normally carried out.

o *Drought*
  - Witzenberg noted that they have had a Drought Management Plan in place since 2007 and update this annually. Previously, the plan considered 3 level restrictions during a drought, but since January 2020, 5 levels were introduced to try and alleviate the strain on scarce water resources.

- **How did you respond to the flood/drought/storm? Was the response effective, what challenges did you have during implementation of control measures?**
  - *Flood*
    - Uthukela noted that site inspections done last year at the WTWs, pump stations and WWTWs identified the need to improve the performance of these facilities. A business plan was developed and submitted to DWS (awaiting feedback). Pollution in the catchment is reported on a weekly basis as plants are monitored. Chlorination has started at the WWTW. Three (3) treatment plants were shut down due to flooding. Abstraction pumps were under water and maintenance crew were not able to reach them. Challenges remain with non-operational pump stations, and accumulation of silt at the treatment works. They also noted that incidents have occurred in the past, which lead to staff suspensions.
    - eThekwini noted that they are not experiencing flooding at plants, but excessive inflow will make unit processes less effective. Acute flooding is managed as best as possible. A drop in the operational capacity of works has recently been noted at eThekwini – may be due to climate change or aging infrastructures. Erosion taking place has led to an increase in grit and sand ingress. New upgrades are urgent.
  - *Drought*
    - Borrowed water from farmers with storage dams. Water outsourced for municipal use. A positive outcome is that the relationship with farmers has improved (e.g. partnership with farmers for the management and operation of the Koekedouw Dam scheme). In the 2017 drought, borehole levels dropped due to heavy use. Investigation into water level drops led to the installation of meters on boreholes

and registration thereof to understand volumes abstracted and time of abstraction.
        - The Breede-Gouritz CMA has been affected by illegal use such as over-abstraction of groundwater. There is a need for more education of water resources. Over abstraction of groundwater, means a lowered water supply by the municipality, which results in a decreased volume of water returned to the WWTW, and this can also result in poor effluent quality.
        - The severity of the recent drought affected the harvest, and there has been a large loss in grapes and fruit harvested.
    - *Storm*
        - Lephalale noted that the recent storms in Limpopo (caused by Cyclone Eloise) did not cause lots of damage within the municipality as the municipality was prepared based on their experiences with previous storms.
    - Limpopo WMA also highlighted several general challenges:
        - Do not have information regarding flood lines.
        - Uncontrolled activities at the government dams (e.g. sand mining).
        - Over abstraction of groundwater resources, canal leakages.
        - There is lack of sharing data/information between transboundary countries on a technical/on the ground level (i.e. only high-level).

- **What lessons will you take forward into your integrated plans (e.g. WSP / W$_2$RAP)?**
    - Uthukela noted the importance of a very active chairperson who is part of the water and sanitation portfolio committee, as this helps with improving integrated planning.
    - Witzenberg indicated that they are currently considering a larger dam for Tulbagh (if full, then have a 6-month supply). They need to ensure that plans incorporate climate change impacts.
    - Breede Gouritz indicated that:
        - Environmental and climate change considerations should be included into the design, planning, and construction of WWTW and WTW.
        - WSP and W$_2$RAP would be helpful when considering design amendments and license applications (audit effluent).
        - Infrastructural and operational risks identified in the W$_2$RAP and WSP must be incorporated into the IDP.
    - A question arose whether there has been a change the behaviour of water and wastewater/sanitation services staff because of feeling the effects of these climate change impacts on their day-to-day activities.
        - DWS KZN noted that they have seen no change in attitude or behaviour. Despite Blue and Green Drop Certification, many municipalities are still not proactively addressing challenges. What does a lack of response and preparedness do to our communities? Does DWS need to assist municipalities by proposing regulations that require risks identified through WSP and W$_2$RAP (Blue and Green Drop) to be prioritised within WSDPs and IDPs?

- **Does your current WSP (and W_2RAP) team have technical experts (climatologists, hydrologists, adaptation specialists), local/regional government members, and community members or only members involved with water supply and distribution?**
    - At Uthukela, engineers from various departments are included in the team.
    - The CMAs/WMAs noted the need to potentially have technical experts or those with knowledge of developing WSP/W_2RAP plans at hand to assist with municipal planning.
    - For Witzenberg, the CMA suggested that Koekedouw Irrigation Board in Ceres be included within the WSP team as they share a resource with Witzenberg Municipality. In addition, the management of the dam is also shared.

- **Do you know which areas in your system are prone to the effects of climate threats and impacts (such as flooding and droughts)?**
    - Uthukela noted that before their flood control dam was built, Ladysmith Wastewater Treatment Works experienced regular flooding. During a recent flood, the flood control dam did not manage to sustain the flow, and some areas were flooded. It was noted that the district municipality needs to work closely with the local municipalities to improve stormwater and flood management. The Pongola Umzimkulu Proto-CMA noted that a report was completed in 2015/2016 for the Ladysmith flood control dam and areas prone to flooding. This report mentioned that if the flow in the river channel is more than 700 m/s then flooding occurs. The dam was built to facilitate 400 m/s river flow. Ladysmith has experienced 29 flood events over the years. Currently they are investigating to try and understand the contribution from Sand River into the Klip River.
    - Witzenberg noted a recent fire hazard. The municipality has a Disaster Management Plan in place, and this assisted greatly in averting danger. Without this plan, the main pipeline feeding water to Ceres could have been damaged, and water provision to Ceres would potentially have stopped. The Breede-Gouritz CMA noted that Witzenberg has helped the CMA to eradicate invasive plant species upstream of the Koekedouw Dam and downstream of the Dwars River, which has helped with water availability. In an extreme scenario of heavy rainfall, the Dwars and Titus Rivers could potentially flood the wastewater treatment works.

- **Do you think it be easy to incorporate the climate considerations into your integrated planning and operations (e.g. WSP and W_2RAP)?**
    - Yes
        - Need top management/leadership buy-in, otherwise will have nice plans and no implementation.
        - Important to consider a phased approach – initially focus on quick wins, build confidence and momentum, and instil within day-to-day operations.

10.3 Municipal Perspectives – sharing experiences and lessons learnt from piloting

Table 48: *Municipal perspectives – sharing experiences and lessons learnt*

	Question	Uthukela	Lephalale	Witzenberg
1.	Mention two aspects that you value the most from being involved in this project (i.e. the development of the CR-WSPs/CR-W_2RAPs Guideline)?	• To work with experts in the field to develop a unique CR-WSP/CR-W_2WRAP that will deal with our own unique challenges in the Uthukela District Municipality. • Access to reports from other municipalities / countries to see how they deal with their challenges. • Access to historical data.	• Climate change aspects that we never really take into considerations have been highlighted clearly for us which is useful. • We liked the Climate Change Summaries provided by the team. • We have discovered that the interventions that came from the process were useful. • This process helped us to think beyond about climate change.	• Limits damages and reduces long-term costs. • Planning and preparation to meet future changes in hazard intensity and frequency.
2.	Mention two aspects that you think can be improved on?	• Municipal Management participation. • Senior Managers' knowledge and commitment to climate change and implementation of CR-WSP/CR-W_2WRAP. • Community participation and understanding the scope of climate change and the impact it will subsequently have on everyone's lives.	• Financial implications which are not clearly addressed (although between the municipality and its service provider team). • It is not clear how this project is going to impact us financially (it would be great to get funding).	• Time constraints – municipalities have a lot of current challenges and backlogs due to COVID-19. • Unclear objectives in terms of timeframes.

	Question	Uthukela	Lephalale	Witzenberg
3.	Based on your participation and inputs provided:			
	a. Will the WRC CR-WSPs/CR-W_2RAPs Guideline assist you?	• It will provide additional guidelines to improve water management and help disseminate information on our unique challenges. However, support and knowledge from management is crucial.	• Yes greatly, as we need all the assistance we can get to overcome the impacts of climate change.	• Yes.
	b. Will you be able to update your WSPs and W_2RAPs to incorporate climate change considerations?	• Yes, but management should be informed on what the updates on the WSPs and W_2RAPs entails and to have their support.	• Yes, especially for WSP. Now that we will take over from the service provider, we need to be ready. • For W_2RAP, here the problem is that we do not have enough skilled staff.	• Yes, through phases as time is a big challenge.
	c. What areas of the value chain (catchment to consumer to environment) will you initially focus on?	• Wastewater and water treatment plants infrastructure is a major challenge. Reticulation and vandalism of the infrastructure causes significant delays and money for repairs that could be used more effectively in terms of addressing climate change impacts and service provision.	• Storage and consumer needs are more our focus than the catchment – we don't really consider catchment aspects.	• Just like our WSP, focus on all aspects from catchment to consumer.

	Question	Uthukela	Lephalale	Witzenberg
4.	What is the best way to?			
	a. Create awareness regarding WRC CR-WSPs/CR-W_2RAPs within the municipal sector?	• Training for senior managers and councilors. • Understanding the concept of CR-WSPs/CR-W_2RAPs in relation to climate change by management and why it will form part thereof. • Commitment by senior managers and councilors. • Public understanding and commitment will be a significant challenge.	• Council prefers it when we do awareness training and call meetings and engage people. However, due to COVID 19 this cannot be done, and therefore we are now using local radio stations and print media (local newspaper) to raise awareness regarding municipal activities.	• By involving all applicable departments and stakeholders. • Additional virtual workshops.
	b. Share the WRC CR-WSPs/CR-W_2RAPs Guideline document?	• A comment was made to perhaps encourage sharing of WSPs/W_2RAPs amongst municipalities, so that they can learn from each other (e.g. peer review).	• Yes, it will be great to get the guideline when it completed and share this with the technical staff.	• Best suitable platform for sharing would be the DWS IRIS system – compulsory to upload municipal data.
5.	What other departments within the municipality would benefit from climate change information and associated risk management planning (e.g. Roads, Stormwater, etc.)?	• Risk Assessment Officer • GIS • Town Planning and Development • Socio-Economic Development Department	• Department of Roads and Stormwater.	• All departments

10.4 CMA/WMA Perspectives – sharing experiences and lessons learnt from piloting

Table 49: *CMA/WMA perspectives – sharing experiences and lessons learnt*

	Question	Pongola-Umzimkulu	Limpopo	Breede-Gouritz
1	Based on your experience is there need for an approach that facilitates the inclusion of climate considerations into the WSP/W_2RAP?	Yes. Water use license can be used as a tool to include climate considerations and WSP/W_2RAP as well.	Yes. It is important to consider climate related impact within WSP/W_2RAPs, and the recently developed documents are incorporating that, which is good. It is acknowledged that this has been ignored for some time, and engagements often only start when there is an emergency.	Yes
2	Are there any challenges with the approach/methodology? (suggested improvements)	Biggest hurdle would be the support from senior management and to see the merit of including climate considerations.	There are no anticipated difficulties in implementing climate related improvement actions because though they are not documented, there are communications regarding them.	It is a beneficial approach, useful to more than just municipalities, e.g. water boards too.
3	How can support from CMAs/WMAs be mobilized?	CMA is responsible for water resource management so indirectly whatever is happening at source, e.g. WWTW and WTW will affect management of water resources so there is merit for CMA to be involved in the process of WSP and W_2RAPs. Regulation of classification of water resources	The WMA can promote use of the methodology by municipalities. It was also recommended that the BD/GD criteria should be reviewed to include climate change aspects. The importance of planning and allocating budget for addressing climate issues should be highlighted to	If CMA is not being asked for money. Engagement of goals from municipal perspective with CMA.

	Question	Pongola-Umzimkulu	Limpopo	Breede-Gouritz
		and resource quality objectives, source directed impacts from climate change and impacting on WWTW can be supported by CMA. E.g. if water at WTW (source) is impacted by climate change and leads to poor quality of water or other negative impacts which do not meet the resource quality objectives set by the national department, CMA is to step in and assist in managing those impacts posing stress on treatment works and system. There is a relationship between RGOs and water quality in treatment works so there is merit for CMA to be involved in WSP and W_2RAP.	municipal HR and finance departments. This will help with supporting CMAs/WMAs to help address challenges.	
4	How can we improve information/data sharing and integrated planning at a catchment level?	Important for CMA to have some involvement in the development of WSP and W_2RAP. Extensive field investigations may also contribute to information going into reports such as risk assessments and assessing status of WWTW and impacts. Rely on head office (national climate change department) for success of roll out as well.	The existing forums where municipalities are expected to participate could be used to bring awareness. In these forums, municipalities could identify areas of challenge in developing and implementing their CR-WSP/W_2RAPs. Furthermore, integrated data/information sharing (e.g. water quantity and quality) should be considered at relevant forums.	Forums, joint platforms for sharing data and information effectively. Forums are only useful if all members and participants contribute to sharing information, data, and knowledge.

Common themes arising from the CMA/WMA workshops discussions included the need for:

- Alignment
- Linking up
- Working closely with
- Collaborating
- Communicating
- Improved understanding of roles and responsibilities
- Acknowledgement that we are all in this together, and that to be successful, we need to work as a team.
- To make an effective change, need support from all.

At the end of each workshop, all participants were asked to complete a feedback form. Despite regular prompting during and after the workshops (via e-mail and telephonic follow-up), not all participants completed the feedback form. Lessons learnt and feedback obtained from the workshop were used to continue to improve and refine the approach and associated methodology, to the benefit of other stakeholders. Furthermore, the feedback, observations and lessons learnt from the CMA/WMA workshops were further explored during the National Workshop.

11. National Workshop

11.1 National Workshop Design and Methodology

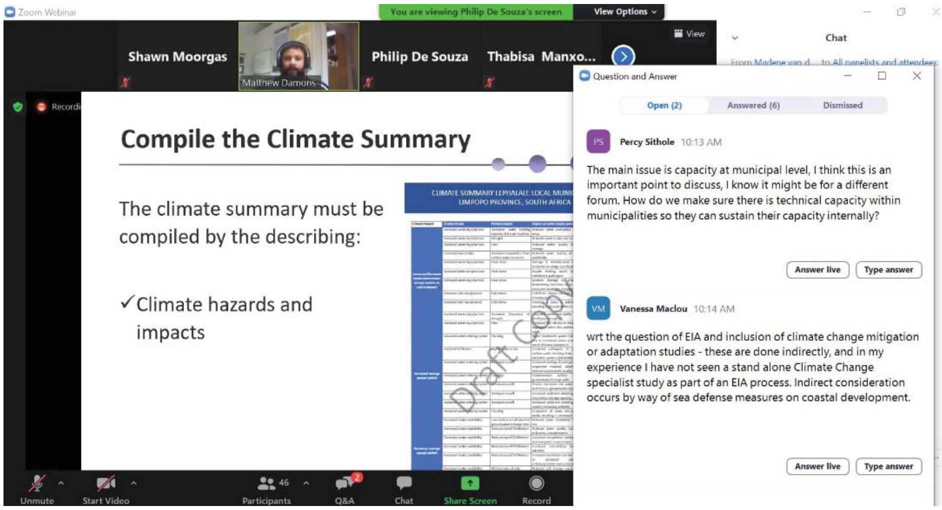
Originally, three (3) regional engagements were proposed (KwaZulu-Natal, Limpopo and Western Cape). However, due to COVID-19 and remaining lockdown restrictions it was decided that these workshops should be held remotely (virtually, instead of face-to-face). Furthermore, to help share the approach and learnings to a wider audience, it was decided to open the invitation to the entire WASH sector in South Africa, including all Water Services Authorities, CMAs/WMAs, relevant departments, consultants, academia, stakeholders, etc. A one-day National Workshop was held on 23rd March 2021 via Zoom.

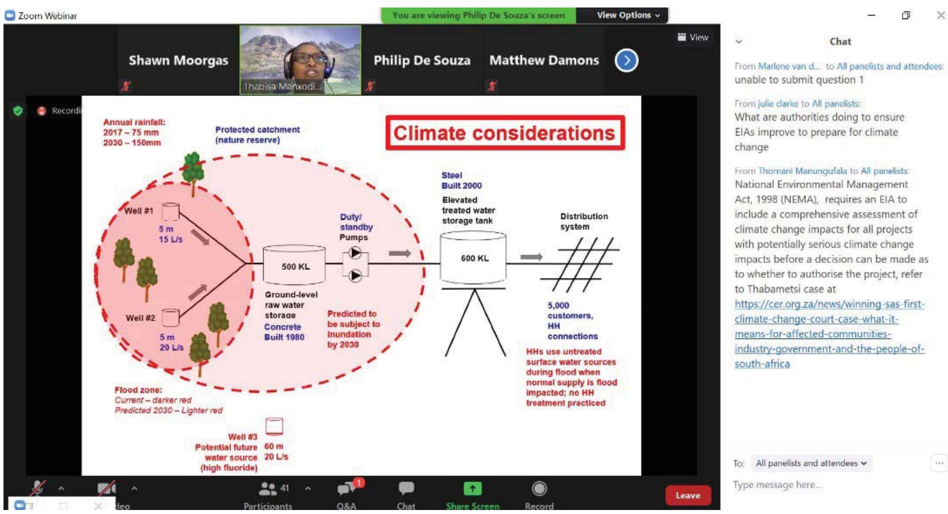
The following workshop programme is noted:

Time	Activity
09:00-09:20	Welcome and introductions
09:20-09:30	Workshop overview
09:30-10:00	Understanding key concepts • Climate change and variability • How may this impact our water and wastewater/sanitation systems? • How best to manage current and predicted risks? • Risk management approaches for climate resilient systems
10:00-10:30	How to source and interpret climate information
10:30-10:45	*Comfort break*
10:45-11:30	How do I include this into my WSP (and W_2RAP)?
11:30-12:15	Municipal perspectives – sharing experiences and lessons learnt • Uthukela • Witzenberg • Lephalale
12:15-13:00	CMA/WMA perspectives – sharing experiences and lessons learnt • *Pongola*-Umzimkulu • Breede Gouritz • Limpopo
13:00-13:30	*Lunch break*
13:30-14:30	Discussion: • Are there any challenges with the approach/methodology? Do you have any suggested/required improvements?

Time	Activity
	• Are you able to develop and implement the methodology internally, and without external support? Can your existing WSPs/W$_2$RAPs be readily modified? • Have you already incorporated climate change, COVID-19, cyber terrorism, etc. threats within your WSPs/W$_2$RAPs? Have your WSP/W$_2$RAP related improvement actions been affected by the COVID-19 pandemic? How can we ensure buy-in for required improvement actions from top management? • How can we mobilise support from CMAs/WMAs? How can we improve information/data sharing at catchment level? How can we improve integrated planning at a catchment level? • How do we mobilise CR-WSP and W$_2$RAP throughout South Africa? What else is required to make this sustainable in the long-term?
14:30-15:00	Wrap up and way forward
15:00	*Workshop closure*

Figure 57: *National Workshop Invitation*





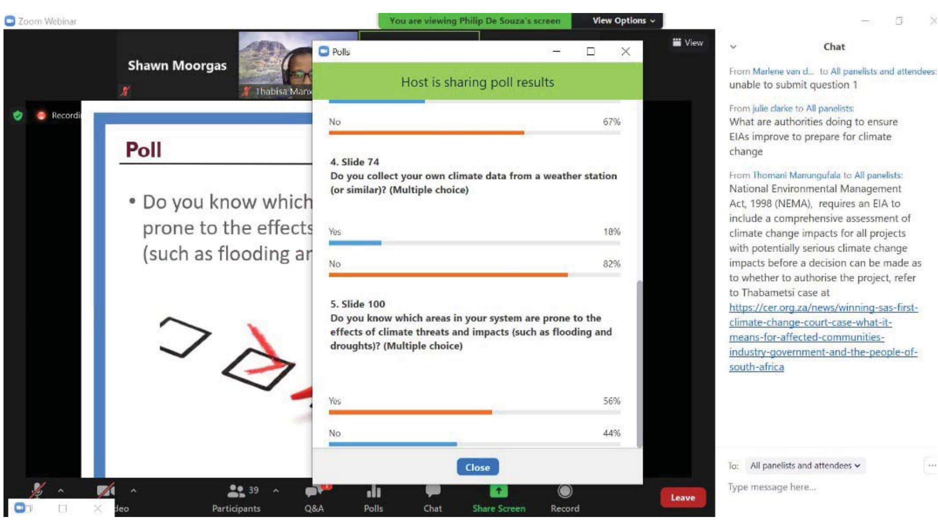


***Figure 58:** National Workshop – 23rd March 2021*

11.2 National Workshop and Outcomes

From the total of 136 persons who registered, 45 persons attended and participated in the national workshop.

During the national workshop, several polls were run to gauge participants' knowledge and experience on key topics. The poll questions and results are presented below:

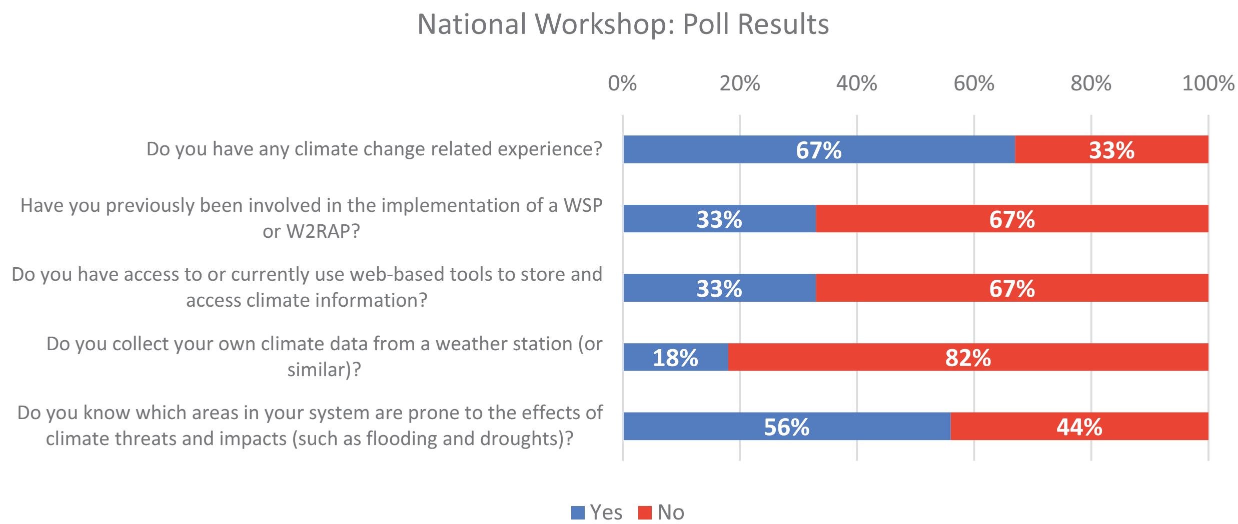


Figure 59: *National workshop poll results*

The following is noted:

- 67% of participants indicated that they have no/limited climate change related experience. This indicates a need for additional awareness and technical training on the topic of climate variability and change.
- Surprisingly, 67% of participants had not yet been involved in the implementation of the WSP and W_2RAP. This could indicate that participants were junior/new staff or had not yet been involved in a WSP/W_2RAP or Blue/Green Drop Certification process. Additional time was therefore spent expanding on what WSPs and W_2RAPs entail.
- 67% of participants are not currently using a web-based tool to store and access climate information. This indicates a need to improve knowledge dissemination of resources that are already available for use.
- 82% of participants do not collect their own data and would therefore be reliant on data collected by others (e.g. South African Weather Service).
- Although some participants did not have any/very little knowledge of climate change, 56% of participants noted that they were still able to indicate areas within their water supply and

wastewater/sanitation systems that are prone to the effects of climate variability and change. This highlights the power of observation and local knowledge. A key next step is to act on this knowledge and implement actions to mitigate any significant risks.

The overall feedback for the national workshop was positive, with the following key feedback noted:

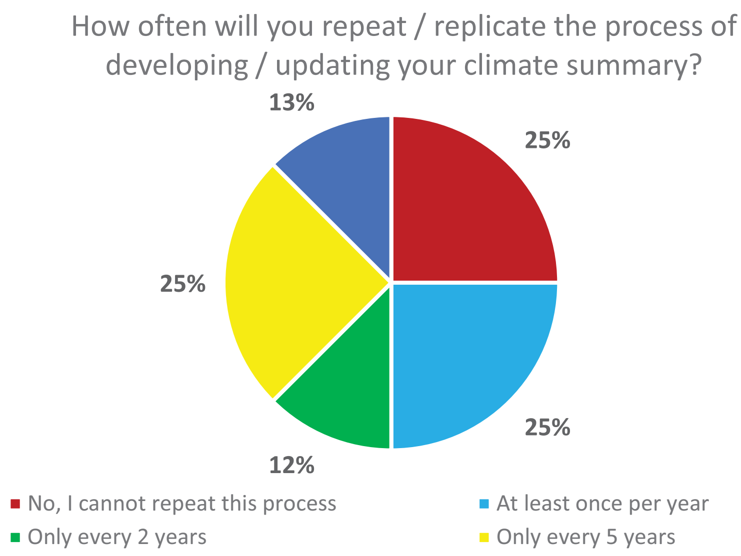


Figure 60: *National workshop feedback: key question analysis*

The following is noted:

- Some participants noted that they would not be able to develop their own climate summary, or frequently update their climate summary. The team will give this further consideration when developing the guideline, and in particular aim to provide some guidance regarding the suggested frequency for updating a climate summary.

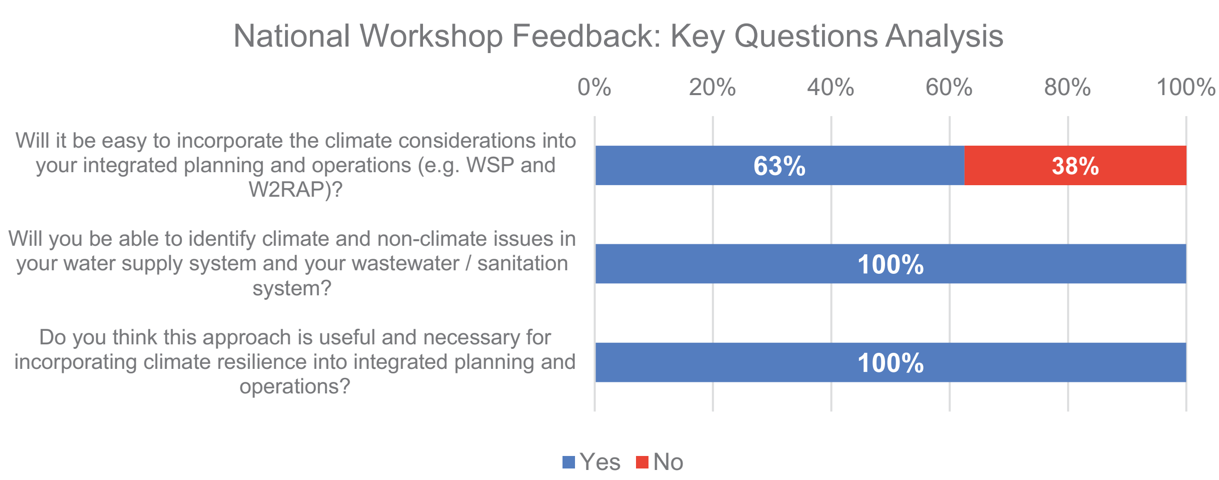


Figure 61: *National workshop feedback: key question analysis*

The following is noted:

- 63% of participants providing feedback indicated that it would be relatively easy to incorporate climate considerations into your integrated planning and operations (e.g. WSP and W_2RAP).
- All (100%) participants providing feedback indicated that they would be able to identify climate and non-climate issues in their water supply and wastewater/sanitation systems.
- All (100%) participants providing feedback indicated support for the approach and noted the usefulness and need necessary for improving climate resilience.

The inputs and feedback from both the CMA/WMA Workshops and National Workshop were used to further refine the approach and methodology and inform the development of the guideline document.

12. Guideline

A guidance document has been developed that accompanies this detailed technical report.

The guidance document has been developed with WSIs in mind and provides easy-to-follow practical steps that a WSI should follow. The guidance describes how a WSI can access climate data and information, summarise the information into a climate summary and integrate the climate information into their WSP and W_2RAP. The guidance document includes the following main sections:

1. Introduction
    a. Background
    b. Aim and purpose of this guideline
2. Guideline Roadmap
3. Accessing Data and Information
    a. Accessing climate information
    b. Availability, accessibility, and ease of use
4. Developing A Climate Summary
    a. What is a climate summary?
    b. Accessing data / information
    c. Reviewing the data / information and compiling the climate summary
    d. What is the geographic location of the local municipality within South Africa?
    e. Accessing climate information
    f. Accessing Green Book
    g. What is the average temperature and rainfall observed within your municipality?
    h. Accessing Climate Information Platform
    i. What is the seasonal and long-term (~30year) trend of extreme rainfall / temperature for your municipality?
    j. How is rainfall / temperature projected to change in the future for your municipality?
    k. What is the climate change hazards for your area?
5. Integrating Climate Information into the WSP and W_2RAP
    a. Assembling the CR-WSP and CR-W_2RAP teams
    b. Describing, documenting, and assessing the water and wastewater systems
    c. Identifying climate related hazards, hazardous events, assessing the risks and control measures
    d. Determine and validate control measures, reassess, and prioritize the risks
    e. Develop, implement, and maintain an improvement/upgrade plan
    f. Preparing management procedures
    g. Developing supporting programmes

13. Conclusions and Recommendations

The goal of this project was to promote climate change resilient water services institutions and communities by increasing understanding of climate change and improving planning and co-ordination at local and catchment level, thereby facilitating implementation of required investments in climate change adaptation and contributing to the achievement of the Sustainable Development Goals (SDGs). Responding to climate change is also one of the key elements of the Department of Water and Sanitation National Water and Sanitation Master Plan (DWS, 2018).

The following has been achieved through this project:

- Develop a South African appropriate climate assessment methodology, which can be incorporated into, and enhance existing WSP/W_2RAP processes, or used to develop new CR-WSPs/W_2RAPs.
- Pilot this methodology at three (3) selected municipalities (Western Cape (recent drought), KwaZulu-Natal (recent floods) and Limpopo (potential transboundary issues).
- Conduct workshops (3 Municipal and CMA/WMA workshops (Breede-Gouritz (WC), Pongola-Umzimkulu (KZN), Limpopo (LP)) workshops and a National Workshop) to gather feedback, refine the approach and methodology, share knowledge, raise awareness, and help advocate for more widespread use of the developed methodology.

Through this project, local government have access to easily interpretable climate information that can be used to improve their planning, and thereby facilitate increased local resilience through appropriate climate change adaptation investments. The approach and methodology will benefit municipalities (e.g. improved planning and risk management) and CMAs/WMAs alike (e.g. contribute to catchment wide strategies and plans). Importantly, the approach and methodology are appropriate for use elsewhere in Africa and beyond.

The need for such an approach and methodology has been stressed by the participating municipalities and stakeholders, and feedback received has been positive. The guideline document accompanying this technical report outlines the steps that a municipality/water utility would need to follow to develop and implement CR-WSPs/CR-W_2RAPs within their area of jurisdiction.

In general, the metropolitan municipalities in South Africa appear to be well equipped to perform climate resilient water safety planning/wastewater risk abatement planning, as they already have climate change related strategies and plans in place. The challenge, however, lies with the smaller, rural and peri-urban municipalities that do not have this capacity and require support to improve their adaptation capacity and improve climate resilience. There is need to further operationalise the approach and methodology at Water Services Institutions through: (1) Practical solutions, (2) Improving adaptive capacity, and (3) Increasing knowledge.

This project has emphasized that although there are good climate data and information tools available that are relevant in the South African context, it often remains a challenge for municipalities (and other stakeholders) to understand the relevance of climate information, interpret the information and incorporate the findings into existing risk management processes and day-to-day activities. Importantly, these processes often do not consider a holistic integrated water management approach (i.e. water supply and sanitation, including both off-site and on-site sanitation systems). An integrated water management approach will not only improve water supply and sanitation management systems through making them more resilient to climate variability and change, but also ensure water resources are safely and sustainably managed.

Climate resilience needs to be built and coordinated at both the catchment and local government/water board levels to ensure adaptation measures for water supply and sanitation systems are effective and integrated. Although the project has successfully improved understanding, planning and co-operation at both municipal and catchment level, it has also highlighted the need for improved alignment, collaboration and communication between CMAs/WMAs and their associated municipalities. Therefore, although good progress has been made in some instances, there is still much work to do. The piloting and workshops have opened channels of communication and initiated collaboration within the three selected CMAs/WMAs. These relationships need to be fostered to allow sustainable collaboration, data sharing and establishing effective partnerships that solve local challenges. All water services institutions in South Africa should be encouraged to use the developed methodology, and the collaborative approach should be duplicated at the other CMAs/WMAs to allow improved capacity and capability within the water sector at local, regional and national level.

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Appendices

- **Appendix A: Climate information data sources**
- **Appendix B: Climate summary for three pilot municipalities**
- **Appendix C: WSP and W_2RAP recommendations for three pilot municipalities**

Appendix A: Climate information data sources

Questions	Information source	Type of data or product	Scale of data Spatial resolution	Coverage	Intended Audience	Access cost	Example with comments
			Temperature				
What is the historic pattern of surface temperature within the region?	Focus groups	Various	Local	Local	Generalist	Free	*Focus group discussions either with local stakeholders or experts may provide valuable information on historical climate. Its accuracy and precision may have some limitations.*
	Newspapers	Newspaper reports	Various	National / local	Generalists	Free	*Newspapers may provide a source of valuable information on past temperature records, especially during notable events (e.g. heatwaves). The data itself is likely sourced from government records, but its presentation may be useful for WSP and W_2RAP teams*
What are the typical means, maximum and minimum temperatures?	National Meteorological and Hydrological Services	Station data (time series or summary statistics)	Individual locations Individual locations Sub-national (regions, districts)	National	Technical specialists	Free	Provides users access to historical data, forecast, and projections http://www.csag.uct.ac.za/ SA Risk and Vulnerability Atlas http://sarva2.dirisa.org/
What is the		Monthly or seasonal summary reports Short-term forecasts Seasonal forecasts			Generalists	Paid	South African Weather Services (SAWS) https://www.weathersa.co.za/ *National meteorological services may be able to provide access to time series (hourly, or daily), or summary statistics (monthly, seasonally). Other products include historical summary reports, annual summary reports, short-term forecasts (up to several days), or seasonal forecasts. Conditions and fees for access will vary on the data requested*

Questions	Information source	Type of data or product	Scale of data Spatial resolution	Coverage	Intended Audience	Access cost	Example with comments
pattern of extreme temperatures (both hot and cold weather)?							https://www.hydronet.com/ *HydroNET is a web-based decision support system, which transfers weather and water data into sophisticated applications and dashboards. Weather related data is collected y SAWS and transferred to the HydroNET platform. The data added to the platform becomes available to registered users in the form of maps and graphs*
	Regional Meteorological and Hydrological services	Station data (time series or summary statistics)	Individual locations	Regional	Technical specialists	Free	Regional Climate Center, Pune, Intergovernmental Authority on Development (IGAD) Climate Prediction and Applications Centre (ICPAC) http://www.imdpune.gov.in/Clim_RCC_LRF/Climate.html *Other regional climate centers include:*
		Monthly or seasonal summary reports	Individual locations Sub-national (regions, districts)		Generalists	Free	Tokyo Regional Climate Centre (http://ds.data.jma.go.jp/tcc/tcc/)
			National				African Centre of Meteorological Applications for Development (ACMAD) http://acmad.net/rcc/
		Short-term forecasts	Regional				
		Seasonal forecasts					

Questions	Information source	Type of data or product	Scale of data Spatial resolution	Coverage	Intended Audience	Access cost	Example with comments
	International databases or services	Station data (time series or summary statistics)	Individual locations	International	Technical specialists	Free	Global Historical Climatology Network (GHCN) *Accessible through other web-browsers such as* NOAA Climate Data Online (https://www.ncdc.noaa.gov/cdo-web/). This service can provide time series or summary data
							UN Data (http://data.un.org) *Contains average monthly data on individual stations globally. Parameters contained include daily means, maxima and minima temperature.*
		Temperature maps or visualisations Climate maps and charts (time series) or summaries	Gridded data over selected river basins	International	Technical specialists	Free	IWA Flood and Drought monitoring tools http://www.flooddroughtmonitor.com/home *Data can be presented in the form of maps for selected river basins*
							Met Office Hadley Centre observations datasets http://hadobs.metoffice.com/index.html
							Climate Engine http://climateengine.org/app *This tool allows users to access a wide range of climate observations and produce maps and time series across scales or at locations. Temperature data includes maximum, minimum and mean daily temperatures, which can then be easily summarised.*

Questions	Information source	Type of data or product	Scale of data Spatial resolution	Coverage	Intended Audience	Access cost	Example with comments
		Recent surface and satellite observations Short-term forecasts Seasonal forecasts	Gridded data (scale varies)	International	Technical specialists	Free	Climate Prediction Center https://www.cpc.ncep.noaa.gov/products/international/ This tool provides access to climate maps across various time scales. Data can be presented as absolute values, or relative to normal values.
		National summary statistics National vulnerability assessments	National or sub-national	International	Generalists	Free	World Bank Climate Knowledge portal, Country Information https://climateknowledgeportal.worldbank.org/country/south-africa *This tool provides access to national summary (monthly) data and briefings on climate statistics*
	Academic centres	Recent observations Short-term forecasts Seasonal forecasts	Gridded data (typically large scale)	International	Technical specialists	Free	University of Columbia International Research Institute for Climate and Society Climate: Analysis, Monitoring and Forecasts http://iridl.ldeo.columbia.edu/maproom/ *This tool provides access to a broad range of temperature data, in the form of maps that can be explored. Data are presented as absolute values or relative to normal values.*
	Climate Vulnerability and Adaptation (V and A) Assessments	Assessment reports	National Regional	National Regional	Generalists	Free	Climate change risk and vulnerability assessment for rural human settlements, 2013 http://www.ruraldevelopment.gov.za/phocadownload/spatial_Planning_Information/Climate_Change/Latest_Risk_and_Vulnerability_july_2013_09072013.pdf Annual state of climate summary for South Africa, 2019 https://www.weathersa.co.za/Documents/Corporate/Annual%20State%20of%20the%20Climate%202019.pdf

Questions	Information source	Type of data or product	Scale of data Spatial resolution	Coverage	Intended Audience	Access cost	Example with comments
							Council for Scientific and Industrial Research, Climate Risk and Vulnerability: A handbook for Southern Africa https://www.csir.co.za/sites/default/files/Documents/SADC%20Handbook_Second%20Edition_full%20report.pdf
							South Africa's annual climate reports published by the Department of Environmental Affairs https://www.environment.gov.za/otherdocuments/reports/southafricas_secondnational_climatechange
							World Bank Climate Knowledge portal, Country Information https://climateknowledgeportal.worldbank.org/country/south-africa
							Let's respond toolkit – Department of Environmental Affairs http://www.letsrespondtoolkit.org/
How might the temperatures change in the future?	National Meteorological and Hydrological Services (or other government bodies)	Climate Vulnerability and Adaptation Assessments	Sub-national to national	National	General	Free	Department of Environmental Affairs – Long Term Adaptation Scenarios https://www.environment.gov.za/sites/default/files/docs/climate_trends_bookV3.pdf
							South African Weather Services https://www.weathersa.co.za/Documents/Climate/SAWS_CC_REFERENCE_ATLAS_PAGES.pdf *National meteorological services may be able to provide access to time series (hourly, or daily), or summary statistics (monthly, seasonally). Other products include historical summary reports, short-term forecasts (up to several days), or seasonal forecasts. Conditions and fees for access will vary on the data requested*

Questions	Information source	Type of data or product	Scale of data Spatial resolution	Coverage	Intended Audience	Access cost	Example with comments
	International services	Climate projection data	Gridded data	International	Technical specialists		International Governmental Panel on Climate Change Data Distribution Centre http://www.ipcc-data.org *Provides access to climate model output for different scenarios. However, this information is likely to be beyond the expertise of WSPs/W$_2$RAPs and the data may be out of date.*
	Climate web-tools	Maps and charts of climate projections	Typically grid scale Chart presented as national averages	International	Generalists	Free	Climate Data Factory presents climate model data indicating changes temperature and precipitation under future scenarios https://theclimatedatafactory.com/
							World Bank Climate Knowledge portal, Country Information https://climateknowledgeportal.worldbank.org/country/south-africa *This tool provides access to maps of projected temperature and charts, using a range of climate models.*
							CMIP5 Global Climate Change Viewer http://regclim.coas.oregonstate.edu/visualization/gccv/cmip5-global-climate-change-viewer/
							Copernicus https://www.copernicus.eu/en
							Intergovernmental Panel on Climate Change http://www.ipcc-data.org/sim/index.html
							Climate change risk and vulnerability assessment for rural human settlements, 2013 http://www.ruraldevelopment.gov.za/phocadownload/spatial_Planning_Information/Climate_Change/Latest_Risk_and_Vulnerability_july_2013_09072013.pdf

Questions	Information source	Type of data or product	Scale of data Spatial resolution	Coverage	Intended Audience	Access cost	Example with comments
							Climate explorer https://climexp.knmi.nl/
							Annual state of climate summary for South Africa, 2019 https://www.weathersa.co.za/Documents/Corporate/Annual%20State%20of%20the%20Climate%202019.pdf
							Council for Scientific and Industrial Research, Climate Risk and Vulnerability: A handbook for Southern Africa https://www.csir.co.za/sites/default/files/Documents/SADC%20Handbook_Second%20Edition_full%20report.pdf
							National Climate Change Information System https://ccis.environment.gov.za/#/
		Precipitation (including snow)					
What is the historic pattern of precipitation within the region?	Focus groups	Various	Local	Local	Generalist	*Free*	*Focus group discussions either with local stakeholders or experts may provide valuable information on historical climate. Its accuracy and precision may have some limitations.*
	Newspapers	Newspaper reports	Various	National / local	Generalists	*Free*	*Newspapers may provide a source of valuable information on past rainfall records, especially during notable events (e.g. floods and droughts). The data itself is likely sourced from government records, but its presentation may be useful for WSP and W_2RAP teams*
What are the seasonal patterns in	National Meteorological and Hydrological Services	Station data (time series or summary statistics)	Individual locations	National	Technical specialists	Free	South African Environmental Observation Network (SAEON) Station data for selected sites available upon request
							Local WTW and WWTW measuring rainfall

Questions	Information source	Type of data or product	Scale of data Spatial resolution	Coverage	Intended Audience	Access cost	Example with comments
precipitation?							
How variable are historical rainfalls?							Provides users access to historical data, forecast, and projections http://www.csag.uct.ac.za/ Provides average rainfall for a selected location based on calculation from CRU CL 2.0 dataset https://www.samsamwater.com/
					Generalists	Paid	South African Weather Services (SAWS) https://www.weathersa.co.za/ *National meteorological services may be able to provide access to time series (hourly, or daily), or summary statistics (monthly, seasonally). Other products include historical summary reports, annual summary reports, short-term forecasts (up to several days), or seasonal forecasts. Conditions and fees for access will vary on the data requested*
What is the pattern of extreme rainfall?		Monthly or seasonal summary reports	Individual locations Sub-national (regions, districts)				https://www.hydronet.com/ *HydroNET is a web-based decision support system, which transfers weather and water data into sophisticated applications and dashboards. Weather related data is collected y SAWS and transferred to the HydroNET platform. The data added to the platform becomes available to registered users in the form of maps and graphs.*
		Short-term forecasts	National				
		Seasonal forecasts					SA Risk and Vulnerability Atlas http://sarva2.dirisa.org/

Questions	Information source	Type of data or product	Scale of data Spatial resolution	Coverage	Intended Audience	Access cost	Example with comments
	Regional Meteorological and Hydrological services	Station data (time series or summary statistics)	Individual locations	Regional	Technical specialists	Free	Regional Climate Center, Pune, Intergovernmental Authority on Development (IGAD) Climate Prediction and Applications Centre (ICPAC) http://www.imdpune.gov.in/Clim_RCC_LRF/Climate.html *Other regional climate centers include:* Tokyo Regional Climate Centre (http://ds.data.jma.go.jp/tcc/tcc/) African Centre of Meteorological Applications for Development (ACMAD) (http://acmad.net/rcc/)
		Monthly or seasonal summary reports	Individual locations Sub-national (regions, districts)		Generalists		
			National				
		Short-term forecasts	Regional				
		Seasonal forecasts					
	International databases or services	Station data (time series or summary statistics)	Individual locations	International	Technical specialists	Free	Global Historical Climatology Network (GHCN) [1] *Accessible through other web-browsers such as* NOAA Climate Data Online (https://www.ncdc.noaa.gov/cdo-web/). This service can provide time series or summary data

Questions	Information source	Type of data or product	Scale of data Spatial resolution	Coverage	Intended Audience	Access cost	Example with comments
		Precipitation maps or visualisations	Gridded data over selected river basins	International	Technical specialists	Free	IWA Flood and Drought monitoring tools http://www.flooddroughtmonitor.com/home *Data can be presented in the form of maps for selected river basins*
		Climate maps and charts (time series) or summaries	Gridded data (scale varies)				Climate Engine http://climateengine.org/app This tool allows users to access a wide range of climate observations and produce maps and time series across scales or at locations. Daily precipitation data comes from the CHIRPS database, and can be presented as maps or time series/charts. Values can be presented as absolute values or relative to
							Met Office Hadley Centre observations datasets http://hadobs.metoffice.com/index.html
							CHIRPS https://www.chc.ucsb.edu/data/chirps
		Surface and satellite observations Short-term forecasts	Gridded data (scale varies)				Climate Prediction Center https://www.cpc.ncep.noaa.gov/products/international/ This tool provides access to climate maps across various time scales. Data can be presented as absolute values, or relative to normal values.

Questions	Information source	Type of data or product	Scale of data Spatial resolution	Coverage	Intended Audience	Access cost	Example with comments
		Seasonal forecasts					
		National summary statistics Natural vulnerability assessments	National		Generalists	Free	World Bank Climate Knowledge portal, Country Information https://climateknowledgeportal.worldbank.org/country/south-africa *This tool provides access to maps of projected temperature and charts, using a range of climate models.* *This tool provides access to national summary (monthly) data and briefings on climate statistics*
	Academic centres	Recent observations Short-term forecasts Seasonal forecasts	Gridded data (typically large scale)	International	Technical specialists	free	University of Columbia International Research Institute for Climate and Society Climate: Analysis, Monitoring and Forecasts http://iridl.ldeo.columbia.edu/maproom/ *This tool provides access to a broad range of precipitation data, in the form of maps that can be explored. Data are presented as absolute values or relative to normal values.*
	Climate V and A summaries	Assessment reports	National	Regional / national	Generalists	Free	Climate change risk and vulnerability assessment for rural human settlements, 2013 http://www.ruraldevelopment.gov.za/phocadownload/spatial_Planning_Information/Climate_Change/Latest_Risk_and_Vulnerability_july_2013_09072013.pdf
				International			Annual state of climate summary for South Africa, 2019 https://www.weathersa.co.za/Documents/Corporate/Annual%20State%20of%20the%20Climate%202019.pdf
							Council for Scientific and Industrial Research, Climate Risk and Vulnerability: A handbook for Southern Africa https://www.csir.co.za/sites/default/files/Documents/SADC%20Handbook_Second%20Edition_full%20report.pdf

Questions	Information source	Type of data or product	Scale of data Spatial resolution	Coverage	Intended Audience	Access cost	Example with comments
							South Africa's annual climate reports published by the Department of Environmental Affairs https://www.environment.gov.za/otherdocuments/reports/southafricas_secondnational_climatechange
							World Bank Climate Knowledge portal, Country Information https://climateknowledgeportal.worldbank.org/country/south-africa
How could these precipitation patterns change in the futures?							Let's respond toolkit – Department of Environmental Affairs http://www.letsrespondtoolkit.org/
	National Meteorological and Hydrological Services (or other government bodies)	Climate projection data	Sub-national to national	National	General	Free	Climate Data Factory presents climate model data indicating changes temperature and precipitation under future scenarios https://theclimatedatafactory.com/
							Department of Environmental Affairs – Long Term Adaptation Scenarios https://www.environment.gov.za/sites/default/files/docs/climate_trends_bookV3.pdf
							South African Weather Services https://www.weathersa.co.za/Documents/Climate/SAWS_CC_REFERENCE_ATLAS_PAGES.pdf *National meteorological services may be able to provide access to time series (hourly, or daily), or summary statistics (monthly, seasonally). Other products include historical summary reports, short-term forecasts (up to several days), or seasonal forecasts.* *Conditions and fees for access depend on the volume of data required.*

Questions	Information source	Type of data or product	Scale of data Spatial resolution	Coverage	Intended Audience	Access cost	Example with comments
	International services	Climate projection data	Gridded data	International	Technical specialists	Free	International Governmental Panel on Climate Change Data Distribution Centre http://www.ipcc-data.org Provides access to climate model output for different scenarios. However, this information is likely to be beyond the expertise of WSPs/W_2RAPs
							Met Office Hadley Centre observations datasets http://hadobs.metoffice.com/index.html *Climate explorer https://climexp.knmi.nl/*
	Climate web-tools	Maps and charts of climate projections	Typically gridded data		Generalists	free	World Bank Climate Knowledge portal, Country Information https://climateknowledgeportal.worldbank.org/country/south-africa This tool provides access to maps of projected precipitation and charts, using a range of climate models.
			Chart presented as national averages				Intergovernmental Panel on Climate Change http://www.ipcc-data.org/sim/index.html
							Copernicus https://www.copernicus.eu/en
							CMIP5 Global Climate Change Viewer http://regclim.coas.oregonstate.edu/visualization/gccv/cmip5-global-climate-change-viewer/ National Climate Change Information System https://ccis.environment.gov.za/#/ Climate explorer https://climexp.knmi.nl/

Questions	Information source	Type of data or product	Scale of data Spatial resolution	Coverage	Intended Audience	Access cost	Example with comments
	Climate V and A Assessments	Summaries	Sub-national or gridded data	National	Generalists	Free	Climate change risk and vulnerability assessment for rural human settlements, 2013 http://www.ruraldevelopment.gov.za/phocadownload/spatial_Planning_Information/Climate_Change/Latest_Risk_and_Vulnerability_july_2013_09072013.pdf Annual state of climate summary for South Africa, 2019 https://www.weathersa.co.za/Documents/Corporate/Annual%20State%20of%20the%20Climate%202019.pdf Council for Scientific and Industrial Research, Climate Risk and Vulnerability: A handbook for Southern Africa https://www.csir.co.za/sites/default/files/Documents/SADC%20Handbook_Second%20Edition_full%20report.pdf National Climate Change Information System https://ccis.environment.gov.za/#/ World Bank Climate Knowledge portal, Country Information https://climateknowledgeportal.worldbank.org/country/south-africa
			Surface water information:				
			River flows				
What is the historic pattern of river flows within the region?	National Hydrology Services	Time series data or summaries	Individual locations	National	Technical Specialists	Free	South Africa's Department of Water and Sanitation http://www.dwa.gov.za/projects.aspx *Access to data on water levels (surface water and groundwater), river discharges, salinity, water quality, evapotranspiration*

Questions	Information source	Type of data or product	Scale of data Spatial resolution	Coverage	Intended Audience	Access cost	Example with comments
What are the levels of extreme peak flows?							
							SA Risk and Vulnerability Atlas http://sarva2.dirisa.org/
How long do low flows last?	International databases	Time series data or summaries	Individual locations	International	Technical specialists	Free	Global Runoff Database (GRDB) https://www.bafg.de/GRDC/EN/02_srvcs/21_tmsrs/riverdischarge_node.html;jsessionid=463E83A1E34CCEE82E0804AF304A947B.live21303 *This is a global database of over 9,500 stations globally, containing monthly river flow data*
How might this pattern change in the future?							Global River Discharge Database [(available at http://nelson.wisc.edu/sage/data-and-models/riverdata/index.php)](http://nelson.wisc.edu/sage/data-and-models/riverdata/index.php) *Database of over 3,500 stations*
							National Climate Change Information System https://ccis.environment.gov.za/#/
	National Hydrology Services or other government body	Climate Vulnerability Assessments or similar assessments	From individual locations to national summaries	National	Technical specialists	Free	*Such studies are likely to be based on hydrological modelling requiring technical expertise.*
			Flood history				
What is the history of flooding in the area?	Focus groups	Various	Local	Local	Generalist	*Free*	*Focus group discussions either with local stakeholders or experts may provide valuable information on historical climate. Its accuracy and precision may have some limitations. Field visits should be incorporated in focus group activities.*

Questions	Information source	Type of data or product	Scale of data Spatial resolution	Coverage	Intended Audience	Access cost	Example with comments
How long do floods last?	Newspapers	Newspaper reports	Various	National / local	Generalists	*Free*	*Newspapers may provide a source of valuable information on past temperature records, especially during notable events (e.g. heatwaves). The data itself is likely sourced from government records, but its presentation may be useful for WSP and W_2RAP teams*
How often do floods occur?	National hydrological services	Various	Catchments and regions	National		Free	South African Weather Services
							https://www.weathersa.co.za/
							South Africa's Department of Water and Sanitation
							http://www.dwa.gov.za/projects.aspx
							Access to data on water levels (surface water and groundwater), river discharges, salinity, water quality, evapotranspiration
							eThekwini datafeeds provide river levels for various river in the eThekwini municipality area
							https://data.ethekwinifews.durban/instrument/storm
							SA Risk and Vulnerability Atlas http://sarva2.dirisa.org/
	Internationa l databases	Reports and statistics	Catchments and regions	International			Dartmouth Flood Observatory
							https://floodobservatory.colorado.edu
							The Global Flood Detection System
							http://www.gdacs.org/flooddetection/

Questions	Information source	Type of data or product	Scale of data Spatial resolution	Coverage	Intended Audience	Access cost	Example with comments
How might this change in the future							National Climate Change Information System https://ccis.environment.gov.za/#/
	National Hydrology Services or other government body	Climate Vulnerability Assessments or Web tools	From individual locations to national summaries	National	Technical specialists	Free	Climate change risk and vulnerability assessment for rural human settlements, 2013 http://www.ruraldevelopment.gov.za/phocadownload/spatial_Planning_Information/Climate_Change/Latest_Risk_and_Vulnerability_july_2013_09072013.pdf
							Council for Scientific and Industrial Research, Climate Risk and Vulnerability: A handbook for Southern Africa https://www.csir.co.za/sites/default/files/Documents/SADC%20Handbook_Second%20Edition_full%20report.pdf
							National Climate Change Information System https://ccis.environment.gov.za/#/
							World Bank Climate Knowledge portal, Country Information
							https://climateknowledgeportal.worldbank.org/country/south-africa
	Global web-tools	Flood maps	Catchments or grid locations	International	Generalists	Free	WRI flood analyzer
							https://floods.wri.org/#/
			Water storage levels				

Questions	Information source	Type of data or product	Scale of data Spatial resolution	Coverage	Intended Audience	Access cost	Example with comments
How do water storage levels vary?	Focus groups	Various	Local	Local	Generalist	Free	*Focus group discussions either with local stakeholders or experts may provide valuable information on historical climate. Its accuracy and precision may have some limitations. Field visits should be incorporated in focus group activities.*
	Water utilities	Station data	Individual locations	Nationals	Technical specialists		*Water utilities should themselves keep data on water levels in storage structures such as reservoirs. Time scales and quality may vary.* South Africa's Department of Water and Sanitation http://www.dwa.gov.za/projects.aspx
How long do low water levels persist?	National hydrological services	Various	Catchments and regions	National	Technical specialists		City of Cape Town weekly dam levels https://www.capetown.gov.za/
							SAWX state of dams in South Africa https://sawx.co.za/state-of-dams/ *Access to data on water levels (surface water and groundwater), river discharges, salinity, water quality, evapotranspiration*
			Drought history				
What is the history of drought in	Focus groups	Various	Local	Local	Generalist	*Free*	*Focus group discussions either with local stakeholders or experts may provide valuable information on historical climate. Its accuracy and precision may have some limitations.*

Questions	Information source	Type of data or product	Scale of data Spatial resolution	Coverage	Intended Audience	Access cost	Example with comments
the region?	Newspapers	Newspaper reports	Various	National / local	Generalists	*Free*	*Newspapers may provide a source of valuable information on past rainfall records, especially during notable events (e.g. floods and droughts). The data itself is likely sourced from government records, but its presentation may be useful for WSP and W_2RAP teams*
How might this change?	National hydrological services	Various	Catchments and regions	National	Technical specialists	Free	South African Weather Services https://www.weathersa.co.za/
							South Africa's Department of Water and Sanitation http://www.dwa.gov.za/projects.aspx *Access to data on water levels (surface water and groundwater), river discharges, salinity, water quality, evapotranspiration*
	International services	Various – maps and reports	Catchments and regions	International	Technical specialists	Free	IWA Flood and Drought monitoring tools http://www.flooddroughtmonitor.com/home *Data can be presented in the form of maps for selected river basins*
							University of Columbia International Research Institute for Climate and Society. Global Drought Tools http://iridl.ldeo.columbia.edu/maproom/Global/Drought/Global/ *This tool provides access to a broad range of drought assessment data*
							Global Drought Monitor http://spei.csic.es

Questions	Information source	Type of data or product	Scale of data Spatial resolution	Coverage	Intended Audience	Access cost	Example with comments
							FEWS-NET https://earlywarning.usgs.gov/fews *Provides updates and archived maps on information related to droughts (precipitation, soil moisture, relative to normal conditions)*
	Climate Vulnerability assessments	Assessment reports	National	Regional / national	Generalists	Free	Climate change risk and vulnerability assessment for rural human settlements, 2013 http://www.ruraldevelopment.gov.za/phocadownload/spatial_Planning_Information/Climate_Change/Latest_Risk_and_Vulnerability_july_2013_09072013.pdf
				International			Annual state of climate summary for South Africa, 2019 https://www.weathersa.co.za/Documents/Corporate/Annual%20State%20of%20the%20Climate%202019.pdf

Questions	Information source	Type of data or product	Scale of data Spatial resolution	Coverage	Intended Audience	Access cost	Example with comments
							World Bank Climate Knowledge portal, Country Information https://climateknowledgeportal.worldbank.org/country/south-africa *This tool provides access to maps of projected precipitation and charts, using a range of climate models.*
							Let's respond toolkit – Department of Environmental Affairs http://www.letsrespondtoolkit.org/
		Water temperatures					
What is the pattern of water body temperatures? (rivers, lakes and reservoirs)	Water utilities	Station data	Individual locations	Nationals	Technical specialists	Free	Measured by WTW and WWTW available on request
	National hydrological services					Paid	https://www.hydronet.com/ *HydroNET is a web-based decision support system, which transfers weather and water data into sophisticated applications and dashboards. Weather related data is collected y SAWS and transferred to the HydroNET platform. The data added to the platform becomes available to registered users in the form of maps and graphs.*
						Free	Integrated Regulatory Information System – Provides drinking water and treated wastewater quality as uploaded by the WTW and WWTW http://ws.dwa.gov.za/IRIS/mywater.aspx

Questions	Information source	Type of data or product	Scale of data Spatial resolution	Coverage	Intended Audience	Access cost	Example with comments
			Water quality				
How does water quality vary over time?	Water utilities	Station data	Individual locations	Nationals	Technical specialists	Free	Measured by WTW and WWTW available on request
How are these water quality variables connected to weather?	National hydrological services					Paid	https://www.hydronet.com/ *HydroNET is a web-based decision support system, which transfers weather and water data into sophisticated applications and dashboards. Weather related data is collected y SAWS and transferred to the HydroNET platform. The data added to the platform becomes available to registered users in the form of maps and graphs.*
						Free	Integrated Regulatory Information System – Provides drinking water and treated wastewater quality as uploaded by the WTW and WWTW http://ws.dwa.gov.za/IRIS/mywater.aspx
			Groundwater information				
			Aquifer levels				
How do aquifer levels vary?	Focus groups	Various	Local	Local	Generalist	Free	*Focus group discussions either with local stakeholders or experts may provide valuable information on historical groundwater levels. Its accuracy and precision may have some limitations. Local communities may provide valuable information on depths to water table and how it varies*
	Water utilities	Station data	Individual locations	Nationals	Technical specialists	Free	WTW and WWTW available on request

Questions	Information source	Type of data or product	Scale of data Spatial resolution	Coverage	Intended Audience	Access cost	Example with comments
	National hydrological services	Station data	Individual locations	National	Technical specialists	Free	South Africa's Department of Water and Sanitation http://www.dwa.gov.za/projects.aspx
							National Climate Change Information System https://ccis.environment.gov.za/#/
How might this change in the future?	National hydrological services or other government agencies	Climate Vulnerability assessments	Various	National	Generalist	Free	*Estimates of the impacts of climate change on groundwater levels are likely to require complex modelling and depend highly on local conditions.*
			Coastal				
			Sea levels				
How have sea levels varied in the past?	Focus groups	Various	Various	National/Loca l	Generalist	Free	*Focus group discussions either with local stakeholders or experts may provide valuable information on historical sea levels. Its accuracy and precision may have some limitations.*
	Newspapers	Newspaper reports	Various	National / local	Generalists	Free	*Newspapers may provide a source of valuable information on past temperature records, especially during notable events (e.g. storm surge). The data itself is likely sourced from government records, but its presentation may be useful for WSP and W_2RAP teams*
	National hydrological or coastal monitoring services	Station data	Individual locations	National	Technical specialists	Free	South African Weather Services Marine Portal http://marine.weathersa.co.za/

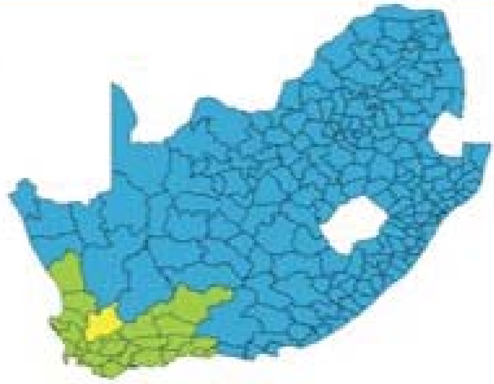
Questions	Information source	Type of data or product	Scale of data Spatial resolution	Coverage	Intended Audience	Access cost	Example with comments
	International services	Station data Satellite data	Individual locations	Global	Technical specialists	Free	Global Sea Level Observing System (GLOSS) http://www.ioc-sealevelmonitoring.org/gloss.php *A network of around 300 gauging stations*
							Permanent Service for Mean Sea Level https://www.psmsl.org
							NASA Sea Level Analysis Tool https://sealevel.nasa.gov/data-analysis-tool/
What are the projections of sea level rise?	National coastal management services or other government agencies	Sea level data	Various	National	Technical specialists	Free	South African Weather Services Marine Portal http://marine.weathersa.co.za/
		Summary data from assessment reports	National and sub-national	National	Generalist	Free	City of Cape Town Global Climate Change and Adaptation: A Sea-Level Risk Assessment https://www.ipcc.ch/apps/njlite/ar5wg2/njlite_download2.php?id=10647
							Department of Environmental Affairs and Development Planning https://www.westerncape.gov.za/text/2010/11/eden_sea_level_rise_phase_1_literature_review_final_(may_2010).pdf
							Climate Change Adaptation: Perspectives for Disaster Risk Reduction and Management in South Africa https://www.environment.gov.za/sites/default/files/docs/ltasphase2report3_adaptation_ddrm.pdf
							Managing the Risk of Flooding and Sea-level Rise in Cape Town: the Power of Collective Governance https://www.idrc.ca/en/project/managing-risk-flooding-and-sea-level-rise-cape-town-power-collective-governance

Questions	Information source	Type of data or product	Scale of data Spatial resolution	Coverage	Intended Audience	Access cost	Example with comments
							South African Environmental Observation Network http://www.saeon.ac.za/Observations-on-Environmental-Change-in-SA-e-version-Section-4.pdf
	International assessments	Assessment reports	Various	International	Generalist	Free	IPCC 5th Assessment Report
							https://www.ipcc.ch/report/ar5/wg1/sea-level-change/
	Web-tools	Maps	Gridded locations		Generalist	Free	Surging seas https://ss2.climatecentral.org *Web-tool that allows user to overlay sea level rise scenarios*
							National Climate Change Information System https://ccis.environment.gov.za/#/
							South African Weather Services Marine Portal http://marine.weathersa.co.za/

Appendix B: Climate summary for three pilot municipalities

CLIMATE SUMMARY WITZENBERG LOCAL MUNICIPALITY, WESTERN CAPE, SOUTH AFRICA

Witzenberg Local Municipality is located in the Western cape province, and forms part of the Cape Winelands District. According to the Köppen-Geiger climate classification most of Witzenberg experiences Mediterranean climate. Witzenberg experiences with hot dry summers, and cool wet winters. Typical Climate related hazards for Witzenberg include droughts, fires and floods.



Population
130548

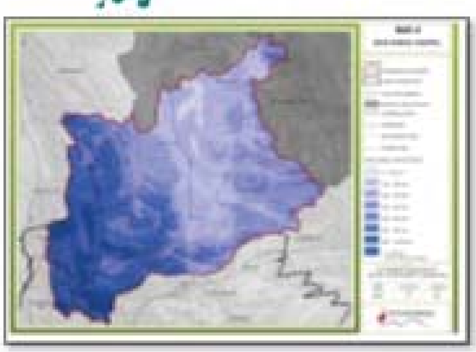
Households
35 976

Water Demand

Municipality	Residential per capita water use (L/c/d)	Municipal water losses (%)	Jobs per million cubic metre in heavily water-dependent sectors (Mm³/a)	Total income per cubic metre in heavily water-dependent sectors (ZAR/m³/a)
Bergrivier	139	13	114	79 ± 28
Saldanha Bay	112	18	790	259 ± 90
Swartland	107	15	234	102 ± 32
Drakenstein	106	11	41	18 ± 6
Stellenbosch	152	[illegible]	7	9 ± 3
Witzenberg	107	10	112	15 ± 5
City of Cape Town	125	14	932	167 ± 62
Berg WMA	124	16	177	104 ± 61

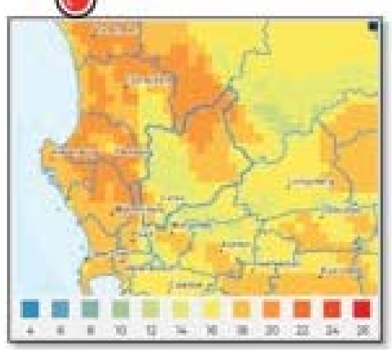
Rainfall

Average annual: 629.6mm



Temperature

Minimum: 4.3 °C
Maximum: 29.2 °C



CLIMATE SUMMARY WITZENBERG LOCAL MUNICIPALITY, WESTERN CAPE, SOUTH AFRICA

Climate Trends

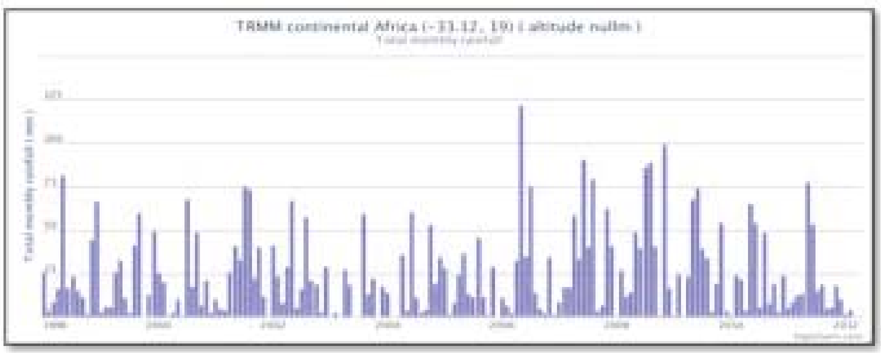
The analysis of quantitative data for the Western Cape indicate the number of rainfall days has decreased especially in the dry season (November –April), whereas the rainy season (typically May – October) is starting later each year.

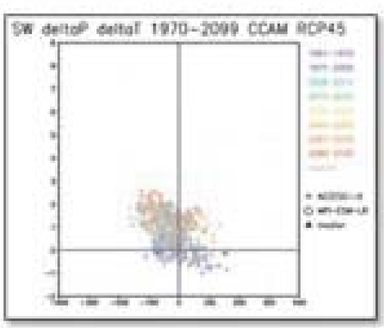
Temperatures for the province indicate an increasing trend in minimum, maximum and mean temperature. Temperature over the past decade has increased by about 1°C. increases in temperature have also been observed in ocean currents such as the Agulhas current. The warming trend for the Agulhas current indicates that since 1980, the temperature has increased by 1.5°C

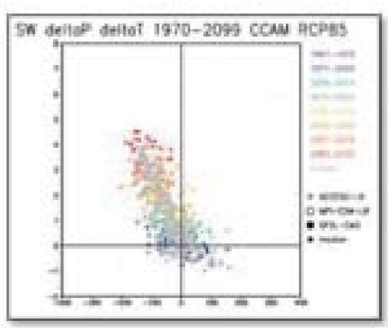
Climate Projections

Under the high emissions scenario, temperatures are projected to increase by about 1.5°C in the near future (2015-2035), in the mid-future (2040-2060) temperatures are expected to increase by 1°C to 2°C, and for the far future (2080-2100) up to 2°C to 4°C. Under the RCP85 scenario, rainfall is projected to decrease. Model projections indicate that, rainfall for the area is likely to decrease. Additionally, rainfall is expected to be well out of range of present day climate variability.

Under the medium emissions scenario RCP45 temperatures are projected to increase but by the end of the century (2080-2100) increases are projected to remain below 3°C. The projected drying trends for rainfall are likely to occur. Additionally, rainfall is expected to be well out of range of present day climate variability.







CLIMATE SUMMARY WITZENBERG LOCAL MUNICIPALITY, WESTERN CAPE, SOUTH AFRICA

Climate hazard	Climate threat	Primary impact	Impact on water supply systems	Risk (H, M, L)
Increases/decreases temperature (mean annual, maximum, and minimum)	Increased warm days/periods	Increased water holding capacity of the atmosphere	Reduced water availability within catchment areas	
	Increased warm days/periods	Drought	Reduced water quality and quantity	
	Increased warm days/periods	Fires	Reduced water quality and infrastructure damage	
	Increased evaporation	Increased evaporation from surface water resources	Reduced water quality, and reduced water availability	
	Increased warm days/periods	Heat stress	Damage to infrastructure due to exceeding temperature design specification.	
	Increased water temperatures	Heat stress	Unsafe drinking water due to increased waterborne pathogens	
	Increased warm days/periods	Heat stress	Sunburn damage to green infrastructure (biodiversity loss) that serve as natural control measures (wetlands, mangroves, etc.)	
	Increased cold days/periods	Cold stress	Cold/frost related damage to green and grey infrastructure	
	Increased cold days/periods	Cold stress	Freezing of pipes in water supply systems, resulting in reduced ability to supply water	
	Increased warm days/periods	Increased frequency of drought	Long-term water availability and quality issues (multi-year droughts)	
	Increased warm days/periods	Fires	Increased fire risk due to desiccation of soil and vegetation within the catchment and treatment works	
Increased average annual rainfall	Increased water entering system	Flooding	Water treatment system infrastructure failure due to increased water entering system as a result of heavy downpours	
	Increased infiltration	Higher water tables	Increased pathogens in groundwater and surface water resulting from overflow of onsite sanitation systems (pit latrines etc.)	
	Increased water entering system	Increased runoff	Increased loading of pathogens, chemicals, and suspended material, which may result in reduced source water quality	
	Increased water entering system	Flooding	Contaminated surface water entering groundwater through wells	
	Increased water entering system	Increased runoff	Erosion decreases soil water holding capacity, and reduces groundwater storage potential	
	Increased water entering system	Increased runoff	Increased sediment entering rivers and dams, may reduce storage capacity	
	Increased water entering system	Increased runoff	Increased sediment entering water treatment system, increasing turbidity	
	Increased water entering system	Flooding	Inundation of areas around the treatment works, resulting in decreased site accessibility	
Decreased average annual rainfall	Decreased water availability	Low surface runoff and low groundwater recharge rates	Reduced water availability for diverse water mix	
	Decreased water availability	Reduced runoff/infiltration	Reduced water quality (lack of dilution of pollutants /contaminants)	
	Decreased water availability	Reduced runoff/infiltration	Increased competition between anthropogenic and ecosystem requirements	
	Decreased water availability	Reduced runoff/infiltration	Increased competition for anthropogenic activities	
	Decreased water availability	Reduced runoff/infiltration	Increased treatment cost and requirements due to increased pathogen and pollution/contaminant concentrations	
	Decreased water availability	Wind erosion of soils	Reduced soil storage capacity due to wind erosion	
	Erratic rainfall	Flooding	Damage to infrastructure; over capacitated water treatment systems	

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1. DEA (Department of Environmental Affairs). 2013. Long-Term Adaptation Scenarios Flagship Research Programme (LTAS) for South Africa. Climate Trends and Scenarios for South Africa. Pretoria, South Africa.
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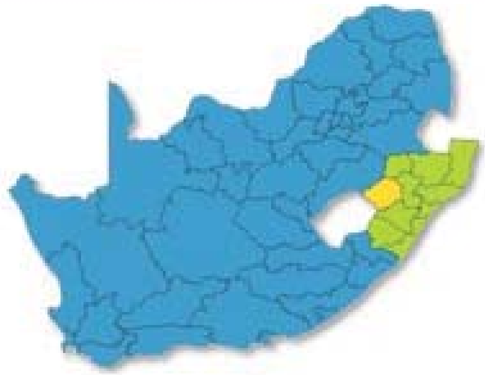
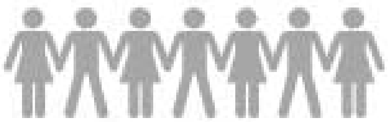
3. Witzenberg spatial development framework. (2012). Witzenberg Municipality
4. https://cip.csag.uct.ac.za/webclient2/datasets/africa-merged-cmip5/#datasets
5. https://riskprofiles.greenbook.co.za/

CLIMATE SUMMARY UTHUKELA DISTRICT MUNICIPALITY, KWAZULU-NATAL, SOUTH AFRICA

Uthukela District Municipality is located in the KwaZulu-Natal Province, South Africa. According to the Köppen-Geiger climate classification most of Uthukela experiences Humid sub-tropical climate, whereas other areas experience marine climates. Uthukela experiences warm wet summers, and cool dry winters. Typical climate related hazards for Uthukela include, flooding, fires, storms, and in recent years droughts.

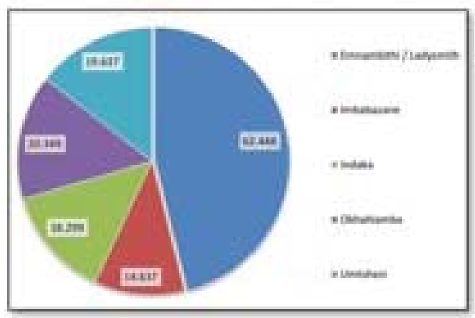




Population
706 589

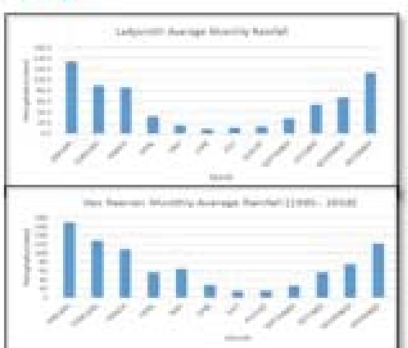
Households
161 788

Water Demand



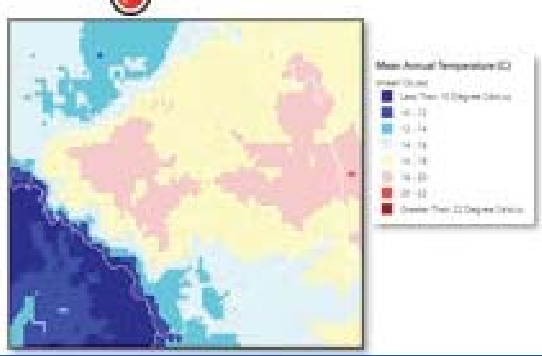
Rainfall

Average annual: 700mm



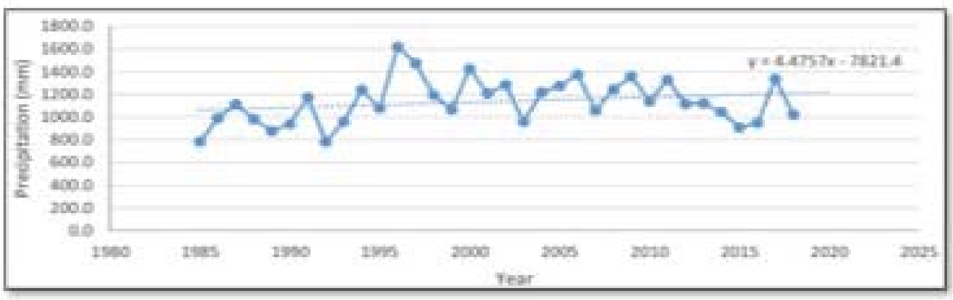
Temperature

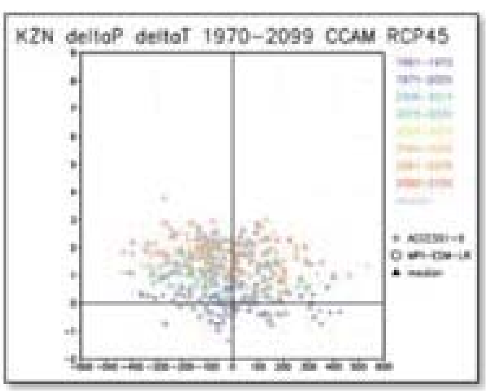
Minimum: 3°C
Maximum: 30°C

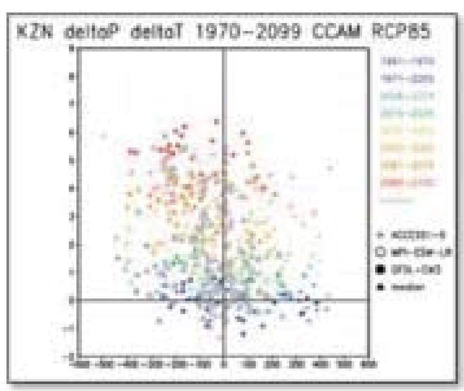


CLIMATE SUMMARY UTHUKELA DISTRICT MUNICIPALITY, KWAZULU-NATAL, SOUTH AFRICA

Climate Trends[3]	Climate Projections
Temperature for the area has shown an overall warming trend, with observed increase being as much as 2°C per century. Maximum daily temperatures have also shown an increase over time. The increase in temperatures and the impact has certainly been evident during 2015-2016. The area experienced a drought during this period, which had a ripple effect on other industry such as livestock and other agricultural sectors. According to Chabalala et al (2019), rainfall for the area indicates an increases for the period 1985-2018. These increases in rainfall have occurred mainly during the provinces wet season.	Under the high emissions scenario, temperatures are projected to increase by 1°C to 2°C in the near future (2015-2035), in the mid-future (204-2060) temperatures are expected to increase by 1°C to 4°C, and for the far future (2080-2100) up to 3°C to 5°C. Under the RCP85 scenario, rainfall is projected to decrease. The projected rising temperatures and decrease in rainfall, is likely to result in heatwaves, fires, and droughts. Under the medium emissions scenario RCP45 temperatures are projected to increase but by the end of the century (2080-2100) increases are projected to only have increased by between 1°C and 3°C. Modest drying trends for rainfall are likely to occur.







CLIMATE SUMMARY UTHUKELA DISTRICT MUNICIPALITY, KWAZULU-NATAL, SOUTH AFRICA

Climate hazard	Climate threat	Primary impact	Impact on water supply systems	Risk (H, M, L)
Increases/decreases temperature (mean annual, maximum, and minimum)	Increased warm days/periods	Increased water holding capacity of the atmosphere	Reduced water availability within catchment areas	
	Increased warm days/periods	Drought	Reduced water quality and quantity	
	Increased warm days/periods	Fires	Reduced water quality and infrastructure damage	
	Increased evaporation	Increased evaporation from surface water resources	Reduced water quality, and reduced water availability	
	Increased warm days/periods	Heat stress	Damage to infrastructure due to exceeding temperature design specification.	
	Increased water temperatures	Heat stress	Unsafe drinking water due to increased waterborne pathogens	
	Increased warm days/periods	Heat stress	Sunburn damage to green infrastructure (biodiversity loss) that serve as natural control measures (wetlands, mangroves, etc.)	
	Increased cold days/periods	Cold stress	Cold/frost related damage to green and grey infrastructure	
	Increased cold days/periods	Cold stress	Freezing of pipes in water supply systems, resulting in reduced ability to supply water	
	Increased warm days/periods	Increased frequency of drought	Long-term water availability and quality issues (multi-year droughts)	
	Increased warm days/periods	Fires	Increased fire risk due to desiccation of soil and vegetation within the catchment and treatment works	
Increased average annual rainfall	Increased water entering system	Flooding	Water treatment system infrastructure failure due to increased water entering system as a result of heavy downpours	
	Increased infiltration	Higher water tables	Increased pathogens in groundwater and surface water resulting from overflow of onsite sanitation systems (pit latrines etc.)	
	Increased water entering system	Increased runoff	Increased loading of pathogens, chemicals, and suspended material, which may result in reduced source water quality	
	Increased water entering system	Flooding	Contaminated surface water entering groundwater through wells	
	Increased water entering system	Increased runoff	Erosion decreases soil water holding capacity, and reduces groundwater storage potential	
	Increased water entering system	Increased runoff	Increased sediment entering rivers and dams, may reduce storage capacity	
	Increased water entering system	Increased runoff	Increased sediment entering water treatment system, increasing turbidity	
	Increased water entering system	Flooding	Inundation of areas around the treatment works, resulting in decreased site accessibility	
Decreased average annual rainfall	Decreased water availability	Low surface runoff and low groundwater recharge rates	Reduced water availability for diverse water mix	
	Decreased water availability	Reduced runoff/infiltration	Reduced water quality (lack of dilution of pollutants /contaminants)	
	Decreased water availability	Reduced runoff/infiltration	Increased competition between anthropogenic and ecosystem requirements	
	Decreased water availability	Reduced runoff/infiltration	Increased competition for anthropogenic activities	
	Decreased water availability	Reduced runoff/infiltration	Increased treatment cost and requirements due to increased pathogen and pollution/contaminant concentrations	
	Decreased water availability	Wind erosion of soils	Reduced soil storage capacity due to wind erosion	
	Erratic rainfall	Flooding	Damage to infrastructure; over capacitated water treatment systems	

References

1. Integrated Development Plan Review 2019/2020, Uthukela District Municipality. IDP Unit
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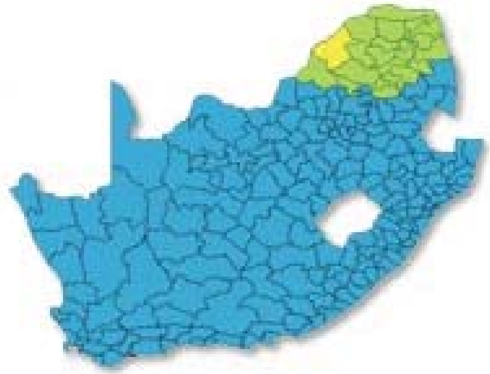
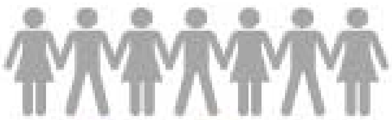
3. DEA (Department of Environmental Affairs). 2013. Long-Term Adaptation Scenarios Flagship Research Programme (LTAS) for South Africa. Climate Trends and Scenarios for South Africa. Pretoria, South Africa.
4. Esterhuizen, M. (2016). Planning water supply for basic services in rural areas. UWP Consulting. EE Publishers
5. https://ccis.environment.gov.za/#/climate-atlas

CLIMATE SUMMARY LEPHALALE LOCAL MUNICIPALITY, LIMPOPO PROVINCE, SOUTH AFRICA

Lephalale Local Municipality is located in the Limpopo province, and forms part of the Waterberg District Municipality. According to the Köppen-Geiger climate classification most of Lephalale experiences hot and semi-arid climate. Lephalale experiences hot wet summers, and cool dry winters. Typical climate related hazards for Lephalale include, flooding and droughts.





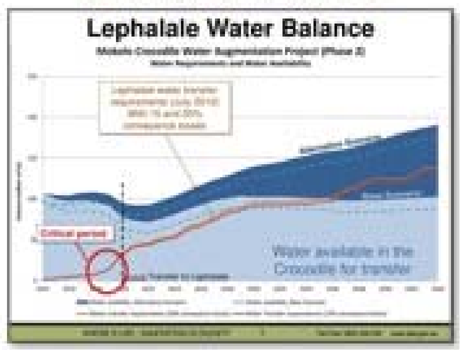
Population

140 240

Households

43 002

Water Demand



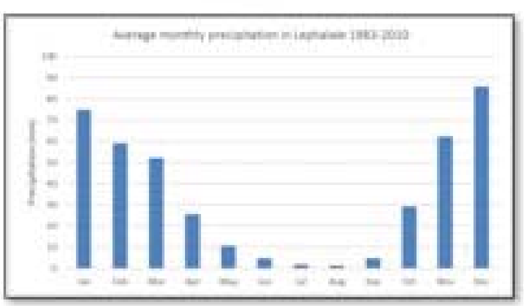
Rainfall

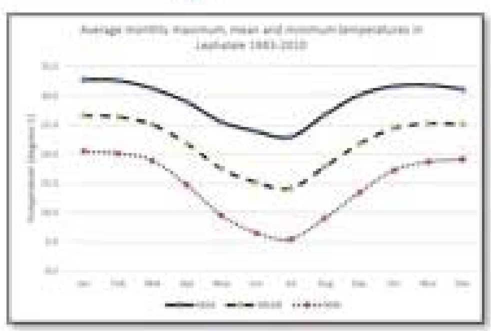
Average annual: 401mm

Temperature

Winter: 15.7 °C

Summer: 26 °C





CLIMATE SUMMARY LEPHALALE LOCAL MUNICIPALITY, LIMPOPO PROVINCE, SOUTH AFRICA

Climate Trends

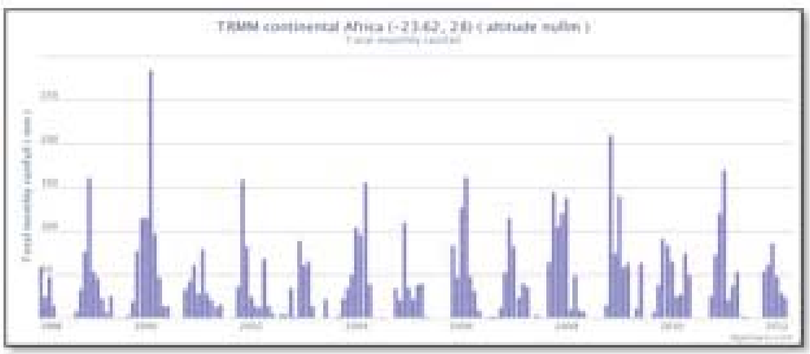
According to the National Climate Change Information System, the province has experience a warming trend of more than 1 °C per century for the period 1931-2015. This is also reflected in the number of hot days, as the number of hot days has increased by about 1 day/decade for the same period.

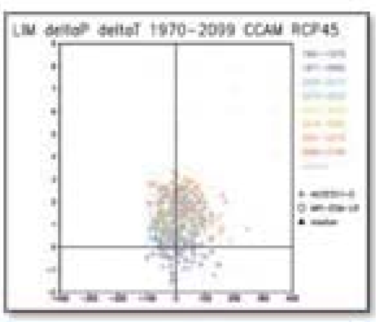
Stations in the located in the northern regions of the province indicate significant decreases in annual precipitation, which has been found to be more than 10 mm/decade. It should be noted however, that based on the station data statistically significant increases in extreme daily rainfall events have been identified.

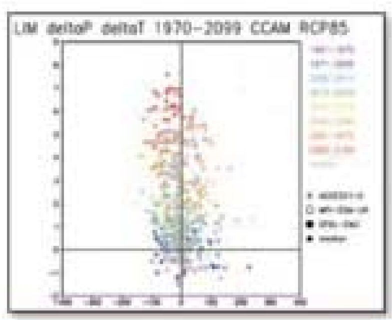
Climate Projections

Under the high emissions scenario, temperatures are projected to increase by about 2°C in the near future (2015-2035), in the mid-future (2040-2060) temperatures are expected to increase by 1°C to 3°C, and for the far future (2080-2100) up to 3°C to 6°C. Under the RCP85 scenario, rainfall is projected to decrease. Rainfall for the area is likely to become more erratic, as some models project decreases in rainfall whereas other project increases. However rainfall is expected to be within range of present day climate variability.

Under the medium emissions scenario RCP45 temperatures are projected to increase but by the end of the century (2080-2100) increases are projected to only have increased by between 2°C and 3°C. Modest drying trends for rainfall are likely to occur. Rainfall is expected to be within range of present day climate variability







CLIMATE SUMMARY LEPHALALE LOCAL MUNICIPALITY, LIMPOPO PROVINCE, SOUTH AFRICA

Climate hazard	Climate threat	Primary impact	Impact on water supply systems	Risk (H, M, L)
Increases/decreases temperature (mean annual, maximum, and minimum)	Increased warm days/periods	Increased water holding capacity of the atmosphere	Reduced water availability within catchment areas	
	Increased warm days/periods	Drought	Reduced water quality and quantity	
	Increased warm days/periods	Fires	Reduced water quality and infrastructure damage	
	Increased evaporation	Increased evaporation from surface water resources	Reduced water quality, and reduced water availability	
	Increased warm days/periods	Heat stress	Damage to infrastructure due to exceeding temperature design specification.	
	Increased water temperatures	Heat stress	Unsafe drinking water due to increased waterborne pathogens	
	Increased warm days/periods	Heat stress	Sunburn damage to green infrastructure (biodiversity loss) that serve as natural control measures (wetlands, mangroves, etc.)	
	Increased cold days/periods	Cold stress	Cold/frost related damage to green and grey infrastructure	
	Increased cold days/periods	Cold stress	Freezing of pipes in water supply systems, resulting in reduced ability to supply water	
	Increased warm days/periods	Increased frequency of drought	Long-term water availability and quality issues (multi-year droughts)	
	Increased warm days/periods	Fires	Increased fire risk due to desiccation of soil and vegetation within the catchment and treatment works	
Increased average annual rainfall	Increased water entering system	Flooding	Water treatment system infrastructure failure due to increased water entering system as a result of heavy downpours	
	Increased infiltration	Higher water tables	Increased pathogens in groundwater and surface water resulting from overflow of onsite sanitation systems (pit latrines etc.)	
	Increased water entering system	Increased runoff	Increased loading of pathogens, chemicals, and suspended material, which may result in reduced source water quality	
	Increased water entering system	Flooding	Contaminated surface water entering groundwater through wells	
	Increased water entering system	Increased runoff	Erosion decreases soil water holding capacity, and reduces groundwater storage potential	
	Increased water entering system	Increased runoff	Increased sediment entering rivers and dams, may reduce storage capacity	
	Increased water entering system	Increased runoff	Increased sediment entering water treatment system, increasing turbidity	
	Increased water entering system	Flooding	Inundation of areas around the treatment works, resulting in decreased site accessibility	
Decreased average annual rainfall	Decreased water availability	Low surface runoff and low groundwater recharge rates	Reduced water availability for diverse water mix	
	Decreased water availability	Reduced runoff/infiltration	Reduced water quality (lack of dilution of pollutants /contaminants)	
	Decreased water availability	Reduced runoff/infiltration	Increased competition between anthropogenic and ecosystem requirements	
	Decreased water availability	Reduced runoff/infiltration	Increased competition for anthropogenic activities	
	Decreased water availability	Reduced runoff/infiltration	Increased treatment cost and requirements due to increased pathogen and pollution/contaminant concentrations	
	Decreased water availability	Wind erosion of soils	Reduced soil storage capacity due to wind erosion	
	Erratic rainfall	Flooding	Damage to infrastructure; over capacitated water treatment systems	

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3. Draft Integrated Development Plan 2020. (2020). Lephalale Municipality
4. Rademeyer, S. (2016). Vaal River system Tariff: water and sanitation's long-term water requirement scenarios. Department of water and sanitation
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Appendix C: WSP and W_2RAP recommendations

Integrating climate information into the water safety plan and wastewater risk abatement plan

Witzenberg Municipality

WATER RESEARCH COMMISSION

EMANTI Water & Environmental Engineering Services

OBSERVATIONS OF CURRENT WSP

WATER SAFETY PLAN REVIEW FOR WITZENBERG: TULBAGH WTW	
Developed By	**Witzenberg Municipality based on WSP prepared by Chris Swartz Water Utilization Engineers**
Module 1: **Assemble the WSP Team**	WSP observations 1. WSP team in place however it does not contain all required members 2. WSP team member roles need to be more clearly defined Recommendations 1. Need to additional team members such as: Decision makers, National departments (DWS, Dept. of health) Human Resources, Finance department, Laboratories, water service providers, Disaster Risk Reduction specialists, locals, other key role players (Refer to Module 1 for additional information below) 2. Outline each members role clearly and their level of participation (permanent or ad-hoc)
Module 2: **Describe your water supply system**	WSP Observations 1. System is adequately described in the WSP and includes information on planned upgrades 2. Location information is provided for reservoirs, pump stations, pressure towers, etc. 3. Flow diagrams have been included Recommendations 1. Include an aerial photo of the works 2. Update the system description to include climate related information (refer to Module 2 below for more information): • Rainfall data and forecasting/predictions (at least 30-year historical period) • Temperature data and forecasting/predictions • Water demand analysis and reporting • Drought considerations – availability of water and period of availability • Changes in areas affected by climate related threats/impacts (Flood lines). Historical information: areas prone to/affected by floods and droughts – frequency of such events • Groundwater levels (yields), River flows / Dam levels • Surface and groundwater quality • Understanding the Resource Quality Objectives (RQOs) and EWR (Ecological Water Requirements) set by DWS and the implications thereof • Precipitation data • Evaporation data • Ecological infrastructure and their status • Spatial / land use information • Abstraction volumes / discharge volumes

Module 3: **Identify Hazards and Hazardous Events and Assess the Risks**	WSP observations 1. Hazards and hazardous events identified from catchment to consumer 2. Highly Comprehensive risk register covering the source area, the treatment area and the distribution network 3. Risk assessment done using a 5x5 risk matrix 4. Control measures are identified for each risk Recommendations 1. Need to include additional risks as not all risks included such as OHS risks, and internal departmental risks, financial risks (refer to Module 3 and 4 below for more information) 2. Update the Risk matrix to include climate related hazards and hazardous events (refer to Module 3 and 4 below for more information)
Module 4: **Determine and Validate Control Measures, Reassess and Prioritize the Risks**	WSP observations 1. Control measures available for all 'Valid Hazards' 2. Risks not reassessed after control measures were identified and no additional actions were provided Recommendations 1. Need to provide additional actions where and as required 2. Hazards and hazardous events should be classified, and control measures should be developed all hazards and hazardous events including the 'non-valid hazards'. This should be done even if the likelihood and consequence is low. 3. Update the control measures to account for the impact of climate change on the system, and add new control measures where required (refer to Module 3 and 4 below for more information)
Module 5: **Develop, Implement and Maintain an Improvement / Upgrade Plan**	WSP observations 1. Improvement plan provided and contains the responsible person and time frames 2. Budget not included Recommendations 1. Improvement plan needs to be updated annually to account for newly identified hazards and hazardous events 2. Risks should be adequately prioritized. WTW should consider implementing control measures with low-cost high reward as well as implementing short term control measures while the funds become available for long term control measures. 3. Reprioritize risks and consider the impact of climate change on the system 4. Noting the climate change additions the WSP team need to consider the short to medium to long term plans to address climate trends and forecasts
Module 6: **Define Monitoring of the Control Measures**	WSP observations 1. Parameters measured as per SANS 241 at various points within the treatment works and within the distribution network Recommendations 1. With Climate Resilient monitoring one needs to reflect on the data which is available to assist in this process

Module 7: **Verify the Effectiveness of the WSP**	WSP observations 1. Operational and compliance monitoring in place according to SANS 241 2. Monitoring schedules per parameter at various points provided Recommendations 1. The effectiveness of the WSP must be verified and consider the impact of climate change
Module 8: **Prepare Management Procedures**	WSP observations 1. Alert levels provided 2. Names of responsible person not provided. Only contact number of responsible institutions 3. Examples when incidents are provided per alert level Recommendations **1.** The impact of COVID-19 has warranted alternate thinking and innovation to ensure operations continue in these difficult times. One needs to amend management procedures to consider such future impacts **2.** 2. This also applies to the Climate change aspects which also needs to be included when updating the WSP going forward
Module 9: **Develop Supporting Programmes**	WSP observations 1. These are discussed but no plan has been presented within the WSP 2. The WSP indicates that supporting programmes need to be developed at various levels including HR, Catchment and Drinking water supply Recommendations 1. Supporting programmes need to be developed to consider the impact of COVID-19 or similar. 2. Supporting programmes need to be developed to train process controllers to understand the effects of climate change and how to manage risks that are as a result of climate change
Module 10/11: **Plan and Carry Out Periodic Review of the WSP / Revise the WSP following an Incident**	WSP Observations 1. WSP review almost annually 2. Most recent review done in 2020 Recommendations 6. No Recommendations required as the municipality already follows best practice related to these modules

MODULE 1: CLIMATE RESILIENT TEAM ASSEMBLE

A typical water safety plan team consists of key internal and external stakeholders for a particular water supply system. Therefore, a team includes people with the following characteristics:

- Water supply system knowledge (catchment to consumer)
- Authority to make decisions (e.g. allocating human and financial resources, approving system changes)
- Responsibility for, and capacity to, help manage and prevent risks
- Adequate expertise to support the identification & management of all risks within the water supply system

Witzenberg required typical WSP team members

- Technical Director
- Water Engineers and Technicians
- Water Network and Distribution personnel
- Water Works Superintendents and Senior Process Controllers
- Human Resources Departments
- Financial Department
- Catchment Management
- Water Monitoring and Laboratories (if in-house)
- National Departments (DWS, DEA, etc.)
- Public Health specialists
- Disaster reduction specialists
- Local people with a knowledge of the local climate and climate threats
- Managers, ward leaders and decision makers
- Water utility personnel with knowledge of drinking water related issues
- Water utility personnel with knowledge of natural water resources
- Experts on disaster and risk reduction and identification
- Other key role players

Climate Resilient Water Safety Plan Team make-up

In terms of climate resilience, the WSP team should include sector professionals that understand:

- climate information
- water system knowledge
- authority figures and supporting members

Witzenberg identified the following additional team members that would assist with enhancing climate resilience

- Hydrologist to understand local level hydrology
- Geologist to understand type of geological material
- Climate scientist from SAWS to assist with climate data analysis for climate forecasting and projections
- Witzenberg Environmental department, and
- Tulbagh water association.

MODULE 2: CLIMATE SUMMARY DESCRIPTION

CLIMATE PROJECTIONS

Under *RCP4.5 temperatures are expected to increase by 1.67-2.26°C 2050 but are expected to remain below 3°C (Figure 1b). Under **RCP8.5 temperatures are expected to increase by 2.19-2.69°C, however by 2100 temperatures are expected to increase by 2-4°C. The number of extreme hot/dry days are expected to increase (Figure 1c)

Under both climate scenarios rainfall is projected to decrease well out of range of present-day climate variability (Figure 2b). *RCP 45 scenario projects rainfall will decrease by as much as 136.74mm/yr. **RCP 85 scenario indicates that rainfall will decrease by as much as 193.74mm/yr. Extreme rainfall days is expected to increase (Figure 2c)

KEY WATER SERVICES BUSINESS IMPACTS

COVID 19 Impacts

COVID-19 and the associated lockdown restrictions have resulted in delays in repairs and refurbishment of infrastructure.

Vandalism

High incidents of vandalism occurring in the area which has an impact financially for the municipality.

Operations

Water treatment plant not operating at full capacity and one storage reservoir is available.

OVERVIEW OF THE AREA

Witzenberg Local Municipality is located in the Western Cape Province, and forms part of the Cape Winelands District. According to the Köppen-Geiger climate classification most of Witzenberg experiences Mediterranean climate. Witzenberg experiences with hot dry summers, and cool wet winters. Typical Climate related hazards for Witzenberg include droughts, fires and floods. The water system of focus is for the Tulbagh area. There are three main sources of water for the area mainly Klein Berg, Moordenaarskloof and Tierkloof. During the site visits it was noted that though the area typically does not experience severe droughts, the system is only designed to store enough water for 6-months. The system is highly dependent on the on-time arrival of annual winter precipitation, for the continued supply of water during and after the winter season.

Tulbagh currently has plans in place to improve water security in the future with the construction of a dam.

CLIMATE SUMMARY

Historical Climate

Temperatures in the province indicate an increasing trend for the Western Cape Province (Figure 1a). Increases over the past decade indicate an increase of about 1°C trend in ocean currents also indicate an increase with the Agulhas current temperature having increased by 1.5°C since 1980. Rainfall data for the Western Cape indicate a decrease in the number of rainfall days and that the rainy season is starting later each year (Figure 2a).

Implications of the above is that there is increased risk of insufficient water availability for consumption, i.e. when the storage dam has dried out for the year.

Future Climate

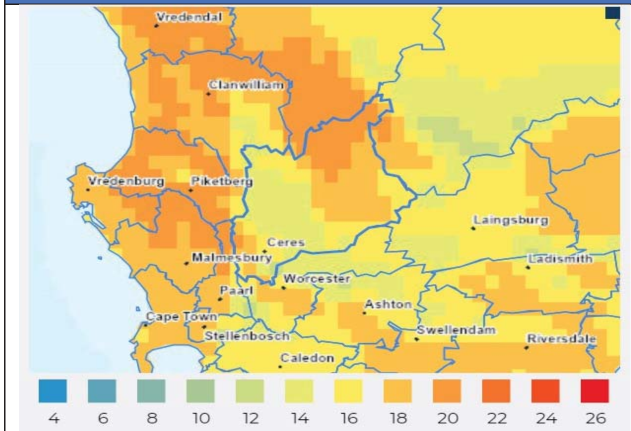
Under the RCP 45 scenario temperature is expected to increase between 1.67 and 2.26°C. Whereas under the RCP 85 scenario temperature is expected to increase between 2.19°C and 2.69°C. Under both RCP 45 and RCP 85 scenarios rainfall is projected to decrease. These changes are expected to be well out of range of present-day climate variability.

The major implication of the above is there will be decreased water availability during the season. Other implications include the increased occurrence of fires.

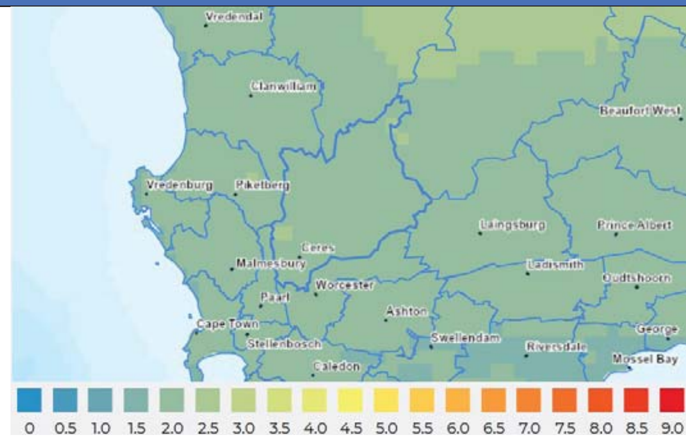
*RCP4.5 represents a scenario whereby Greenhouse emissions have stabilized before 2100.
**RCP8.5 represents a scenario whereby greenhouse gas emissions continue to increase over time, and results in high concentrations of atmospheric greenhouse gases.
(Chaturvedi et al., 2012)

WITZENBERG MUNICIPALITY CLIMATE STATUS

a) AVERAGE TEMPERATURE (°C)



b) AVERAGE PROJECTED TEMP (°C) INCREASE 2050



c) VERY HOT DAYS (2050)

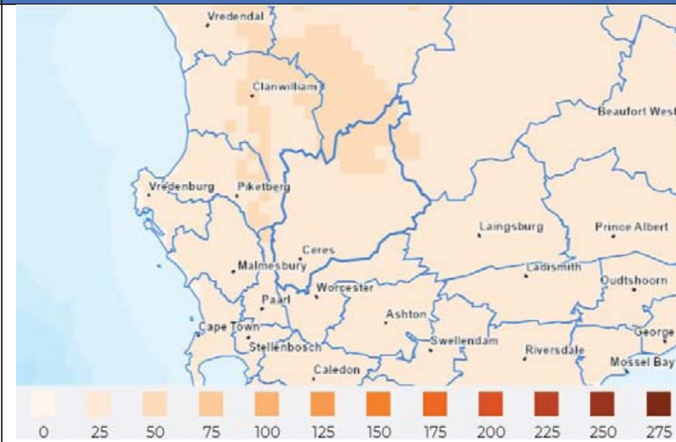
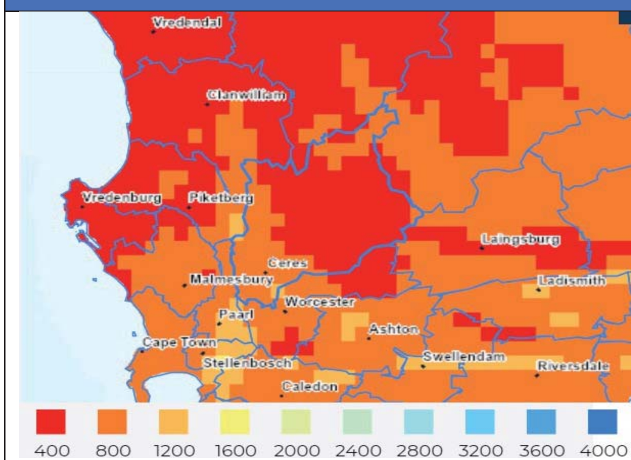
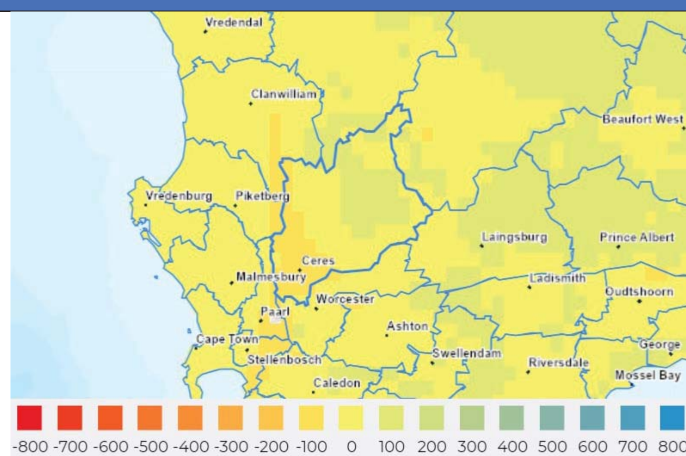


Figure 1: Witzenberg Municipality a) current average temperatures b) average projected temperatures c) projected very hot days (greenbook.co.za)

a) AVERAGE RAINFALL (mm)



b) AVG PROJ CHANGE IN RAINFALL (mm) 2050



c) EXTREME RAINFALL DAYS

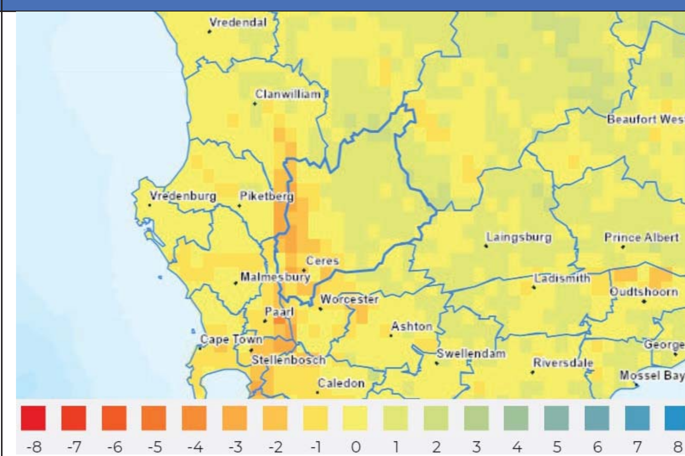


Figure 2: Witzenberg Municipality a) current average rainfall b) average projected rainfall c) projected extreme rainfall days (greenbook.co.za)

The following table provides you with observations from the site visits and review of material as to possible climate risks at your source, treatment and distribution. It is important that when updating the WSP going forward that you review the risks and recommended control measures. Thereafter, complete the validation and assess the effectiveness of the control measures and determine associated residual risk.

	Severity				
Likelihood	Insignificant 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
Almost Certain 5	5	10	15	20	25
Likely 4	4	8	12	16	20
Moderate 3	3	6	9	12	15
Unlikely 2	2	4	6	8	10
Rare 1	1	2	3	4	5

Score	**Risk profile**	
0-10	Low	These systems operate with minor deficiencies. Usually the systems met the water quality parameters specified by the appropriate guidelines (SANS 241)
11-20	Moderate	These are system with deficiencies which individually or combined pose a high risk to the quality of water and human health. These systems would not generally require immediate action, but the deficiencies could be more easily to avoid future problems.
21-25	High	These are systems with major deficiencies which individually or combined pose a high risk to the quality of water and may lead to potential health and safety or environmental concerns. Once systems are classified under this category, immediate corrective action is required to minimise or eliminate deficiencies.

Climate resilient risk observations							
Process Step	**Hazardous Event**	**Hazard Type**	**Likelihood**	**Consequence**	**Risk score**	**Risk level**	**Suggested control measure**
Source	Source water storage only has 6-month supply capacity	Physical	3	5	15	M	Witzenberg Municipality currently has a plan in place to build a dam to improve water security in Tulbagh
Source	Lower water quality into the treatment works due to the occurrence of fires	Chemical	2	3	6	L	Develop fire management plan, and have firebreaks at vulnerable points within the source area
Source	Decrease in rainfall resulting in reduced water availability, storage quantity and quality in both surface water and groundwater	Physical	1	5	5	L	Witzenberg Municipality currently has a plan in place to build a dam to improve water security in Tulbagh. Develop additional water resources such as groundwater, to improve the water mix
Source	Infrastructure damage to pipelines at the source due to high rainfall	Physical	2	4	8	L	Stabilize areas prone to erosion through the planting of vegetation
Source	Decrease in water availability due to reduced rainfall	Physical	3	5	15	M	Witzenberg Municipality currently has plans in place to build a dam to improve water security in Tulbagh
Source	Increased turbidity in source water due to high wind speeds	Chemical	3	3	9	L	Increase settling times of raw water before entering the treatment works
Source	Increased pollution at the source waters due to dumping at the source/catchment area	Physical	3	4	12	M	Improve security/fencing around the source/catchment area
Source	Operational health and safety risk due to wild animals (snakes and baboons) in the source/catchment area	Physical	3	5	15	M	Train staff on how operational health and safety methods when encountering wild animals
Source	Contamination of source waters due to illegal dumping of chemical waste	chemical	3	5	15	M	Improve security around the source waters, and restrict access to source water areas

Source	Contamination of source water in the storage dam due to locals swimming in the dam	Chemical, Microbiological	2	5	10	L	Improve security around the storage dam, and restrict access to source water areas
Treatment works	Algal and cyanobacterial growth in sand filters due to increased temperatures	Microbiological	3	4	12	M	Increase the frequency of filter cleaning
Treatment works	Infrastructure damage due to increase in extreme rainfall days	Physical, Chemical	3	4	12	M	Reduce flows into the works during periods of extreme rainfall
Treatment works	Operational health and safety risk due to wild animals (snakes) entering the WTW	Physical	3	5	15	M	Train staff on how operational health and safety methods when encountering wild animals
Treatment works	Decreased surface water and groundwater quality due to decreased rainfall	chemical	2	4	8	L	Upgrade WTW to be able to treat raw water of a lower water quality
Treatment works	Flooding of access roads leading to water treatment works due to increase in extreme rainfall days	Physical	2	4	8	L	Improve drainage system of access roads to draw off flood waters
Reservoirs	Algal and cyanobacterial growth in reservoirs due to increased temperatures	Microbiological	3	4	12	M	Introduce temperature control in reservoirs
Reservoirs	Infrastructure damage to reservoirs due to extreme rainfall	Physical	3	3	9	L	Introduce runoff features on the reservoir roof

CONCLUSIONS

A review of the Witzenberg Municipality Water Safety Plan for the Tulbagh area indicates a comprehensive and well-developed plan. The municipality has shown commitment to the WSP process through the regular updating of the WSP. Though the risk register does not capture climate related threats, the municipality has drafted some plans to address climate issues. By way of example, the municipality has identified droughts as an issue, and subsequently developed a Drought Management Plan.

However, it is noted that some action is required for the WSP to consider climate resilience aspects including:

- Updating the WSP Team to include the additional members identified that can assist with analysis and interpretation of climate related data/information. These members should also be able to recommend solutions to abate climate related threats.
- Update the system description to include an understanding of the current and projected climate of the area. Include the parts of the system that will be affected by climate threats.
- Include additional risks in the risk register related to Finance, OHS, departmental risks, etc.
- Include climate related hazards and hazardous events in the risk register.
- Develop control measures to address climate impacts. Control measures should be applicable in both the short and the long-term.
- Prioritise climate risks.

Integrating climate information into the water safety plan and wastewater risk abatement plan

Witzenberg Municipality

WATER RESEARCH COMMISSION

EMANTI Water & Environmental Engineering Services

GENERAL OBSERVATIONS OF CURRENT W_2RAP

WASTEWATER RISK ABATEMENT PLAN REVIEW FOR WITZENBERG: CERES WWTW	
Developed By	**Witzenberg Municipality**
Step 1: **Assemble a team to develop the W_2RAP**	W_2RAP observations 1. W_2RAP team is in place, however it does not include all members (such as decision makers, DWS representatives, other stakeholders). 2. Roles within the W_2RAP team is not clearly outlined, need to refer to W_2RAP guideline for information on additional members Recommendations **1.** Need to additional team members such as: Decision makers, National departments (DWS, Dept. of health) Human resources, Finance department, Laboratories, water service providers, Disaster Risk Reductions specialists, locals, other key role players **2.** Outline each member's role clearly and their level of participation (permanent or ad-hoc)
Step 2: **Document and describe the system**	W_2RAP observations 1. System is adequately described 2. Flow of wastewater is described from the sewers to the outlet 3. PFD included however it does not have CCP, pump stations or sampling points. Liquid and solid streams are not presented on the PFD. 4. Not all pump stations have not been added to the PFD, only the pump station on site. Recommendations 1. Include all network pump stations to the PFD 2. Include typical inflow Volumes from residential and industrial 3. Include CCP on the PFD 4. Update system description to discuss pump stations and CCPs
Step 3: **Assess the existing or proposed system**	W_2RAP Observations 1. This is not covered in the W_2RAP Recommendations 1. This section needs to be included in the W_2RAP
Step 4: **Hazard assessment and risk characterisation**	W_2RAP observations 1. Hazard and hazardous event risks scores are calculated using a 5x5 risk matrix 2. Hazards are not characterized as either microbial, chemical, or physical. Only hazardous events are described. 3. Hazardous event per process unit Recommendations

	1. Include the Hazard description as either microbial, chemical, or physical 2. Need to include additional risks as not all risks included such as OHS risks, and internal departmental risks, financial risks (refer to Module 3 and 4 below for more information) 3. Update the Risk matrix to include climate related hazards and hazardous events (refer to Module 4 and 5 below for more information)
Step 5: **Identify hazards, control measures and preventative actions/validation**	W_2RAP observations 1. Highly comprehensive hazardous event and risk register 2. Control measures in place for various risks 3. Update on the implementation of control measures is provided for the most recent revision of the W_2RAP Recommendations 1. Hazards and hazardous events should be classified, and control measures should be developed all hazards and hazardous events including the 'non-valid hazards'. This should be done even if the likelihood and consequence is low. 2. Update the control measures to account for the impact of climate change on the system, and add new control measures where required (refer to Module 5 and 6 below for more information)
Step 6: **Operational monitoring and maintaining control**	W_2RAP observations 1. Special standard applied to receiving catchment (WULA) 2. Operating on General limits, however new license application has been submitted to DWS 3. Under responsible person only a job description is provided, no name is given. Recommendations 1. With Climate Resilient monitoring one needs to reflect on the data which is available to assist in this process 2. Improvement plan needs to be updated annually to account for newly identified hazards and hazardous events 3. Risks should be adequately prioritized. WWTW should consider implementing control measures with low-cost high reward as well as implementing short term control measures while the funds become available for long term control measures. 4. Reprioritize risks and consider the impact of climate change on the system **5.** Noting the climate change additions the WSP team need to consider the short to medium to long term plans to address climate trends and forecasts

Step 7: **Verification that the W_2RAP is effective and meets health- and environmental-based targets**	W_2RAP Observations 1. Control measures are effective as compliance results indicate very good compliance on all parameters. However, the 2014/2015 FY Green Drop was not achieved based on compliance data Recommendations 1. The effectiveness of the WSP must be verified and consider the impact of climate change
Step 8: **Management procedures for wastewater systems**	W_2RAP Observations 1. Alert levels provided with relevant contact persons information. 2. Examples of management procedures are provided Recommendations 1. The impact of COVID-19 has warranted alternate thinking and innovation to ensure operations continue in these difficult times. One needs to amend management procedures to consider such future impacts **2.** This also applies to the Climate change aspects which also needs to be included when updating the WSP going forward 3. Supporting programmes need to be developed to consider the impact of COVID-19 or similar. **4.** Supporting programmes need to be developed to train process controllers to understand the effects of climate change and how to manage risks that are as a result of climate change
Step 9: **Documentation and communication**	W_2RAP observations 1. No indication of how documentation of monitoring is captured/logged. Recommendations 1. Improve documentation and record keeping procedures 2. Develop and SOP for documentation and record keeping procedures
Step 10: **Review of W_2RAP**	W_2RAP observations 1. W_2RAP has gone through various reviews, however these are not always done annually. The latest review was done in December 2019, i.e. up to date W_2RAP Recommendations **1.** No Recommendations required as the municipality already follows best practice related to these modules

STEP 1: CLIMATE RESILIENT TEAM ASSEMBLE

A typical wastewater risk abatement plan team consists of key internal and external stakeholders for a particular wastewater treatment system. Therefore, a team includes people with the following characteristics:

- Wastewater system knowledge (catchment to consumer)
- Authority to make decisions (e.g. allocating human and financial resources, approving system changes)
- Responsibility for, and capacity to, help manage and prevent risks
- Adequate expertise to support the identification & management of all risks within the wastewater system

Witzenberg required typical WSP team members

- Technical Director
- Water Engineers and Technicians
- Water Network and Distribution personnel
- Water Works Superintendents and Senior Process Controllers
- Human Resources Departments
- Financial Department
- Catchment Management
- Water Monitoring and Laboratories (if in-house)
- National Departments (DWS, DEA, etc.)
- Public Health specialists
- Disaster reduction specialists
- Local people with a knowledge of the local climate and climate threats
- Managers, ward leaders and decision makers
- Water utility personnel with knowledge of drinking water related issues
- Water utility personnel with knowledge of natural water resources
- Experts on disaster and risk reduction and identification
- Other key role players

Climate Resilient Water Safety Plan Team make-up

In terms of climate resilience, the WSP team should include sector professionals that understand

- climate information
- water system knowledge
- authority figures and supporting members

Witzenberg identified the following members as to assist with climate resilience

- Hydrologist to understand local level hydrology
- Geologist to understand type of geological material
- Climate scientist from SAWS to assist with climate data analysis for climate forecasting and projections
- Witzenberg Environmental department, and
- Tulbagh water association.

STEP 2: CLIMATE SUMMARY DESCRIPTION

CLIMATE PROJECTIONS

Under *RCP 45 temperatures are expected to increase by 1.67-2.26°C 2050 but are expected to remain below 3°C (Figure 1b). Under **RCP 85 temperatures are expected to increase by 2.19-2.69°C, however by 2100 temperatures are expected to increase by 2-4°C. The number of extreme hot/dry days are expected to increase (Figure 1c)

Under both climate scenarios rainfall is projected to decrease well out of range of present-day climate variability (Figure 2b). * RCP 45 scenario projects rainfall will decrease by as much as 136.74mm/yr. **RCP 85 scenario indicates that rainfall will decrease by as much as 193.74mm/yr. Extreme rainfall days is expected to increase (Figure 2c)

KEY WATER SERVICES BUSINESS IMPACTS

COVID 19 Impacts

COVID-19 and the associated lockdown restrictions have resulted in delays in repairs and refurbishment of infrastructure.

Vandalism

High incidents of vandalism occurring in the area which has an impact financially for the municipality.

Operations

Wastewater treatment plant has delayed maintenance schedules as a result of COVID-19.

OVERVIEW OF THE AREA

Witzenberg Local Municipality is located in the Western Cape Province, and forms part of the Cape Winelands District. According to the Köppen-Geiger climate classification most of Witzenberg experiences Mediterranean climate. Witzenberg experiences with hot dry summers, and cool wet winters. Typical Climate related hazards for Witzenberg include droughts, fires and floods. The water system of focus is for the Tulbagh area. The wastewater treatment works treats both domestic wastewater and industrial wastewater

CLIMATE SUMMARY

Historical Climate

Temperatures in the province indicate an increasing trend for the Western Cape Province (Figure 1a). Increases over the past decade indicate an increase of about 1°C trend in ocean currents also indicate an increase with the Agulhas current temperature having increased by 1.5°C since 1980. Rainfall data for the Western Cape indicate a decrease in the number of rainfall days and that the rainy season is starting later each year (Figure 2a).

Implications of the above is that there is increased risk of insufficient water availability for consumption, i.e. when the storage dam has dried out for the year.

Future Climate

Under the RCP 45 scenario temperature is expected to increase between 1.67 °C and 2.26°C. Whereas under the RCP 85 scenario temperature is expected to increase between 2.19°C and 2.69°C. Under both *RCP 45 and **RCP 85 scenarios rainfall is projected to decrease. These changes are expected to be well out of range of present-day climate variability.

The major implication of the above is there will be decreased water availability during the season. Other implications include the increased occurrence of fires.

*RCP4.5 represents a scenario whereby Greenhouse emissions have stabilized before 2100.
**RCP8.5 represents a scenario whereby greenhouse gas emissions continue to increase over time, and results in high concentrations of atmospheric greenhouse gases.
(Chaturvedi et al., 2012)

WITZENBERG MUNICIPALITY CLIMATE STATUS

a) AVERAGE TEMPERATURE (°C) | **b) AVERAGE PROJECTED TEMP (°C) INCREASE 2050** | **c) VERY HOT DAYS (2050)**

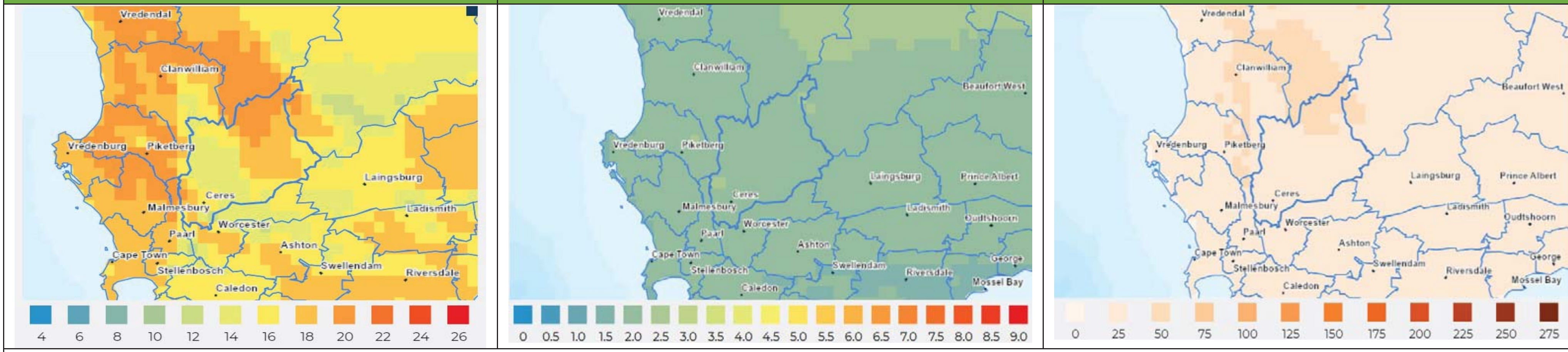


Figure 1: Witzenberg Municipality a) current average temperatures b) average projected temperatures c) projected very hot days (greenbook.co.za)

a) AVERAGE RAINFALL (mm) | **b) AVG PROJ. CHANGE IN RAINFALL (mm) 2050** | **c) EXTREME RAINFALL DAYS (2050)**

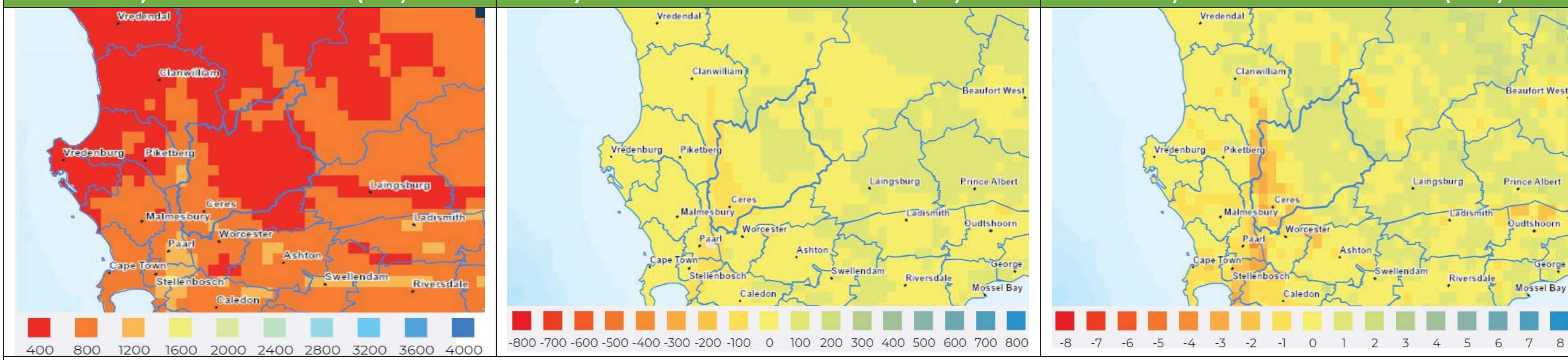


Figure 2: Witzenberg Municipality a) current average rainfall b) average projected rainfall c) projected extreme rainfall days (greenbook.co.za)

STEP 4/5: IDENTIFICATION OF CLIMATE HAZARD & HAZARDOUS EVENTS/DETERMINATION & VALIDATE CONTROL MEASURES, ASSESS & PRIORITISE RISK

The following table provides you with observations from the site visits and review of material as to possible climate risks at your pump stations, wastewater treatment, catchment and network. It is important that when updating the W_2RAP going forward that you review the risks and recommended control measures. Thereafter, complete the validation and assess effectiveness of the control measure and residual risk.

	Severity				
Likelihood	Insignificant 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
Almost Certain 5	5	10	15	20	25
Likely 4	4	8	12	16	20
Moderate 3	3	6	9	12	15
Unlikely 2	2	4	6	8	10
Rare 1	1	2	3	4	5

Score	**Risk profile**	
0-10	Low	These are systems that operate with minor deficiency and usually meet the effluent quality specifications set by the Department of Water Affairs. It is unlikely that this level of risk is harmful to the health of people and the environment. Aesthetically and/or physical non-compliance can be expected for short periods.
11-20	Moderate	These are systems with deficiencies which individually or combined pose a moderate risk to the quality of the receiving environment and health. These systems would not generally require immediate action but the deficiencies should be rectified to avoid future problems and associated cost to rectify once in HIGH risk. Aesthetically and/or physically non-compliance can be expected over a medium term. Medium term impact on infrastructure and partial failure of the wastewater treatment plant and disinfection process is likely.
21-25	High	These are systems with deficiencies which individually or combined pose a high risk to the quality of the receiving environment and health, and may lead to potential health, safety and environmental concerns. Once a system (or part of a system) is classified under this category, immediate corrective action is required to arrest or eliminate the deficiency. High impact on the health of people and the environment and/or significant damage to infrastructure can be expected. Total failure of the collector, treatment and disinfection facility is likely.

Climate resilient risk observations							
Process Step	**Hazardous Event**	**Hazard Type**	**Likelihood**	**Consequence**	**Risk score**	**Risk level**	**Suggested control measure**
Pump Stations	Infrastructure damage to pump stations due to extreme rainfall resulting in pump stations becoming flooded	Physical	2	4	8	L	Upgrade pump stations to handle larger capacity of flow
Pumps stations	Damage to pump station infrastructure due to flooding of maturation ponds	Physical	23	4	12	M	The pump station that is likely to be affected is currently being refurbished. However, may need to implement flood prevention measures such as building a retention wall.
Pump stations	Damage to pump station infrastructure due to fires	Physical	2	4	8	L	Create fire breaks around pump station infrastructure
Pump station	Damage to pump station due to vandalism and theft	Physical	3	4	12	M	Improve the building conditions at the affected pump stations, improve fencing, improve deterring methods such as pepper spray

Pump stations	Overloading of pump stations because of stormwater ingress under to extreme rainfall conditions	Physical	3	4	12	M	Upgrade pump stations to handle larger capacity of flow
Pump stations	Failure of pump stations because of overheating due to increased temperatures	Physical	3	4	12	M	Upgrade/install pumps that can operate at higher temperatures
Pump Stations	Chlorine gas leaks due to incorrect chlorine storage methods	Physical	3	5	15	M	Improve chlorine storage conditions at the pump station by ensuring chlorine is properly isolated/ locked up
WWTW	Overflowing of WWTW under extreme rainfall conditions	Physical	3	4	12	M	Install flow reduction measures such as a balancing dam at the WWTW
WWTW	Grit enters the aeration basin due to no degritting process taking place	Physical	5	3	15	M	Install degritters

WWTW	Failure of aerators because of overheating due to increased temperatures	Physical	3	4	12	M	Upgrade/ install aerators that can operate at higher temperatures
WWTW	Animals accessing the WWTW due to poor fencing conditions	Physical	3	3	9	L	Install higher fencing around the WWTW
WWTW	WWTW treatment works becomes inundated under extreme rainfall conditions	Physical	3	4	12	M	Improve stormwater drainage at the WWTW
WWTW	Flooding of access roads leading to wastewater treatment works due to increase in extreme rainfall days	Physical	3	4	12	M	Improve access road stormwater drainage systems
WWTW	Reduced chlorine contact time due to high temperatures resulting in evaporation of chlorine	Chemical	3	5	15	M	Develop a plan to increase chlorine dosage under higher temperatures

WWTW	Nearby residents get sick due poorly treated sludge being blown by wind	Physical	23	5	15	M	Relocate residence living in informal settlements on the WWTW property
WWTW	Flooding of sludge lagoons under extreme rainfall events	Microbial	3	5	15	M	Install retention walls around sludge lagoons and move informal settlement away from sludge lagoons
WWTW	Contamination of groundwater due to incorrect disposal of sludge(stockpiled)	Microbial	4	5	20	M	Dispose of sludge according to WRC guidelines
WWTW	Animals and people can access the maturation ponds due to poor fencing conditions	Microbial	3	4	12	M	Improve fencing and security around the maturation ponds
WWTW	Chlorine failure due to incorrect sampling point	Chemical	5	4	20	M	Chlorine sampling point should be located at the end of the contact channel

Catchment	Reduced dilution of final effluent because of decreased water availability in the catchment waters due to drought	Physical, Chemical	2	5	10	L	Improve treatment processes and change license conditions to account for periods when catchment flows are low and cannot adequately dilute final effluent
Catchment	Catchment waters become contaminated due to leaching of contaminants into catchment waters due to reduced rainfall (drought)	Chemical	2	5	10	L	Change license conditions to account for periods when catchment flows are low and leaching occurs
Catchment	WULA not yet approved by DWS the original application was submitted in 2009	Physical	5	4	20	M	The municipality needs to follow up with DWS on the approval of their WULA
Network	Stormwater ingress into network due to high extreme rainfall	Physical	2	4	8	L	Ensure routine checks are done and upgrade those points that are likely to be affected by stormwater ingress
Network	Network infrastructure damage because of stormwater ingress due to extreme rainfall	Physical	2	4	8	L	Perform routine maintenance checks, upgrade areas that are prone to overflowing and damage

Network	Network blockages because of excess debris entering the system under extreme rainfall	Physical	3	3	9	L	Identify points prone to blockages and do daily checks during the rainy season

CONCLUSIONS

A review of the Witzenberg Municipality Wastewater Risk Abatement Plan for the Ceres area indicates a comprehensive very well-developed plan. The municipality has shown commitment to the W_2RAP process through the regular updating of the W_2RAP. Though the risk register does not capture climate related threats, the municipality has drafted some plans to tackle climate issues. By way of example the municipality has identified droughts as an issue, and subsequently developed a drought management plan.

However, it is noted that some action is required for the W_2RAP to consider climate resilience aspects including:

- Updating the W_2RAP Team to include the additional members identified that can assist with analysis and interpretation of climate related data/information. These members should also be able to recommend solutions to abate climate related threats.
- Update the system description to understand the current climate of the area and the projected climate. Include the parts of the system that will be affected by climate threats.
- Include additional risks in the risk register related to Finance, OHS, departmental risks, etc.
- Include climate related hazards and hazardous events in the risk register.
- Develop control measures to address climate impacts. Control measures should be applicable in both the short and the long term.
- Prioritise climate risks.

Integrating climate information into the water safety plan and wastewater risk abatement plan

Uthukela District Municipality

WATER RESEARCH COMMISSION

EMANTI
Water & Environmental Engineering Services

General observations of current WSP

UTHUKELA: LADYSMITH WATER SUPPLY SCHEME	
Developed By	**Talbot & Talbot (Review)**
Module 1: **Assemble the WSP Team**	1. Insufficient involvement of WSP Steering Committee 2. No formalized WSP process in place, only drafted document. Limited buy-in from Water officials 3. WSP is applicable to uThukela DM, and not specific to Ladysmith Water Treatment Works (WTW) 4. WSP team does not include all required members. Additional members such as lab personnel, catchment management, HR depts, Finance depts, etc. to be included 5. Team member roles are not clearly defined 6. No Climate Resilient members considered 7. It must be noted that the WSP is four years old, and a review was conducted in 2016 as well. The WSP will require a complete rework to address current risk management and control measures that have been implemented since the last update Recommendations: 1. The municipality has an opportunity now to update the current WSP taking into account the Climate Resilient requirements. This will be applicable to all modules of the WSP 2. The additional members in terms of Climate Change (as described in Module 1 below) will need to be explored and implemented before the updating process is to begin. Start with a small selection of climate specialists and broaden out as the need arises for further input
Module 2: **Describe your water supply system**	1. Sites not thoroughly evaluated 2. System inadequately described as assessed 3. Population information available but based on outdated information 4. Location of the works not adequately provided (location on a map, GPS coordinates, etc.) Recommendations 1. As some time has passed since the update of the WSP the requirements for the describing and assessing of the system will be important to assist in the risk identification 2. Additionally one would also want to consider including some of the following Climate aspects. • Rainfall data and forecasting/predictions (at least 30-year historical period) • Temperature data and forecasting/predictions • Water demand analysis and reporting • Drought considerations – availability of water and period of availability • Changes in areas affected by climate related threats/impacts (Flood lines). Historical information: areas prone to/affected by floods and droughts – frequency of such events • Groundwater levels (yields), River flows / Dam levels • Surface and groundwater quality • Understanding the Resource Quality Objectives (RQOs) and EWR (Ecological Water Requirements) set by DWS and the implications thereof

<table>
<tr><td></td><td>

Precipitation data
Evaporation data
Ecological infrastructure and their status
Spatial / land use information
Abstraction volumes / discharge volumes

3. Update and refine Climate Summaries and forecasting for inclusion into the WSP</td></tr>
<tr><td>Module 3:
Identify Hazards and Hazardous Events and Assess the Risks</td><td>

Mostly global risks, i.e. risk register not specific to Ladysmith WTW
Not all Risks have been captured, i.e. Minimal internal departmental risks, OHS risks, Lab risks, etc.
Comprehensive hazard and hazardous event risk register
No climate/weather related risks captured in the risk register (i.e. impact of high or low rainfalls on water supply, infrastructure, etc.)

Recommendations
1. It is advisable that a separate section of risk identification process with regards the Climate Impacts to identify hazards and hazardous events and assess the risks is accommodated for within this module. Be sure to focus on the water value chain from catchment to consumer.
2. Some area highlighted during the workshop included

Focus on areas that are prone to floods and droughts (current and future). Risks to water sources/abstraction points, bulk conveyance, treatment, reservoirs, pump stations and end users
Significant temperature fluctuations – area does extreme very high temperature in summer months)
Impaired water quality (less rainfall) – compounded if WWTW is discharging poor quality effluent.
Increased rainfall – can lead to increased flows – reduces capacity of infrastructure to cope with events – resulting in overflows / flooding, infrastructure and equipment can be compromised/damaged
Increased rainfall – erosion – can exposed infrastructure (e.g. pipelines), increased litter/debris washed into rivers – make create blockages at abstraction points and/or also blocked pipes.
</td></tr>
<tr><td>Module 4:
Determine and Validate Control Measures, Reassess and Prioritize the Risks</td><td>
1. Control measure are outdated and generic and not applicable the current risk
2. Positions not actual designated officials were captured for responsible action
3. Validation was not in place and control measure effectiveness could not be assessed
4. Re-assessment of risks also not undertaken
Recommendations
1. The current situation is that a Service Provider is to be appointed to implement Preventative Maintenance plan on all WTWs, and Pump stations. An unsolicited bid advertised as from the 10th of September 2020
2. In addition, a Business Plan has been developed based on the directives received from the Department of Water and Sanitation (DWS)
3. Noting the above and the need to update the entire WSP with these validations need to be incorporated and monitored within the WSP process.
4. An associated control measure identification needs to be undertaken with the risk identified in Module 3 above</td></tr>
</table>

Module 5: **Develop, Implement and Maintain an Improvement / Upgrade Plan**	1. No improvement plan was captured within the outdated WSP Recommendations 1. The municipality has established and Blue and Green Drop Steering Committee which focuses on improvement planning against the Blue and Green Drop Criteria. This valuable process must be incorporated into the updating of the WSP 2. Process Audits need also to be updated and findings and recommendations also incorporated into the updating of the WSP 3. The improvement plans need to be monitored and aligned to changing budget priorities 4. Noting the climate change additions the WSP team need to consider the short to medium to long term plans to address climate trends and forecasts
Module 6: **Define Monitoring of the Control Measures**	1. Operational Monitoring: monitoring is inconsistent and has been negatively impacted by COVID-19 2. Compliance monitoring: this has also been adapted to adhere to the COVID-19 regulations and although providing data to IRIS this has been a challenge for the municipality 3. On the 26th of July 2019, the uThukela DM WSA section attended a Water Treatment Works WULA Application meeting with the Umgeni Catchment Management Team at their Head Offices in Pietermaritzburg. 4. All completed DWS documentation for fourteen (14) Water Treatment Works were handed to Umgeni Water for specialized assistance 5. Outstanding information available was also submitted to Umgeni Water on a continuous basis as requested based on the current support being provided by the waterboard 6. A technical Report completed by Umgeni Water was submitted to DWS 7. Last BDS Process Audits conducted by Service Provider during the 2014/2015 Financial Year Recommendations 1. It will be important to re-establish the operational and compliance monitoring programs in accordance with SANS241 2015 which need to include risk monitoring requirements 2. DWS to be approached to finalize WULA. It is recommended that the regional office be approached to progress matters With Climate Resilient monitoring one needs to reflect on the data which is available to assist in this process
Module 7: **Verify the Effectiveness of the WSP**	1. Not presented within the WSP. Indicated as 'Still to be initiated' Recommendations 1. In order establish effectiveness of the WSP the process needs to be followed to update the working document. One must ensure that monitoring of the effectiveness of the WSP is undertaken and residual risk rating is conducted. This can be done biannually or yearly with the larger team
Module 8: **Prepare Management Procedures**	1. Weekly Compliance meetings were re-instated on the 03/02/2020. Unfortunately, due to COVID meetings were postponed. Recommendations

	1. The impact of COVID-19 has warranted alternate thinking and innovation to ensure operations continue in these difficult times. One needs to amend management procedures to consider such future impacts 2. This also applies to the Climate change aspects which also needs to be included when updating the WSP going forward
Module 9: Develop Supporting Programs	1. Not presented within the WSP. Indicated as being 'In progress' Recommendations 1. Supporting programs are always changing and needing amendments however COVID-19 and Climate resilience supporting programs are now also to considered when developing the WSPs
Module 10/11: Plan and Carry Out Periodic Review of the WSP / Revise the WSP following an Incident	1. Not completed as the WSP is outdated and a review was last conducted in 2016. Recommendations 1. This has not been done in the past. It will be essential that the WSP is managed as working document and process and the findings and control measures are taken into account during planning and budgeting processes. To ensure that this happens the WSP needs to be reviewed annually and the WSP adjusted to accommodate for changes in risks, budgets, and planning

MODULE 1: CLIMATE RESILIENT TEAM ASSEMBLE

A typical Water Safety Plan key team make up consists of members of the internal and external stakeholders on a particular water supply system. Therefore, a team includes people with the following characteristics:

- Water supply system knowledge (catchment to consumer)
- Authority to make decisions (e.g. allocating human and financial resources, approving system changes)
- Responsibility for, and capacity to, help manage and prevent risks
- Adequate expertise to support the identification & management of all risks within the water supply system

Uthukela required typical WSP team members

- Technical Director
- Water Engineers and Technicians
- Water Network and Distribution personnel
- Water Works Superintendents and Senior Process Controllers
- Human Resources Departments
- Financial Department
- Catchment Management
- Water Monitoring and Laboratories (if in-house)
- National Departments (DWS, DEA, etc.)
- Public Health specialists
- Disaster reduction specialists
- Local people with a knowledge of the local climate and climate threats
- Managers, ward leaders and decision makers
- Water utility personnel with knowledge of drinking water related issues
- Water utility personnel with knowledge of natural water resources
- Experts on disaster and risk reduction and identification
- Other key role players

Climate Resilient Water Safety Plan Team make-up

In terms of climate resilience, the WSP team should include sector professionals that understand

- climate information
- water system knowledge
- authority figures and supporting members

Uthukela identified the following key members as to assist with climate resilience. These members will not be permanent members however invited to provide assistance and guidance on an ad-hoc basis to address climate impacts within the area and will include.

- Department of Water and Sanitation (Regional)
- South African Weather Service (SAWS) – climate information
- South African National Biodiversity Institute (SANBI)
- Umgeni Water
- Academics: UKZN, CSIR and other higher learning organisations could be used to source hydrologist, geologist, water resources specialist, climate adaptation specialist, etc.
- Department of Environment, Forestry & Fisheries (Climate Section) (National)
- Provincial Department. of Economic Development, Tourism and Environment Affairs (Climate section) including KZN Wildlife (EZEMVELO)
- COGTA/MISA however further exploration of the level of their involvement will need to take place

MODULE 2: CLIMATE SUMMARY DESCRIPTION

CLIMATE PROJECTIONS 2050

Under *RCP4.5 temperatures are expected to increase by 1.86-2.33°C 2050 but are expected to remain below 3°C (Figure 1b). Under **RCP8.5 temperatures are expected to increase by 2.27-2.64°C. Very Hot Days is expected to increase by 8.58 days under *RCP4.5 and 11.88 days under **RCP8.5 (Figure 1c)

Under both climate scenarios rainfall is projected to increase. *RCP4.5 scenario projects rainfall will increase by as much as 185.05mm/yr by 2050. **RCP8.5 scenario indicates that rainfall will increase by as much as 280.16mm/yr. Extreme rainfall days is expected to increase up to 2.86 days under *RCP4.5 and 4.08 days per annum under **RCP8.5. (Figure 2c)

KEY WATER SERVICES BUSINESS IMPACTS

COVID 19 Impacts

COVID-19 and the associated lockdown restrictions have resulted in delays in repairs and refurbishment of infrastructure.

Infrastructure Maintenance and Repairs

Aging infrastructure and reactive maintenance is impacting on all water systems and formal preventive maintenance is lacking with no or limited budgets.

Budget Priorities

Budget cuts and priority spending have negatively impacted on operations and maintenance at all water supply systems

OVERVIEW OF THE AREA

Uthukela District Municipality is located in the KwaZulu-Natal Province, South Africa. According to the Köppen-Geiger climate classification most of Uthukela experiences Humid sub-tropical climate, whereas other areas experience marine climates. Uthukela experiences warm wet summers, and cool dry winters. Typical climate related hazards for Uthukela include, flooding, fires, storms, and in recent years droughts.

The drought and flooding impacts over recent years has escalated within this area.

CLIMATE SUMMARY

Historical Climate

Temperature for the area has shown an overall warming trend, with observed increase being as much as 2°C per century. Maximum daily temperatures have also shown an increase over time. The increase in temperatures and the impact has certainly been evident during 2015-2016. The area experienced a drought during this period, which had a ripple effect on other industry such as livestock and other agricultural sectors.

According to Chabalala et al. (2019), rainfall for the area indicates an increase for the period 1985-2018. These increases in rainfall have occurred mainly during the provinces wet season.

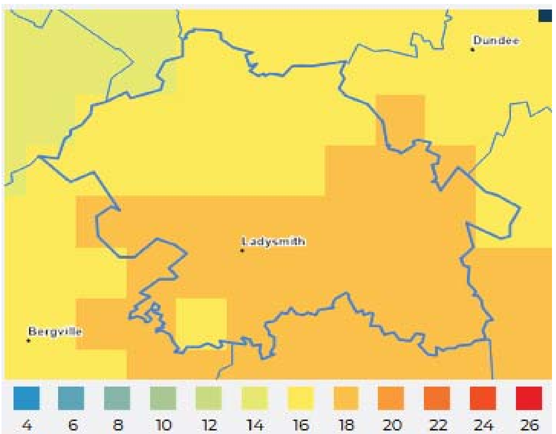
Future Climate

Under the high emissions scenario, temperatures are projected to increase by 1°C to 2°C in the near future (2015-2035), in the mid-future (204-2060) temperatures are expected to increase by 1°C to 4°C, and for the far future (2080-2100) up to 3°C to 5°C. Under the RCP85 scenario, rainfall is projected to decrease. The projected rising temperatures and decrease in rainfall, is likely to result in heatwaves, fires, and droughts.

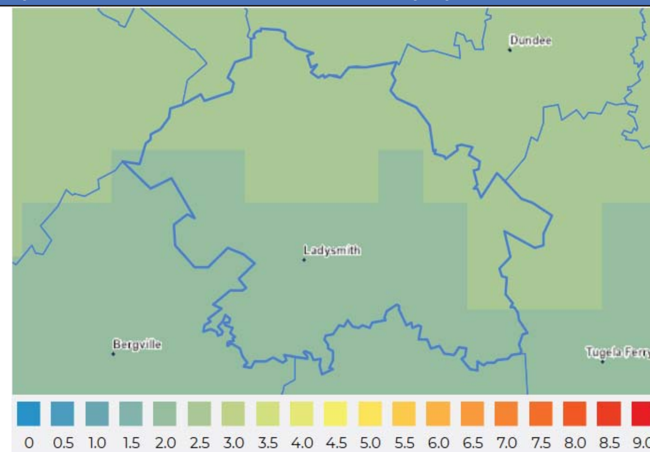
Under the medium emissions scenario RCP45 temperatures are projected to increase but by the end of the century (2080-2100) increases are projected to only have increased by between 1°C and 3°C. Modest drying trends for rainfall are likely to occur.

*RCP4.5 represents a scenario whereby Greenhouse emissions have stabilized before 2100.
**RCP8.5 represents a scenario whereby greenhouse gas emissions continue to increase over time, and results in high concentrations of atmospheric greenhouse gases.
(Chaturvedi et al., 2012)

b) AVERAGE TEMPERATURE (°C)



b) AVERAGE PROJECTED TEMP (°C) INCREASE 2050



c) VERY HOT DAYS (2050)

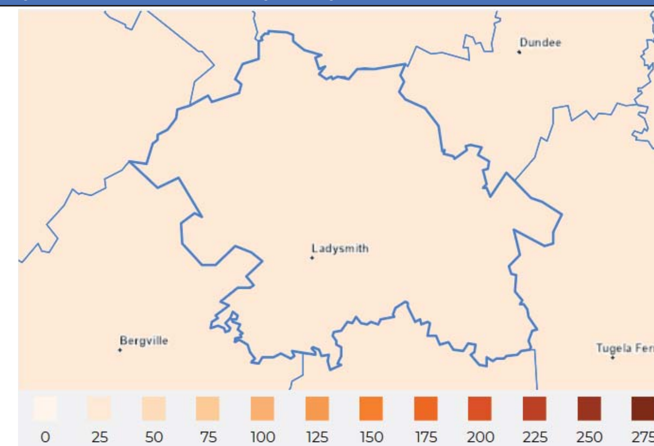
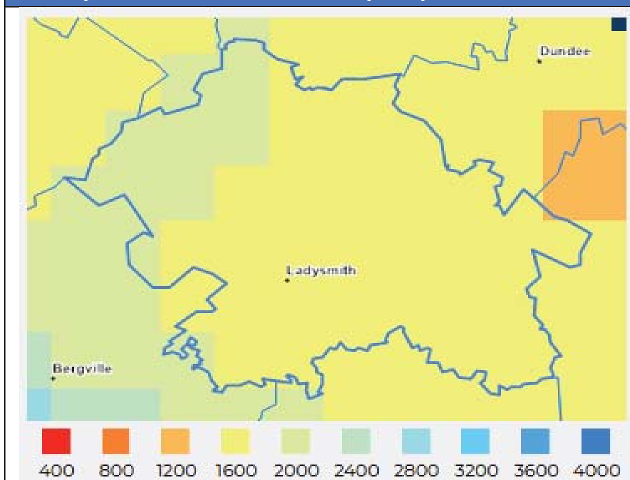
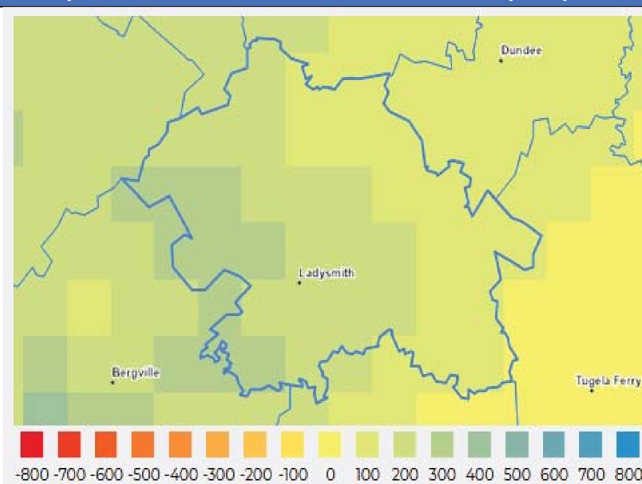


Figure 1: Uthukela District Municipality a) current average temperatures b) average projected temperatures c) projected very hot days (greenbook.co.za)

d) AVERAGE RAINFALL (mm)



e) AVG PROJ. CHANGE IN RAINFALL (mm) 2050



f) EXTREME RAINFALL DAYS (2050)

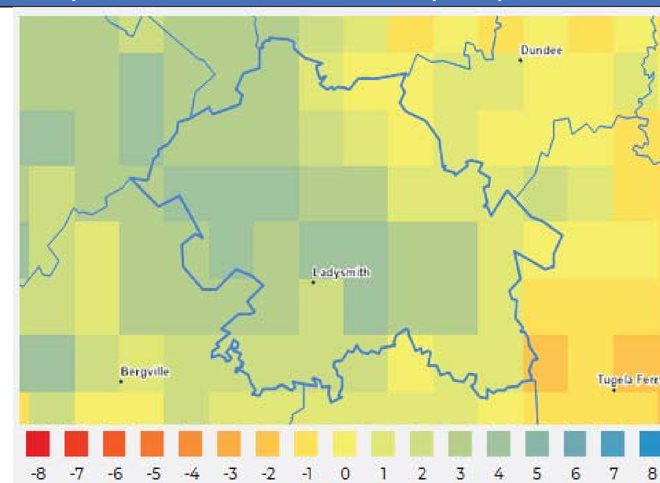


Figure 2: Uthukela District Municipality a) current average rainfall b) average projected rainfall c) projected extreme rainfall days (greenbook.co.za)

The following table provides you with observations from the site visits and review of material as to possible climate risks at your source, treatment and distribution. It is important that when updating the WSP going forward that you review the risks and recommended control measures. Thereafter, complete the validation and assess effectiveness of the control measure and residual risk. If one considers the simple/generic risk matrix below, the following is noted.

	Severity				
Likelihood	Insignificant 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
Almost Certain 5	5	10	15	20	25
Likely 4	4	8	12	16	20
Moderate 3	3	6	9	12	15
Unlikely 2	2	4	6	8	10
Rare 1	1	2	3	4	5

Score	**Risk profile**	
0-10	Low	These systems operate with minor deficiencies. Usually the systems met the water quality parameters specified by the appropriate guidelines (SANS 241)
11-20	Moderate	These are system with deficiencies which individually or combined pose a high risk to the quality of water and human health. These systems would not generally require immediate action, but the deficiencies could be more easily to avoid future problems.
21-25	High	These are systems with major deficiencies which individually or combined pose a high risk to the quality of water and may lead to potential health and safety or environmental concerns. Once systems are classified under this category, immediate corrective action is required to minimise or eliminate deficiencies.

Climate resilient risk observations							
Process Step	**Hazardous Event**	**Hazard Type**	**Likelihood**	**Consequence**	**Risk score**	**Risk level**	**Suggested control measure**
Source	Decrease in rainfall resulting in reduced water availability, storage quantity in both surface water and groundwater	Physical/Quality	4	5	20	M	Water resource planning is to be undertaken together with WCDM measures and Water Restrictions based on lowering the water demand. Community involvement will be essential for this being a success and water conservation awareness programmes are to be implemented and properly reported on a weekly basis for communities to see the impacts of their contribution
Source	Lower water quality as a result of drought and fire impacts	Quality	4	4	16	M	Water quality monitoring to be undertaken at the source and changes to treatment processes to be accommodated accordingly.
Source	Damage to infrastructure from Fires	Physical	3	4	12	M	Environmental partnerships to be explored to clear vegetation from surrounding areas and establish fire breaks to protect resources
Source	Damage to infrastructure from Flooding	Physical	3	4	12	M	Environmental partnerships to be explored to provide structured runoff areas/channels to protect erosion of soil thereby not exposing infrastructure to possible damage
Source	Contaminated surface water entering groundwater as a result of increased rainfall	Quality	4	5	20	M	Increased monitoring of ground water to be undertaken. Further treatment/disinfection to be investigated and implemented

Process Step	Hazardous Event	Hazard Type	Likelihood	Consequence	Risk score	Risk level	Suggested control measure
Treatment	Water treatment system infrastructure failure due to increased flooding	Physical	3	4	12	M	Weather forecasting to be used to mitigate impact. It will be important ascertain flow patterns to assess and predict probability risk. Further investigation into structural diversion considerations to be undertaken
Treatment	Damage to infrastructure from Fires	Physical	3	4	12	M	Improved housekeeping is to be undertaken around the works to ensure that fire risk is kept to a minimum. This needs to be included into the preventative operation and maintenance plans
Treatment	Algal and cyanobacterial growth in filter media due to increased temperatures	Quality	3	4	12	M	Water quality monitoring to be undertaken at the treatment works and changes to treatment processes to be accommodated accordingly.
Treatment	Unsafe drinking water due to increased waterborne pathogens	Quality	3	5	15	M	Improved water quality monitoring to be undertaken with regards to waterborne pathogens. Treatment process to be adjusted accordingly with increased disinfection taking place
Treatment	Increased operations and maintenance cost due to medium to long term drought and flooding impacts	Budgets	3	4	12	M	Analysis of drought and flooding impacts on the operations and maintenance budget to be undertaken. Budgets to be adjusted to manage the increase in cost based on the drought and flooding impacts

Process Step	Hazardous Event	Hazard Type	Likelihood	Consequence	Risk score	Risk level	Suggested control measure
Reservoirs & Reticulation	Algal and cyanobacterial growth in reservoirs due to increased temperatures	Quality	3	4	12	M	Water quality monitoring to be undertaken at the reservoir and consider possible secondary disinfection at the reservoirs, e.g. portable sodium hypochlorite dosing
Reservoirs & Reticulation	Infrastructure damage to infrastructure due to extreme rainfall and flooding	Physical	3	4	12	M	Investigate possible diversion measures to protect reservoirs from flooding
Reservoirs & Reticulation	Damage to infrastructure from Fires	Physical	3	4	12	M	Good housekeeping is to be undertaken around the reservoirs to ensure that fire risk is kept to a minimum. This needs to be included into the preventative operation and maintenance plans

CONCLUSIONS

Uthukela District Municipality has an opportunity to update the WSP and take into consideration the climate change methodology as well. The risks identified and reviewed in 2016 are no longer applicable to the current situation that the municipality is facing. The additional impact of COVID-19 needs to be factored into the risk management process as well. In going forward the municipality needs to address the following.

- The WSP team needs to be broadened to include more stakeholder participation and include climate change and environmental specialists based on their need within the updating of the WSP.
- The system description and assessment needs to be updated accordingly to the current situation and include the aspects needed to evaluate the climate impacts. This includes climate summaries, climate profile and forecasting.
- It will be important during the risk categorisation and prioritisation that new risks be identified during actual site assessments. Climate risks need to be assessed based on the threat to source, treatment and distribution.
- Updated control measures need to be crafted with the aim of monitoring and validating their effectiveness
- Improved operational and compliance monitoring is essential and needs to be aligned to SANS:241 2015 and also the municipality's risk profile. This will aid in the monitoring and validation of the control measures identified
- Management incident protocols and support programmes will need to include Climate resilient aspects
- It is noted that there are supporting programmes in place to support WSP processes and that the municipality has setup up committees to address risk mitigation. However, the municipality needs to ensure that WSP becomes a working document and process whereby the findings and control measures are taken into account during planning and budgeting processes. To ensure that this happens the WSP needs to be reviewed annually and adjusted to accommodate for changes in risks, budgets, and planning

Integrating climate information into the water safety plan and wastewater risk abatement plan

Uthukela District Municipality

WATER RESEARCH COMMISSION

EMANTI Water & Environmental Engineering Services

GENERAL OBSERVATIONS OF CURRENT W_2RAP

UTHUKELA: LADYSMITH WASTEWATER SUPPLY SCHEME	
Developed By	Meg Cunningham
Step 1: **Assemble the WSP Team**	1. *NOTE: WSP and W_2RAP processes are very similar in their nature and step wise process. So, there is many areas of overlap with regards the step requirements. The following observations will then apply* 2. It must also be noted that a draft W_2RAP was finalized in in 2015 so it is in the same status as the WSP. 3. Most significantly was the insufficient involvement of WSP Steering Committee. Lack of buy in to the process by officials. 4. Team makeup needed improvement with clearly defined roles and responsibilities 5. No Climate Resilient members considered Recommendations: 1. The municipality has an opportunity now to update the current WSP and W_2RAP taking into account the Climate Resilient requirements. This will be applicable to all steps of the W_2RAP process 2. The additional members in terms of Climate Change (as described in Module 1 below) will need to be explored and implemented before the updating process is to begin. Start with a small selection of climate specialists and broaden out as the need arises for further input
Step 2: **Describe your water supply system**	1. As in the WSP the wastewater sites not thoroughly evaluated, and systems inadequately described as assessed 2. System information especially on the wastewater side was lacking Recommendations 1. As some time has passed since the update of the W_2RAP the requirements for the describing and assessing of the system will be important to assist in the risk identification 2. Additionally one would also want to consider including some of the following Climate aspects. • Rainfall data and forecasting/predictions (at least 30-year historical period) • Temperature data and forecasting/predictions • Water demand analysis and reporting • Drought considerations – availability of water and period of availability • Changes in areas affected by climate related threats/impacts (Flood lines). Historical information: areas prone to/affected by floods and droughts – frequency of such events • Groundwater levels (yields), River flows / Dam levels • Surface and groundwater quality • Understanding the Resource Quality Objectives (RQOs) and EWR (Ecological Water Requirements) set by DWS and the implications thereof (this will be important especially with regards the return to source and the impact of the effluent quality from the wastewater treatment works) • Precipitation data • Evaporation data

	• Ecological infrastructure and their status • Spatial / land use information • Discharge volumes 3. Update and refine Climate Summaries and forecasting for inclusion into the W_2RAP
Step 3: **Assess the existing or proposed system**	**As this step should be managed in conjunction with Step 2 the recommendations above apply**
Step 4: **Hazard assessment and risk characterization**	1. Mostly global risks 2. Risk are outdated 3. No climate/weather related risks captured in the risk register (i.e. impact of high or low rainfalls on water supply, infrastructure, etc.) Recommendations 1. It is advisable that a separate section of risk identification process with regards the Climate Impacts to identify hazards and hazardous events and assess the risks is accommodated for within this module. Be sure to focus on the water value chain from catchment to consumer. 2. Some area highlighted during the workshop included • Focus on areas that are prone to floods and droughts (current and future). Risks to sewer networks, pump stations, treatment, environmental • Significant temperature fluctuations – area does extreme very high temperature in summer months) • Impaired water quality (less rainfall) – compounded if WWTW is discharging poor quality effluent. • Increased rainfall – can lead to increased flows – reduces capacity of infrastructure to cope with events – resulting in overflows / flooding, infrastructure and equipment can be compromised/damaged • Stormwater ingress plays a major role in not just capacity but also quality as wastewater treatment works do not function effectively with diluted (“clean”) water • Increased rainfall – erosion – can exposed infrastructure (e.g. pipelines), increased litter/debris washed into rivers – make create blockages at abstraction points and/or also blocked pipes.
Step 5: **Identify hazards, control measures and preventative actions/validation**	1. Control measures are outdated and generic and not applicable the current risk 2. Validation was not in place and control measure effectiveness could not be assessed 3. Re-assessment of risks also not undertaken Recommendations 1. The current situation is that a Service Provider is to be appointed to implement Preventative Maintenance plan on all WWTWs and related infrastructure. An unsolicited bid advertised as from the 10th of September 2020 2. In addition, a Business Plan has been developed based on the directives received from the Department of Water and Sanitation (DWS) 3. Noting the above and the need to update the entire W_2RAP with these validations need to be incorporated and monitored within the WSP process.

	4. An associated control measure identification needs to be undertaken with the risk identified in Module 3 above
Step 6: **Operational monitoring and maintaining control**	1. Operational Monitoring: monitoring is inconsistent and has been negatively impacted by COVID-19 2. Compliance monitoring: this has also been adapted to adhere to the COVID-19 regulations and although providing data to IRIS this has been a challenge for the municipality 3. Last GDS Process Audits conducted by Service Provider during the 2014/2015 Financial Year Recommendations ɔrograms in accordance with Licenses and Authorizations currently in place even if that the regional office be approached to progress matters ilable to assist in this process
Step 7: **Verification that the W$_2$RAP is effective and meets health- and environmental-based targets**	1. Not presented within the WSP. Indicated as 'Still to be initiated' Recommendations 1. In order establish effectiveness of the W$_2$RAP the process needs to be followed to update the working document. One must ensure that monitoring of the effectiveness of the W$_2$RAP is undertaken and residual risk rating is conducted. This can be done biannually or yearly with the larger team
Step 8: **Management procedures for wastewater systems**	1. Weekly Compliance meetings were re-instated on the 03/02/2020. Unfortunately, due to COVID meetings were postponed. Recommendations 1. The impact of COVID-19 has warranted alternate thinking and innovation to ensure operations continue in these difficult times. One needs to amend management procedures to consider such future impacts 2. This also applies to the Climate change aspects which also needs to be included when updating the W$_2$RAP going forward
Step 9: **Documentation and communication**	1. Not presented within the WSP. Indicated as being 'In progress' Recommendations 1. Supporting programs are always changing and needing amendments however COVID-19 and Climate resilience supporting programs are now also to considered when developing the W$_2$RAPs
Step 10: **Review of W$_2$RAP**	1. Not completed as the W$_2$RAP is outdated and a review was last conducted in 2015. Recommendations 1. This has not been done in the past. It will be essential that the W$_2$RAP is managed as working document and process and the findings and control measures are taken into account during planning and budgeting processes. To ensure that this happens the W$_2$RAP needs to be reviewed annually and the W$_2$RAP adjusted to accommodate for changes in risks, budgets, and planning

STEP 1: CLIMATE RESILIENT TEAM ASSEMBLE

A typical Wastewater Risk Abatement Plan key team make up consists of members of the internal and external stakeholders on a particular wastewater supply system. Therefore, a team includes people with the following characteristics:

- Wastewater system knowledge (Receiving Network, Pump Stations, Treatment, Return to Source)
- Authority to make decisions (e.g. allocating human and financial resources, approving system changes)
- Responsibility for, and capacity to, help manage and prevent risks
- Adequate expertise to support the identification & management of all risks within the water supply system

Uthukela required typical W_2RAP team members

- Technical Director
- Water Engineers and Technicians
- Water Network and Distribution personnel
- Water Works Superintendents and Senior Process Controllers
- Human Resources Departments
- Financial Department
- Catchment Management
- Water Monitoring and Laboratories (if in-house)
- National Departments (DWS, DEA, etc.)
- Public Health specialists
- Disaster reduction specialists
- Local people with a knowledge of the local climate and climate threats
- Managers, ward leaders and decision makers
- Water utility personnel with knowledge of drinking water related issues
- Water utility personnel with knowledge of natural water resources
- Experts on disaster and risk reduction and identification
- Other key role players

Climate Resilient Wastewater Risk Abatement Team make-up
In terms of climate resilience, the W_2RAP team should include sector professionals that understand

- climate information
- Wastewater system knowledge
- authority figures and supporting members

As identified in the WSP team makeup the W_2RAP would require similar members and the following key members apply to assist with climate resilience. These members will not be permanent members however invited to provide assistance and guidance on an ad-hoc basis to address climate impacts within the area and will include.

- Department of Water and Sanitation (Regional)
- South African Weather Service (SAWS) – climate information
- South African National Biodiversity Institute (SANBI)
- Umgeni Water (only if they are supporting Wastewater systems as well)
- Academics: UKZN, CSIR and other higher learning organisations could be used to source hydrologist, geologist, water resources specialist, climate adaptation specialist, etc.
- Department of Environment, Forestry & Fisheries (Climate Section) (National)
- Provincial Department. of Economic Development, Tourism and Environment Affairs (Climate section) including KZN Wildlife (EZEMVELO)
- COGTA/MISA however further exploration of the level of their involvement will need to take place

STEP 2: CLIMATE SUMMARY DESCRIPTION

CLIMATE PROJECTIONS 2050

Under *RCP4.5 temperatures are expected to increase by 1.86-2.33°C 2050 but are expected to remain below 3°C (Figure 1b). Under **RCP8.5 temperatures are expected to increase by 2.27-2.64°C. Very Hot Days is expected to increase by 8.58 days under *RCP4.5 and 11.88 days under **RCP8.5 (Figure 1c)

Under both climate scenarios rainfall is projected to increase. *RCP4.5 scenario projects rainfall will increase by as much as 185.05mm/yr by 2050. **RCP8.5 scenario indicates that rainfall will increase by as much as 280.16mm/yr. Extreme rainfall days is expected to increase up to 2.86 days under *RCP4.5 and 4.08 days per annum under **RCP8.5. (Figure 2c)

KEY WATER SERVICES BUSINESS IMPACTS

COVID 19 Impacts

COVID-19 and the associated lockdown restrictions have resulted in delays in repairs and refurbishment of infrastructure.

Infrastructure Maintenance and Repairs

Aging infrastructure and reactive maintenance is impacting on all wastewater systems and formal preventive maintenance is lacking with no or limited budgets.

Budget Priorities

Budget cuts and priority spending have negatively impacted on operations and maintenance at all wastewater supply systems

OVERVIEW OF THE AREA

Uthukela District Municipality is located in the KwaZulu-Natal Province, South Africa. According to the Köppen-Geiger climate classification most of Uthukela experiences humid sub-tropical climate, whereas other areas experience marine climates. Uthukela experiences warm wet summers, and cool dry winters. Typical climate related hazards for Uthukela include, flooding, fires, storms, and in recent years droughts.

The drought and flooding impacts over recent years has escalated within this area.

CLIMATE SUMMARY

Historical Climate

Temperature for the area has shown an overall warming trend, with observed increase being as much as 2°C per century. Maximum daily temperatures have also shown an increase over time. The increase in temperatures and the impact has certainly been evident during 2015-2016. The area experienced a drought during this period, which had a ripple effect on other industry such as livestock and other agricultural sectors.

According to Chabalala et al. (2019), rainfall for the area indicates an increase for the period 1985-2018. These increases in rainfall have occurred mainly during the provinces wet season.

Future Climate

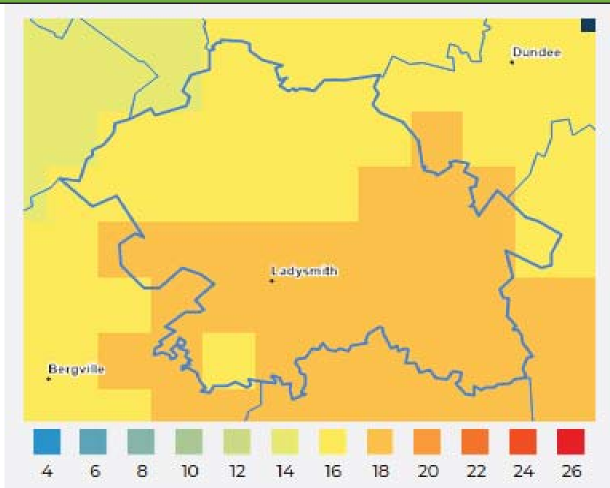
Under the high emissions scenario, temperatures are projected to increase by 1°C to 2°C in the near future (2015-2035), in the mid-future (204-2060) temperatures are expected to increase by 1°C to 4°C, and for the far future (2080-2100) up to 3°C to 5°C. Under the RCP85 scenario, rainfall is projected to decrease. The projected rising temperatures and decrease in rainfall, is likely to result in heatwaves, fires, and droughts.

Under the medium emissions scenario RCP45 temperatures are projected to increase but by the end of the century (2080-2100) increases are projected to only have increased by between 1°C and 3°C. Modest drying trends for rainfall are likely to occur.

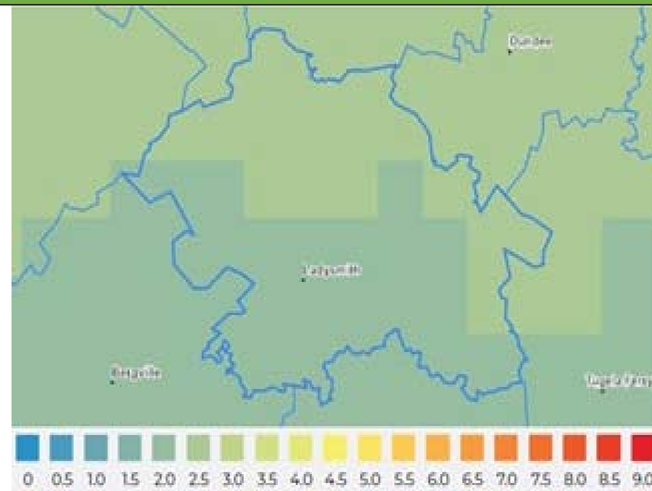
*RCP4.5 represents a scenario whereby Greenhouse emissions have stabilized before 2100.
**RCP8.5 represents a scenario whereby greenhouse gas emissions continue to increase over time, and results in high concentrations of atmospheric greenhouse gases.
(Chaturvedi et al., 2012)

UTHUKELA MUNICIPALITY CLIMATE STATUS: CURRENT CONDITIONS

c) AVERAGE TEMPERATURE (°C)



b) AVERAGE PROJECTED TEMP (°C) INCREASE 2050



c) VERY HOT DAYS (2050)

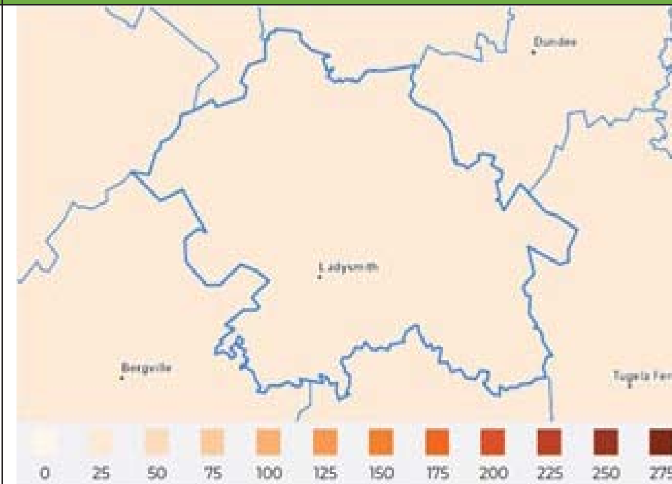
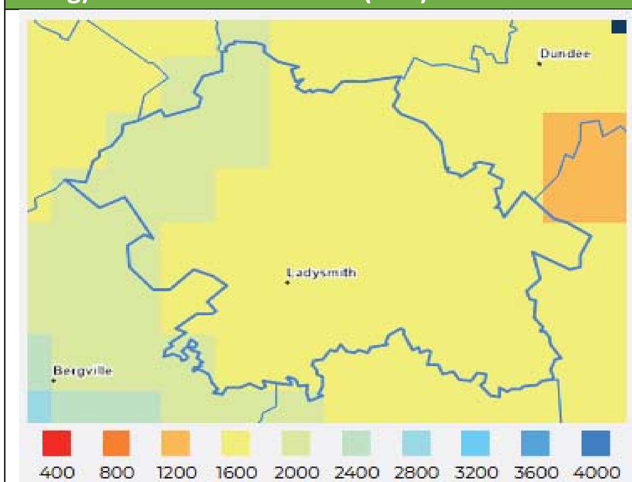
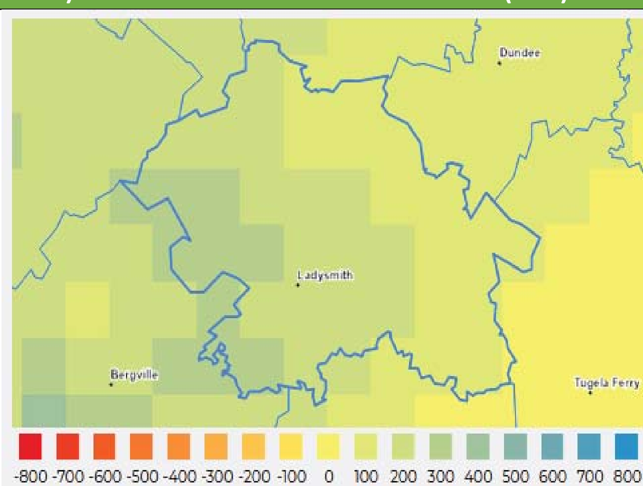


Figure 1: Uthukela District Municipality a) current average temperatures b) average projected temperatures c) projected very hot days (greenbook.co.za)

g) AVERAGE RAINFALL (mm)



h) AVG PROJ. CHANGE IN RAINFALL (mm) 2050



i) EXTREME RAINFALL DAYS (2050)

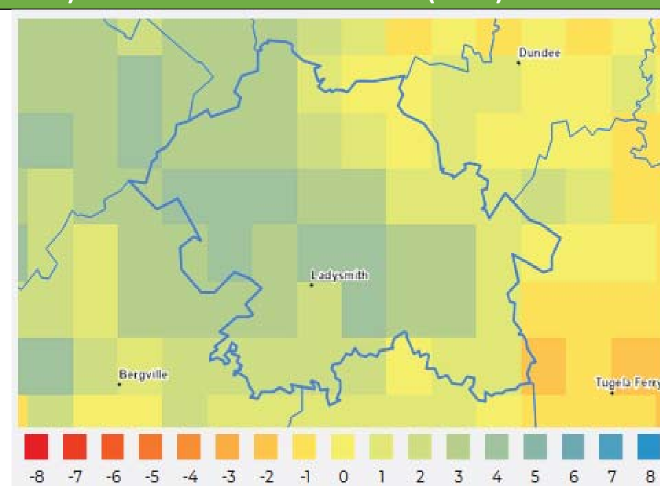


Figure 2: Uthukela District Municipality a) current average rainfall b) average projected rainfall c) projected extreme rainfall days (greenbook.co.za)

STEP 4/5: IDENTIFICATION OF CLIMATE HAZARD & HAZARDOUS EVENTS/DETERMINATION & VALIDATE CONTROL MEASURES ASSESS & PRIORITISE RISK

The following table provides you with observations from the site visits and review of material as to possible climate risks at your source, treatment and distribution. It is important that when updating the WSP going forward that you review the risks and recommended control measures. Thereafter, complete the validation and assess effectiveness of the control measure and residual risk. If one considers the simple/generic risk matrix below, the following is noted.

Likelihood	**Severity**				
	Insignificant 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
Almost Certain 5	5	10	15	20	25
Likely 4	4	8	12	16	20
Moderate 3	3	6	9	12	15
Unlikely 2	2	4	6	8	10
Rare 1	1	2	3	4	5

Score	**Risk profile**	
0-10	Low	These are systems that operate with minor deficiency and usually meet the effluent quality specifications set by the Department of Water Affairs. It is unlikely that this level of risk is harmful to the health of people and the environment. Aesthetically and/or physical non-compliance can be expected for short periods.
11-20	Moderate	These are systems with deficiencies which individually or combined pose a moderate risk to the quality of the receiving environment and health. These systems would not generally require immediate action but the deficiencies should be rectified to avoid future problems and associated cost to rectify once in HIGH risk. Aesthetically and/or physically non-compliance can be expected over a medium term. Medium term impact on infrastructure and partial failure of the wastewater treatment plant and disinfection process is likely.
21-25	High	These are systems with deficiencies which individually or combined pose a high risk to the quality of the receiving environment and health, and may lead to potential health, safety and environmental concerns. Once a system (or part of a system) is classified under this category, immediate corrective action is required to arrest or eliminate the deficiency. High impact on the health of people and the environment and/or significant damage to infrastructure can be expected. Total failure of the collector, treatment and disinfection facility is likely.

Climate resilient risk observations							
Process Step	**Hazardous Event**	**Hazard Type**	**Likelihood**	**Consequence**	**Risk score**	**Risk level**	**Suggested control measure**
Network and Pump Stations	Damaged infrastructure especially that of the pump stations is resulting in low flows and negatively impacting on the operation and functionality of the works as well as polluting to the environment	Physical	5	5	25	H	This is a major risk to the municipality especially for the Ladysmith works. Uthukela has been issued directives in this regard and has been in engagement with DWS Pongola Umzinkulu CMA to address and the municipality has developed an Operation and Maintenance Plan which has been submitted for approval for implementation. This plan needs to be fast tracked as the environmental impact at the moment is already at a catastrophic state
Network and Pump Stations	Stormwater ingressions because of heavy rainfalls impacting on capacity of the works and the operation of the works as treatable water is now diluted with fresh water	Quantity/Quality	5	5	25	H	Undertake Stormwater Ingression Investigation which could be part of a Network Inspection process to identify key areas that can be repaired. This needs to form part of the operations and maintenance plan
Network and Pump Stations	Infrastructure damage to infrastructure due to extreme rainfall and flooding	Physical	3	4	12	M	Investigate possible diversion measures to protect pump stations and network from flooding. The municipality has built a flood dam to mitigate flooding of the area and validation of the control measure should be undertaken which will result in an amended risk prioritization
Network and Pump Stations	Damage to infrastructure from Fires	Physical	3	4	12	M	Good housekeeping is to be undertaken around the pump stations to ensure that fire risk is kept to a minimum. This needs to be included into the preventative operation and maintenance plans

Process Step	Hazardous Event	Hazard Type	Likelihood	Consequence	Risk score	Risk level	Suggested control measure
Treatment	Wastewater treatment system infrastructure failure due to increased flooding	Physical	3	4	12	M	Weather forecasting to be used to mitigate impact. It will be important ascertain flow patterns to assess and predict probability risk. Further investigation into structural diversion considerations to be undertaken
Treatment	Damage to infrastructure from Fires	Physical	3	4	12	M	Improved housekeeping is to be undertaken around the works to ensure that fire risk is kept to a minimum. This needs to be included into the preventative operation and maintenance plans
Treatment	Stormwater ingressions because of heavy rainfalls impacting on capacity of the works and the operation of the works as treatable water is now diluted with fresh water	Quantity/Quality	5	5	25	H	This aspect not only affects the network but also the treatment processes. Undertake Stormwater Ingression Investigation which could be part of a Network Inspection process to identify key areas that can be repaired. This needs to form part of the operations and maintenance plan
Treatment	Increased operations and maintenance cost due to medium to long term drought and flooding impacts	Budgets	4	4	16	M	Analysis of drought and flooding impacts on the operations and maintenance budget to be undertaken. Budgets to be adjusted to manage the increase in cost based on the drought and flooding impacts

Process Step	Hazardous Event	Hazard Type	Likelihood	Consequence	Risk score	Risk level	Suggested control measure
Catchment	Lower water quality as a result of drought and flooding	Quality	5	5	25	H	Water quality monitoring to be undertaken at the catchment (upstream, downstream and final outlet) and changes to treatment processes to be accommodated accordingly and to ascertain if further preventative measures need to be put into place. Biomonitoring is also encouraged at all systems to check that the river is healthy. Preventative measures then need to be identified to mitigate the impacts of the final outlet on the ever-changing quality of the receiving catchment
Catchment	Pollution of the river as a result of network leakages which is compounded by increased rainfall	Quality	5	5	25	H	Currently this hazard is impacting on the entire wastewater value chain and

CONCLUSIONS

Based on the climate observations some of the high risks Uthukela District Municipality is facing is already related to Climate Change.

Furthermore, the outdated WSP and W_2RAP presents an advantage in the disadvantage whereby Uthukela can start a renewed process taking in account the progressed climate change methodology. In so doing risk abatement planning will be strengthen and projects can be identified to be place on planning and budgeting processes.

Again COVID-19 impacts must be considered not only for climate change risk management but also normal operational and maintenance risk management.

In going forward the municipality needs to address the following.

- The W_2RAP team needs to be broadened to include more stakeholder participation and include climate change and environmental specialists based on their need within the updating of the W_2RAP.
- The system description and assessment need to be updated accordingly to the current situation and include the aspects needed to evaluate the climate impacts. This includes climate summaries, climate profile and forecasting.
- It will be important during the risk categorisation and prioritisation that new risks be identified during actual site assessments. Climate risks need to be assessed based on the threat to Network, Treatment and returning water to the receiving catchment
- Updated control measures need to be crafted with the aim of monitoring and validating their effectiveness
- Improved operational and compliance monitoring is essential and needs to be aligned to Licences and Authorisations. This will aid in the monitoring and validation of the control measures identified
- Management incident protocols and support programmes will need to include Climate resilient aspects
- It is noted that there are supporting programmes in place to support W_2RAP processes and that the municipality has setup up committees to address risk mitigation. However, the municipality needs to ensure that W_2RAP becomes a working document and process whereby the findings and control measures are taken into account during planning and budgeting processes. To ensure that this happens the W_2RAP needs to be reviewed annually and adjusted to accommodate for changes in risks, budgets, and planning

Integrating climate information into the water safety plan and wastewater risk abatement plan

Lephalale Local Municipality

WATER RESEARCH COMMISSION

EMANTI Water & Environmental Engineering Services

GENERAL OBSERVATIONS OF CURRENT WSP

ZEELAND: LEPHALALE WATER SUPPLY SCHEME	
Developed By	**Water Safety Plan should be developed by both Exxaro and Lephalale**
Module 1: **Assemble the WSP Team**	1. No Indication of a 'WSP' team, however there is a 'Risk assessment team' 2. The Risk assessment team is a multidisciplinary team; however, it does not have WTW staff such as PCs, and is missing some other key members (Public health specialists, decision makers, etc.) 3. No DWS officials as there has been no engagement with DWS Recommendations 1. The municipality has an opportunity now to update the current WSP taking into account the Climate Resilient requirements that was discussed during the meeting. This will be applicable to all modules of the WSP 2. The additional members in terms of Climate Change will need to be explored and implemented before the updating process is to begin. Start with a small selection of climate specialists and broaden out as the need arises for further input
Module 2: **Describe your water supply system**	1. System is very well described, and explains the transport of water from the catchment to the consumer 2. No System diagram is available, and no map is presented within the WSP 3. GPS coordinates are provided for individual pump stations and reservoirs 4. No climate related information is captured such as rainfall and temperature. However, it was noted that flooding occurs during the wet season, which has an impact on water quality, particularly turbidity. 5. Areas supplied and population are provided Recommendations 1. As some time has passed since the update of the WSP the requirements for the describing and assessing of the system will be important to assist in the risk identification 2. The following climate aspects should also be considered • Rainfall data and forecasting/predictions (at least 30-year historical period) • Temperature data and forecasting/predictions • Water demand analysis and reporting • Drought considerations – availability of water and period of availability • Changes in areas affected by climate related threats/impacts (Flood lines). Historical information: areas prone to/affected by floods and droughts – frequency of such events • Groundwater levels (yields), River flows / Dam levels • Surface and groundwater quality • Understanding the Resource Quality Objectives (RQOs) and EWR (Ecological Water Requirements) set by DWS and the implications thereof • Precipitation data

<table>
<tr><td></td><td>• Evaporation data
• Ecological infrastructure and their status
• Spatial / land use information
• Abstraction volumes / discharge volumes
3. Update and refine Climate Summaries and forecasting for inclusion into the WSP</td></tr>
<tr><td>Module 3:
Identify Hazards and Hazardous Events and Assess the Risks</td><td>1. It is noted within the WSP that the Risk assessment team has identified seasonal risks
2. No catchment level risks identified within the WSP. The WSP indicates that no 'significant' catchment level risks were identified, and that control measure implementation lies with DWS
3. Risk evaluation, for bulk storage and reticulation only lists the hazards and hazardous events, and whether it is under control and if additional action is required. There is no risk-scoring present for these hazards and hazardous events.
4. Hazard and Hazardous events relate to how water quality will be impacted. There are no risks related to how OHS, operations, infrastructure, Finance, staff, etc. included
Recommendations
1. It is advisable that a separate section of risk identification process with regards the Climate Impacts to identify hazards and hazardous events and assess the risks is accommodated for within this module. Be sure to focus on the water value chain from catchment to consumer.</td></tr>
<tr><td>Module 4:
Determine and Validate Control Measures, Reassess and Prioritize the Risks</td><td>1. Control measures for the treatment plant not covered in the WSP and the responsibility lies with Exxaro. Requires engagement with Exxaro before these can be included in the WSP
2. Control measures only address water storage and distribution
3. Not all risks captured in the WSP such as HR risks or internal departmental risks, etc.
4. Under responsible person only a position is given no name
5. No alert levels for risks are given
Recommendations
1. This section should be workshopped with municipality and Exxaro in order to determine the appropriate control measures particularly the risks at source and treatment plants</td></tr>
<tr><td>Module 5:
Develop, Implement and Maintain an Improvement / Upgrade Plan</td><td>This is not covered in the WSP
Recommendations
1. The municipality has established and Blue and Green Drop Steering Committee which focuses on improvement planning against the Blue and Green Drop Criteria. This valuable process must be incorporated into the updating of the WSP
2. Process Audits need also to be updated and findings and recommendations also incorporated into the updating of the WSP
3. The improvement plans need to be monitored and aligned to changing budget priorities</td></tr>
</table>

	4. Noting the climate change additions the WSP team need to consider the short to medium to long term plans to address climate trends and forecasts
Module 6: Define Monitoring of the Control Measures	1. Limits and monitoring related to water treatment remain the responsibility of Exxaro and are therefore not included in this WSP 2. No control measures have been identified for water treatment Recommendations 1. This section should be workshopped with municipality and Exxaro in order to determine the appropriate control measures particularly the risks at source and treatment plants
Module 7: Verify the Effectiveness of the WSP	1. The importance and responsible party are highlighted however it is not presented in the WSP Recommendations 1. In order establish effectiveness of the WSP the process needs to be followed to update the working document. One must ensure that monitoring of the effectiveness of the WSP is undertaken and residual risk rating is conducted. This can be done biannually or yearly with the larger team
Module 8: Prepare Management Procedures	1. This is not covered in the WSP Recommendations **1.** In order establish effectiveness of the WSP the process needs to be followed to update the working document. Management procedures are **an important component to operate and adequately implement the WSP.**
Module 9: Develop Supporting Programmes	1. This is not covered in the WSP Recommendations 1. supporting programs are always changing and needing amendments however COVID-19 and Climate resilience supporting programs are now also to considered when developing the WSPs
Module 10/11: Plan and Carry Out Periodic Review of the WSP / Revise the WSP following an Incident	1. There is no evidence of this being done Recommendations 1. This has not been done in the past. It will be essential that the WSP is managed as working document and process and the findings and control measures are taken into account during planning and budgeting processes. To ensure that this happens the WSP needs to be reviewed annually and the WSP adjusted to accommodate for changes in risks, budgets, and planning

MODULE 1: CLIMATE RESILIENT TEAM ASSEMBLE

A typical Water Safety Plan key team make up consists of members of the internal and external stakeholders on a particular water supply system. Therefore, a team includes people with the following characteristics:

- Water supply system knowledge (catchment to consumer)
- Authority to make decisions (e.g. allocating human and financial resources, approving system changes)
- Responsibility for, and capacity to, help manage and prevent risks
- Adequate expertise to support the identification & management of all risks within the water supply system

Lephalale required typical WSP team members

- Technical Director
- Water Engineers and Technicians
- Water Network and Distribution personnel
- Water Works Superintendents and Senior Process Controllers
- Human Resources Departments
- Financial Department
- Catchment Management
- Water Monitoring and Laboratories (if in-house)
- National Departments (DWS, DEA, etc.)
- Public Health specialists
- Disaster reduction specialists
- Local people with a knowledge of the local climate and climate threats
- Managers, ward leaders and decision makers
- Water utility personnel with knowledge of drinking water related issues
- Water utility personnel with knowledge of natural water resources
- Experts on disaster and risk reduction and identification
- Other key role players

Climate Resilient Water Safety Plan Team make-up

In terms of climate resilience, the WSP team should include sector professionals that understand

- climate information
- water system knowledge
- authority figures and supporting members

Lephalale identified the following key members as to assist with climate resilience. These members will not be permanent members however invited to provide assistance and guidance on an ad-hoc basis to address climate impacts within the area and will include.

- Department of Water and Sanitation (Catchment)
- South African Weather Service (SAWS) – climate information
- Exxaro Operations and Maintenance team
- Municipal Chief Financial Officer
- Cooperate Services Office
- Environmental Health Practitioners
- Other mines representatives
- Eskom representative
- Disaster Management and
- Different portfolios – Councillors

MODULE 2: CLIMATE SUMMARY DESCRIPTION

CLIMATE PROJECTIONS 2050

Under *RCP4.5 temperatures are expected to increase by 1.86-2.33°C 2050 but are expected to remain below 3°C (Figure 1b). Under **RCP8.5 temperatures are expected to increase by 2.27-2.64°C. Very Hot Days is expected to increase by 8.58 days under *RCP4.5 and 11.88 days under **RCP8.5 (Figure 1c)

Under both climate scenarios rainfall is projected to increase. *RCP4.5 scenario projects rainfall will increase by as much as 185.05mm/yr by 2050. **RCP8.5 scenario indicates that rainfall will increase by as much as 280.16mm/yr. Extreme rainfall days is expected to increase up to 2.86 days under *RCP4.5 and 4.08 days per annum under **RCP8.5. (Figure 2c)

KEY WATER SERVICES BUSINESS IMPACTS

COVID 19 Impacts

COVID-19 and the associated lockdown restrictions have resulted in delays in repairs and refurbishment of infrastructure.

Operations and maintenance

There is no proactive maintenance only the municipality conducts reactive maintenance

Budget Priorities

Budget cuts and priority spending have negatively impacted on operations and maintenance at all water supply systems

OVERVIEW OF THE AREA

Lephalale Local Municipality is located in the Limpopo province, and forms part of the Waterberg District Municipality. According to the Köppen-Geiger climate classification most of Lephalale experiences hot and semi-arid climate. Lephalale experiences hot wet summers, and cool dry winters. Typical climate related hazards for Lephalale include flooding and droughts.

The drought and flooding impacts over recent years has escalated within this area.

CLIMATE SUMMARY

Historical Climate

According to the National Climate Change Information System, the province has experienced a warming trend of more than 1 °C per century for the period 1931-2015 (ccis.environment.gov.za). This is also reflected in the number of hot days, as the number of hot days has increased by about 1 day/decade for the same period.

Stations in the located in the northern regions of the province indicate significant decreases in annual precipitation, which has been found to be more than 10 mm/decade (ccis.environment.gov.za). It should be noted however, that based on the station data statistically significant increases in extreme daily rainfall events have been identified.

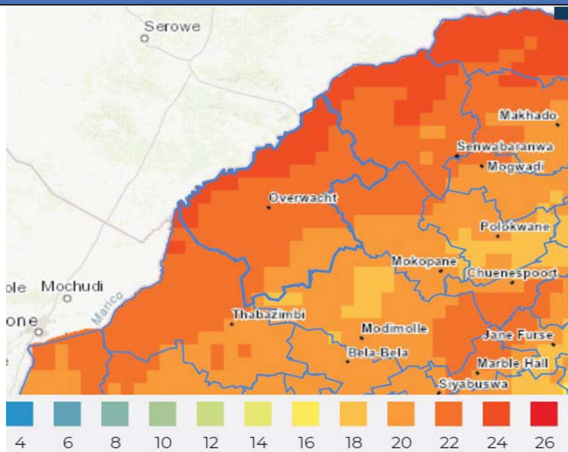
Future Climate

Under the high emissions scenario, temperatures are projected to increase by about 2°C in the near future (2015-2035), in the mid-future (2040-2060) temperatures are expected to increase by 1°C to 3°C, and for the far future (2080-2100) up to 3°C to 6°C (DEA, 2013). Under the **RCP 85 scenario, rainfall is projected to decrease. Rainfall for the area is likely to become more erratic, as some models project decreases in rainfall whereas other project increases (DEA, 2013). However rainfall is expected to be within range of present-day climate variability.

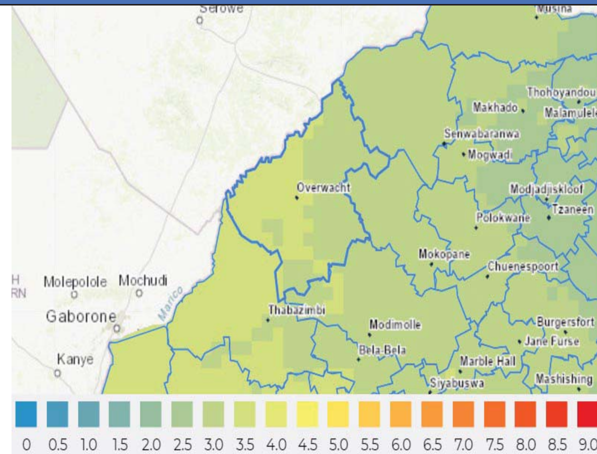
Under the medium emissions scenario *RCP45 temperatures are projected to increase but by the end of the century (2080-2100) increases are projected to only have increased by between 2°C and 3°C (DEA, 2013). Modest drying trends for rainfall are likely to occur. Rainfall is expected to be within range of present-day climate variability

*RCP4.5 represents a scenario whereby Greenhouse emissions have stabilized before 2100.
**RCP8.5 represents a scenario whereby greenhouse gas emissions continue to increase over time, and results in high concentrations of atmospheric greenhouse gases.

d) AVERAGE TEMPERATURE (°C)



b) AVERAGE PROJECTED TEMP (°C) INCREASE 2050



c) VERY HOT DAYS (2050)

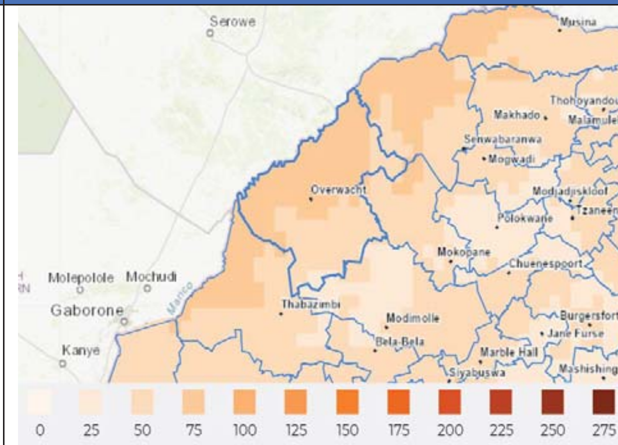
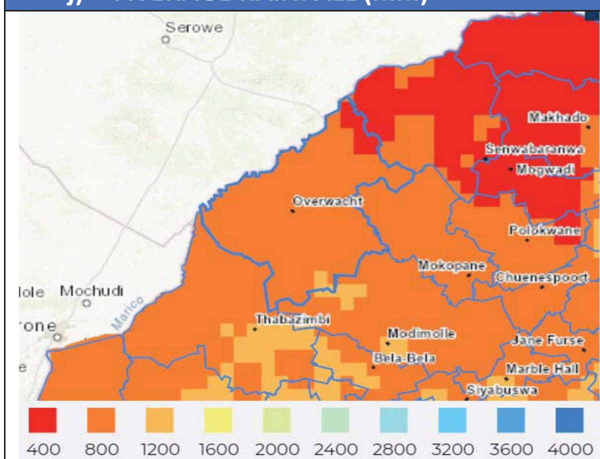
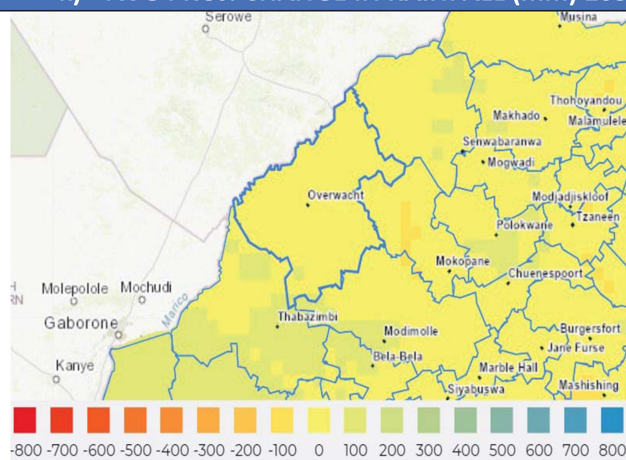


Figure 1: Uthukela District Municipality a) current average temperatures b) average projected temperatures c) projected very hot days (greenbook.co.za)

j) AVERAGE RAINFALL (mm)



k) AVG PROJ. CHANGE IN RAINFALL (mm) 2050



l) EXTREME RAINFALL DAYS (2050)

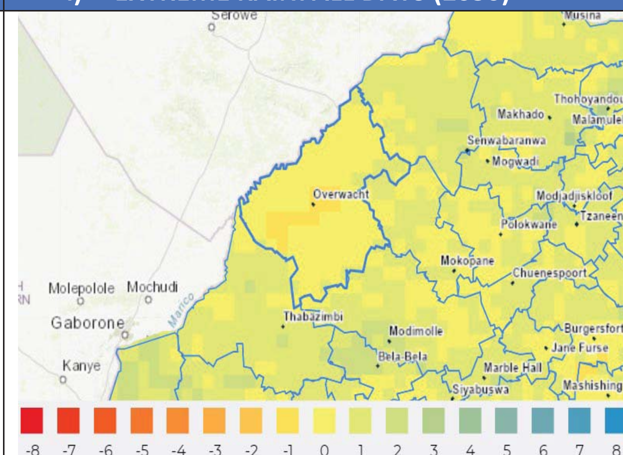


Figure 2: Uthukela District Municipality a) current average rainfall b) average projected rainfall c) projected extreme rainfall days (greenbook.co.za)

The following table provides you with observations from the site visits and review of material as to possible climate risks at your source, treatment and distribution. It is important that when updating the WSP going forward that you review the risks and recommended control measures. Thereafter, complete the validation and assess effectiveness of the control measure and residual risk. Lephalale Municipality largely relies on Exxaro who operates the treatment works.

	Severity				
Likelihood	Insignificant 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
Almost Certain 5	5	10	15	20	25
Likely 4	4	8	12	16	20
Moderate 3	3	6	9	12	15
Unlikely 2	2	4	6	8	10
Rare 1	1	2	3	4	5

Score	**Risk profile**	
0-10	Low	These systems operate with minor deficiencies. Usually the systems met the water quality parameters specified by the appropriate guidelines (SANS 241)
11-20	Moderate	These are system with deficiencies which individually or combined pose a high risk to the quality of water and human health. These systems would not generally require immediate action, but the deficiencies could be more easily to avoid future problems.
21-25	High	These are systems with major deficiencies which individually or combined pose a high risk to the quality of water and may lead to potential health and safety or environmental concerns. Once systems are classified under this category, immediate corrective action is required to minimise or eliminate deficiencies.

Climate resilient risk observations							
Process Step	**Hazardous Event**	**Hazard Type**	**Likelihood**	**Consequence**	**Risk score**	**Risk level**	**Suggested control measure**
Source	Problematic high colour content in raw water particular after heavy rains	Physical	3	3	9	L	Continuous adjustments at the treatment plant-based quality of water coming
Source	Increased turbidity in source water due to heavy rains	Chemical	2	2	4	L	Treatment is effective and able to produce adequately treated water
Source	Occasionally falling water levels due to drought	Quantity	2	2	4	L	Investigate alternative water sources prior to intense drought in the area
Treatment works	Infrastructure damage due to increase in extreme rainfall days	Physical, Chemical	3	3	9	L	Reduce flows into the works during periods of extreme rainfall
Treatment works	Access to the water treatment plant due to heavy rain fall	Physical	3	3	9	L	Exxaro and the municipality to investigate ways to improve the quality of the road to the treatment works
Reservoir	Reservoir dropping due to increase in usage and water losses	Quantity	2	2	4	L	Identify strategies to augment the drinking water supply
Reservoir (Rupert)	Minor corrosion was observed on the side walls of the reservoir	Physical	2	2	4	L	-
Network distribution	Water entering distribution is contaminated	Microbiological	3	4	12	M	Introduce temperature control in reservoirs
Network distribution	Contamination enters distribution system due to uncovered main holes	Physical	3	3	9	L	Develop a programme to check all manhole covers and network infrastructure

CONCLUSIONS

A review of the Lephalale Local Municipality Water Safety Plan based on Zeeland Water Treatment Works indicates that there is a lot of work that needs to be done to improve the plan as it does not have enough details particularly on the treatment plant that is operated by the mine. It is therefore imperative that both Exxaro and Lephalale municipality work together in compiling the Water Safety Plan from Catchment to consumer.

In general, the following is noted in order to update the climate resilience WSP:

- Updating the WSP Team to include the additional members identified that can assist with analysis and interpretation of climate related data/information. These members should also be able to recommend solutions to abate climate related threats
- Update the system description to understand the current climate of the area and the projected climate. Include the parts of the system that will be affected by climate threats
- Include additional risks in the risk register related to Finance, OHS, departmental risks, etc.
- Include climate related hazards and hazardous events in the risk register
- Develop control measures to address climate impacts. Control measures should be applicable in both the short and the long term
- Develop supporting programmes in relation to climate resilient threats
- Prioritise climate risks

Integrating climate information into the water safety plan and wastewater risk abatement plan

Lephalale Local Municipality

GENERAL OBSERVATIONS OF CURRENT W_2RAP

WASTEWATER RISK ABATEMENT PLAN REVIEW FOR LEPHALALE: PAARL WWTW	
Developed By	**HWA Engineers and project managers**
Step 1: **Assemble a team to develop the W_2RAP**	W_2RAP observations 1. W_2RAP team is in place, however, only consists of only 5members. These members include the Divisional Head of Sanitation, Plant supervisor, Technical Assistant, water Quality Specialist, Trainee technician. The W_2RAP team needs to include additional members such as Technical Director, Water Engineers and Technicians, and Water Network and Distribution personnel, etc. Recommendations 1. Need to additional team members such as: Decision makers, National departments (DWS, Dept. of health) Human resources, Finance department, Laboratories, water service providers, Disaster Risk Reductions specialists, locals, other key role players 2. Outline each member's role clearly and their level of participation (permanent or ad-hoc)
Step 2: **Document and describe the system**	W_2RAP observations 1. Basic climate related information is available; however, this is included in the background section of the document not in the system description. No description except the flow diagram. The flow diagram may be out of date, as the risk matrix mentions 3modules and not 2. The system is described; however, there is no understanding of the area/s served by the WWTW. The works is over-capacitated as it discharges 10ML/ day and the design capacity is 5ML/day. Interconnectivity between processes not adequately described. Not included are catchment descriptions, WQ objectives, industrial flows (if any). Solid liquid streams not captured on the PFD. Split between modules not included. Number of pump stations are included in the background section of the document but are not included on the PFD. Outflow from the WWTW not included. Groundwater sampling points not included in the PFD Recommendations 1. Include all network pump stations to the PFD 2. Include typical inflow Volumes from residential and industrial 3. Include CCP on the PFD 4. Update system description to discuss pump stations and CCPs
Step 3: **Assess the existing or proposed system**	1. This is not covered in the W_2RAP Recommendations 1. This section needs to be included in the W_2RAP

Step 4: **Hazard assessment and risk characterisation**	W_2RAP observations 1. Hazards have been adequately assessed using a 5 x 5 risk matrix. 20 of 30 Risks Identified are characterized as being 'High'. 6 of 30 Risks Identified are characterized as being 'Medium'. 4 of 30 Risks Identified are characterized as being 'Low'. Hazardous events not sufficiently described – e.g. X happens because of Y Recommendations 1. Include the detailed hazard description as either microbial, chemical, or physical
Step 5: **Identify hazards, control measures and preventative actions/validation**	W_2RAP observations 1. Not identified for all risks captured, risks do not include collection and reticulation systems, internal departmental risks (technical, IPAP, etc.). Many risks do not have control measures in place, and all risks include additional measures required this is due to control measures not being effective. Adequate validation of control measures also not in place Recommendations 1. Revise and include all the necessary control measures on risk abatement plan
Step 6: **Operational monitoring and maintaining control**	W_2RAP Observations 1. Parameters for operational and compliance monitoring are identified in the W_2RAP. The licensing requirements are discussed, however; the limits for each parameter that requires analysis are covered under management procedures. Additionally, no monitoring is taking place and is captured in the risk matrix Recommendations 1. Develop monitoring programme and implement as necessary
Step 7: **Verification that the W_2RAP is effective and meets health- and environmental-based targets**	1. This is not covered in the W_2RAP Recommendations 1. This section needs to be included in the W_2RAP
Step 8: **Management procedures for wastewater systems**	W_2RAP Observations 1. There is a long description of what management procedures are and when they should be implemented however management procedures have been included as part of an organogram for each alert level. Names for each action required are not provided on the organograms, in most cases only a position or organization is provided. The alert levels are included, alongside an organogram of the responsible parties and the actions required by each person/party and who they need to communicate the action to. Recommendations 1. Develop monitoring programme and implement as necessary
Step 9: **Documentation and communication**	1. Need to indicate how documentation of monitoring is captured/logged

Step 10: **Review of W_2RAP**	1. W_2RAP not reviewed annually as the W_2RAP is dated 2014. It is noted from the document, that the 2014 W_2RAP is the first iteration for Paarl WWTW.

STEP 1: CLIMATE RESILIENT TEAM ASSEMBLE

A typical Wastewater Risk Abatement Plan key team make up consists of members of the internal and external stakeholders on a particular wastewater supply system. Therefore, a team includes people with the following characteristics:

- Wastewater system knowledge (Receiving Network, Pump Stations, Treatment, Return to Source)
- Authority to make decisions (e.g. allocating human and financial resources, approving system changes)
- Responsibility for, and capacity to, help manage and prevent risks
- Adequate expertise to support the identification & management of all risks within the water supply system

Lephalale required typical WSP team members

- Technical Director
- Water Engineers and Technicians
- Water Network and Distribution personnel
- Water Works Superintendents and Senior Process Controllers
- Human Resources Departments
- Financial Department
- Catchment Management
- Water Monitoring and Laboratories (if in-house)
- National Departments (DWS, DEA, etc.)
- Public Health specialists
- Disaster reduction specialists
- Local people with a knowledge of the local climate and climate threats
- Managers, ward leaders and decision makers
- Water utility personnel with knowledge of drinking water related issues
- Water utility personnel with knowledge of natural water resources
- Experts on disaster and risk reduction and identification
- Other key role players

Climate Resilient Water Safety Plan Team make-up

In terms of climate resilience, the WSP team should include sector professionals that understand

- climate information
- water system knowledge
- authority figures and supporting members

Lephalale identified the following key members as to assist with climate resilience. These members will not be permanent members however invited to provide assistance and guidance on an ad-hoc basis to address climate impacts within the area and will include.

- Department of Water and Sanitation (Catchment)
- South African Weather Service (SAWS) – climate information
- Exxaro Operations and Maintenance team
- Municipal Chief Financial Officer
- Cooperate Services Office

- Environmental Health Practitioners
- Other mines representatives
- Eskom representative
- Disaster Management and
- Different portfolios – Councillors

STEP 2: CLIMATE SUMMARY DESCRIPTION

CLIMATE PROJECTIONS

Under *RCP 45 temperatures are expected to increase by 1.67-2.26°C 2050 but are expected to remain below 3°C (Figure 1b). Under **RCP 85 temperatures are expected to increase by 2.19-2.69°C, however by 2100 temperatures are expected to increase by 2-4°C. The number of extreme hot/dry days are expected to increase (Figure 1c)

Under both climate scenarios rainfall is projected to decrease well out of range of present-day climate variability (Figure 2b). * RCP 45 scenario projects rainfall will decrease by as much as 136.74mm/yr. **RCP 85 scenario indicates that rainfall will decrease by as much as 193.74mm/yr. Extreme rainfall days is expected to increase (Figure 2c)

KEY WATER SERVICES BUSINESS IMPACTS

COVID 19 Impacts

COVID-19 and the associated lockdown restrictions have resulted in delays in repairs and refurbishment of infrastructure.

Vandalism

High incidents of vandalism occurring in the area which has an impact financially for the municipality.

Operations

Wastewater treatment plant has delayed maintenance schedules as a result of COVID-19.

OVERVIEW OF THE AREA

Lephalale Local Municipality is located in the Limpopo province, and forms part of the Waterberg District Municipality. According to the Köppen-Geiger climate classification most of Lephalale experiences hot and semi-arid climate. Lephalale experiences hot wet summers, and cool dry winters. Typical climate related hazards for Lephalale include flooding and droughts.

The drought and flooding impacts over recent years has escalated within this area.

CLIMATE SUMMARY

Historical Climate

According to the National Climate Change Information System, the province has experienced a warming trend of more than 1 °C per century for the period 1931-2015 (ccis.environment.gov.za). This is also reflected in the number of hot days, as the number of hot days has increased by about 1 day/decade for the same period.

Stations in the located in the northern regions of the province indicate significant decreases in annual precipitation, which has been found to be more than 10 mm/decade (ccis.environment.gov.za). It should be noted however, that based on the station data statistically significant increases in extreme daily rainfall events have been identified.

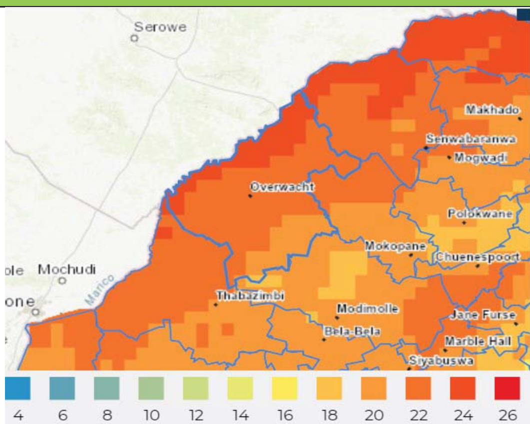
Future Climate

Under the high emissions scenario, temperatures are projected to increase by about 2°C in the near future (2015-2035), in the mid-future (2040-2060) temperatures are expected to increase by 1°C to 3°C, and for the far future (2080-2100) up to 3°C to 6°C (DEA, 2013). Under the RCP85 scenario, rainfall is projected to decrease. Rainfall for the area is likely to become more erratic, as some models project decreases in rainfall whereas other project increases (DEA, 2013). However rainfall is expected to be within range of present-day climate variability.

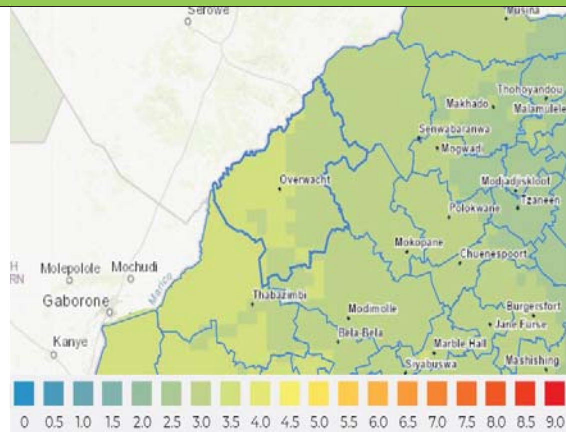
Under the medium emissions scenario RCP45 temperatures are projected to increase but by the end of the century (2080-2100) increases are projected to only have increased by between 2°C and 3°C (DEA, 2013). Modest drying trends for rainfall are likely to occur. Rainfall is expected to be within range of present-day climate variability

*RCP4.5 represents a scenario whereby Greenhouse emissions have stabilized before 2100.
**RCP8.5 represents a scenario whereby greenhouse gas emissions continue to increase over time, and results in high concentrations of atmospheric greenhouse gases.
(Chaturvedi et al., 2012)

e) AVERAGE TEMPERATURE (°C)



b) AVERAGE PROJECTED TEMP (°C) INCREASE 2050



c) VERY HOT DAYS (2050)

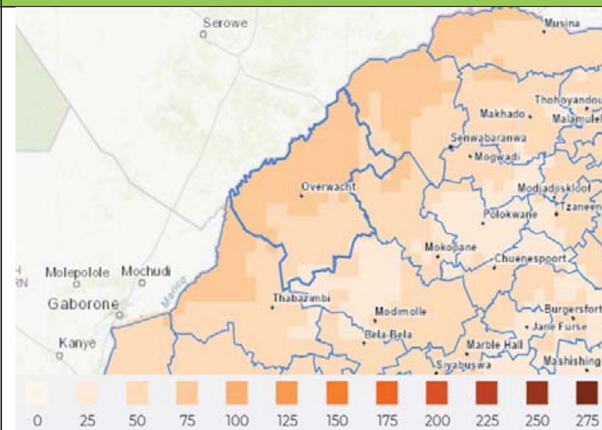
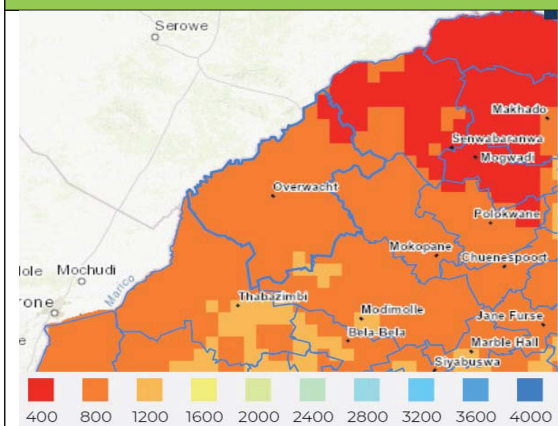
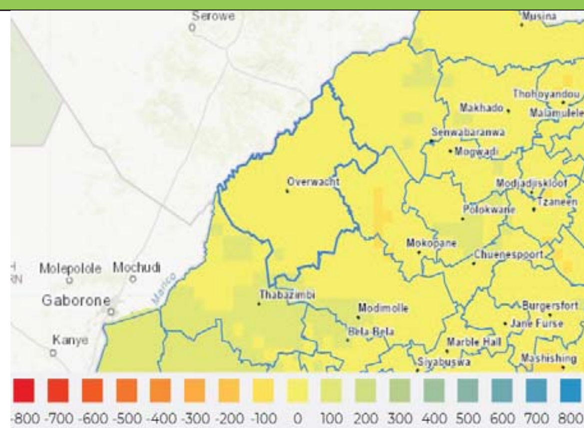


Figure 1: Lephalale Municipality a) current average temperatures b) average projected temperatures c) projected very hot days (greenbook.co.za)

m) AVERAGE RAINFALL (mm)



n) AVG PROJ. CHANGE IN RAINFALL (mm) 2050



o) EXTREME RAINFALL DAYS (2050)

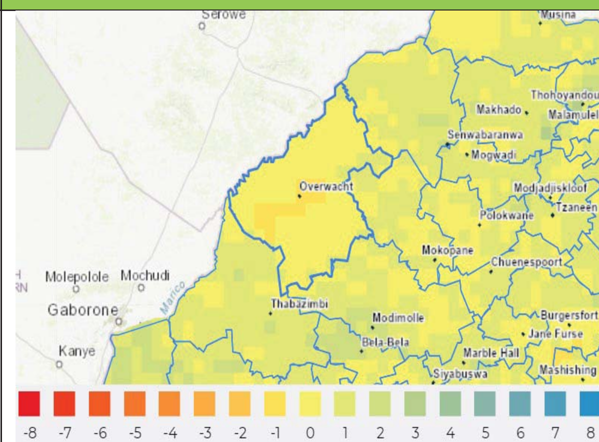


Figure 2: Lephalale Municipality a) current average rainfall b) average projected rainfall c) projected extreme rainfall days (greenbook.co.za)

STEP 4/5: IDENTIFICATION OF CLIMATE HAZARD & HAZARDOUS EVENTS/DETERMINATION & VALIDATE CONTROL MEASURES, ASSESS & PRIORITISE RISK

The following table provides you with observations from the site visits and review of material as to possible climate risks at your source, treatment, and distribution. It is important that when updating the WSP going forward that you review the risks and recommended control measures. Thereafter, complete the validation and assess effectiveness of the control measure and residual risk.

Likelihood	Severity				
	Insignificant 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
Almost Certain 5	5	10	15	20	25
Likely 4	4	8	12	16	20
Moderate 3	3	6	9	12	15
Unlikely 2	2	4	6	8	10
Rare 1	1	2	3	4	5

Score	Risk profile	
0-10	Low	These are systems that operate with minor deficiency and usually meet the effluent quality specifications set by the Department of Water Affairs. It is unlikely that this level of risk is harmful to the health of people and the environment. Aesthetically and/or physical non-compliance can be expected for short periods.
11-20	Moderate	These are systems with deficiencies which individually or combined pose a high risk to the quality of the receiving environment and health. These systems would not generally require immediate action but the deficiencies should be rectified to avoid future problems and associated cost to rectify once in HIGH risk. Aesthetically and/or physically non-compliance can be expected over a medium term. Medium term impact on infrastructure and partial failure of the wastewater treatment plant and disinfection process is likely.
21-25	High	These are systems with deficiencies which individually or combined pose a high risk to the quality of the receiving environment and health, and may lead to potential health, safety and environmental concerns. Once a system (or part of a system) is classified under this category, immediate corrective action is required to arrest or eliminate the deficiency. High impact on the health of people and the environment and/or significant damage to infrastructure can be expected. Total failure of the collector, treatment and disinfection facility is likely.

Climate resilient risk observations							
Process Step	**Hazardous Event**	**Hazard Type**	**Likelihood**	**Consequence**	**Risk score**	**Risk level**	**Suggested control measure**
Insufficient process controllers (numbers).	The works operates only during the day. If there are any malfunctions during the night, they will be attended to in the morning due to lack of process controllers	Quality	4	4	16	H	Update the organogram and employ the adequate process controller required for the plant
Process controllers with inappropriate skills/qualifications.	Process controller's classification does not meet the DWS process controller requirements.	Physical	4	4	16	H	Develop a skills development programme and train the process controllers and classify
Wastewater treatment plant	Treatment works overload and therefore overflowing from time to time	Microbiological	4	4	16	H	Upgrade the treatment works, investigate the requirements to start utilizing the existing ESKOM system that is standing still
Pump stations	Damage to pump station infrastructure due to lack of maintenance	Physical	2	4	8	M	Develop and implement a maintenance programme
WWTW	Overflowing of WWTW under extreme rainfall conditions	Physical	3	4	12	H	Install flow reduction measures such as a balancing dam at the WWTW

WWTW	Grit enters the aeration basin due to no degritting process taking place	Physical	5	2	10	M	Install degritters
WWTW	Animals accessing the WWTW due to poor fencing conditions	Physical	3	3	9	M	Adequately fence the WWTW
WWTW	WWTW treatment works becomes inundated under extreme rainfall conditions	Physical	2	4	8	M	Improve stormwater drainage at the WWTW
WWTW	Flooding of access roads leading to wastewater treatment works due to increase in extreme rainfall days	Physical	1	4	4	L	Improve access road stormwater drainage systems
WWTW	Reduced chlorine contact time due to high temperatures resulting in evaporation of chlorine	Chemical	3	5	15	H	Develop a plan to increase chlorine dosage under higher temperatures
WWTW	Flooding of sludge lagoons under extreme rainfall events	Microbial	2	5	10	H	Install retention walls around sludge lagoons and move informal settlement away from sludge lagoons
Network	Stormwater ingress into network due to high extreme rainfall	Physical	2	4	8	M	Ensure routine checks are done and upgrade those points that are likely to be affected by stormwater ingress

CONCLUSIONS

A review of the Lephalale Local Municipality Wastewater Risk Abatement Plan based on Paarl Wastewater Treatment Works indicates that there is a lot of work that needs to be done to improve the plan as it does not have enough details. It is therefore imperative that both Lephalale Municipality and the mine seeks to address the current work collapse of the treatment system.

In general, the following is noted in order to update the climate resilience W_2RAP:

- Updating the W_2RAP Team to include the additional members identified that can assist with analysis and interpretation of climate related data/information. These members should also be able to recommend solutions to abate climate related threats
- Update the system description to understand the current climate of the area and the projected climate. Include the parts of the system that will be affected by climate threats
- Include additional risks in the risk register related to Finance, OHS, departmental risks, etc.
- Include climate related hazards and hazardous events in the risk register
- Develop control measures to address climate impacts. Control measures should be applicable in both the short and the long term
- Develop supporting programmes in relation to climate resilient threats
- Prioritise climate risks