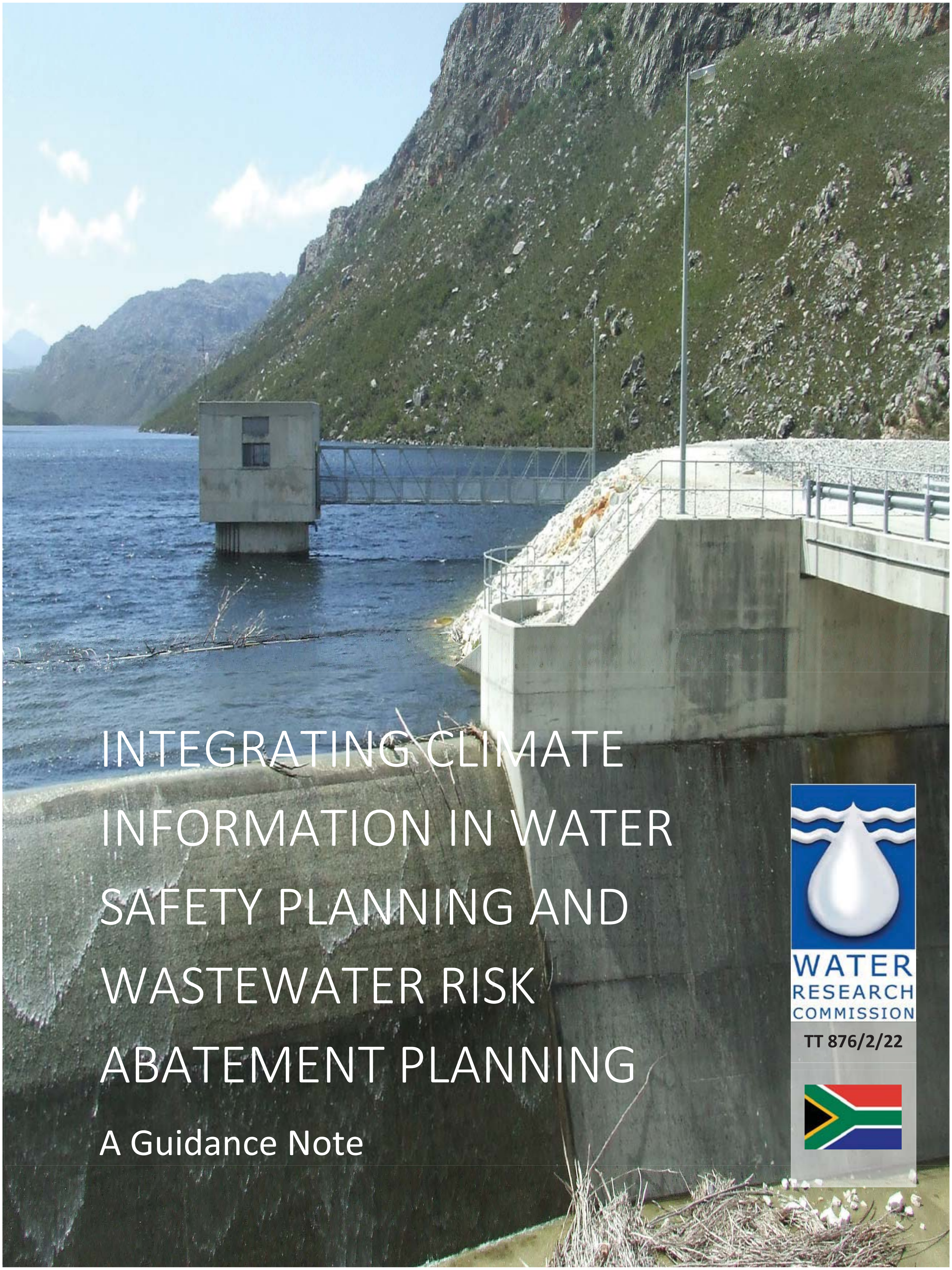
INTEGRATING CLIMATE INFORMATION IN WATER SAFETY PLANNING AND WASTEWATER RISK ABATEMENT PLANNING

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

A Guidance Note

WATER RESEARCH COMMISSION

TT 876/2/22



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This report is Part Two of a set of two reports. The other report is *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* (WRC Report No. TT 876/1/22).

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Executive Summary

Water Services Institutions (WSIs) 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. This guideline attempts to bridge this gap by providing WSIs with a detailed list of climate related data / information sources, and a methodology to draw basic climate impact conclusions for use in risk management and planning activities. The methodology was piloted in three municipalities in South Africa, *viz.* Lephalale Local Municipality (Limpopo), Uthukela District Municipality (KwaZulu-Natal) and Witzenberg Local Municipality (Western Cape). The methodology highlights:

1. The need to consider various sources of climate data and information,
2. Collecting, collating, and summarizing the information,
3. Updating and refining water safety plans (WSPs) and wastewater risk abatement plans (W_2RAPs) to incorporate climate considerations

This guideline document outlines each of the steps that WSIs would need to follow to develop and implement climate resilient water safety plans (CR-WSPs) and climate resilient wastewater risk abatement plans (CR-W_2RAPs) within their area of jurisdiction. In South Africa, metropolitan municipalities 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. The guidance and methodology herein has been designed for ease of use, and therefore primarily considers data / information sources where data has already been analysed. Users of this guideline therefore do not need a high level of technical skill to analyse and generate outputs from the data to draw climate impact related conclusions.

Acknowledgements

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- Dr Joel Botai - South African Weather Services
- Mr Francios Van Wyk - Rand Water
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- Ms Mapula Mametja - Rand Water

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- Witzenberg Local Municipality (Western Cape), and in particular Stephanie Farmer, Marquin Pieterse and Nathan Jacobs

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Abbreviations and Acronyms

CMA	**-**	Catchment Management Area
CR-WSP	**-**	Climate Resilient Water Safety Plan
CR-W_2RAP	-	Climate Resilient Wastewater Risk Abatement Plan
CSAG	-	Climate Systems Analysis Group
CSIR	-	Council for Scientific and Industrial Research
DEA	-	Department of Environmental Affairs
DWS	-	Department of Water and Sanitation
KZN	-	KwaZulu-Natal
RCP	-	Representative Concentration Pathways
SALGA	-	South African Local Government Association
SAWS	-	South African Weather Services
SOP	-	Standard Operating Procedures
W_2RAP	-	Wastewater Risk Abatement plan
WRC	-	Water Research Commission
WSI	-	Water Services Institution
WSP	-	Water Safety Plan
WTW	-	Water Treatment works
WWTW	-	Wastewater Treatment Works

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. The most significant water quality issues 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 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. 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 is likely to be further exacerbated by climate change, with water supply further contracting and demand escalating.

1.2 Purpose of this guideline

This guidance note emanates from the WRC project entitled "*Using Climate Data to Help South African Water Services Institutions Improve Water Safety and Wastewater Risk Abatement Planning and Enhance Resiliency to Climate Change at Local and Catchment Level*". The project has a special focus in the Western Cape (recently affected by drought), KwaZulu-Natal (recently affected by flooding) and Limpopo (recently affected by droughts and flooding, and potential transboundary water issues with neighbouring countries).

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

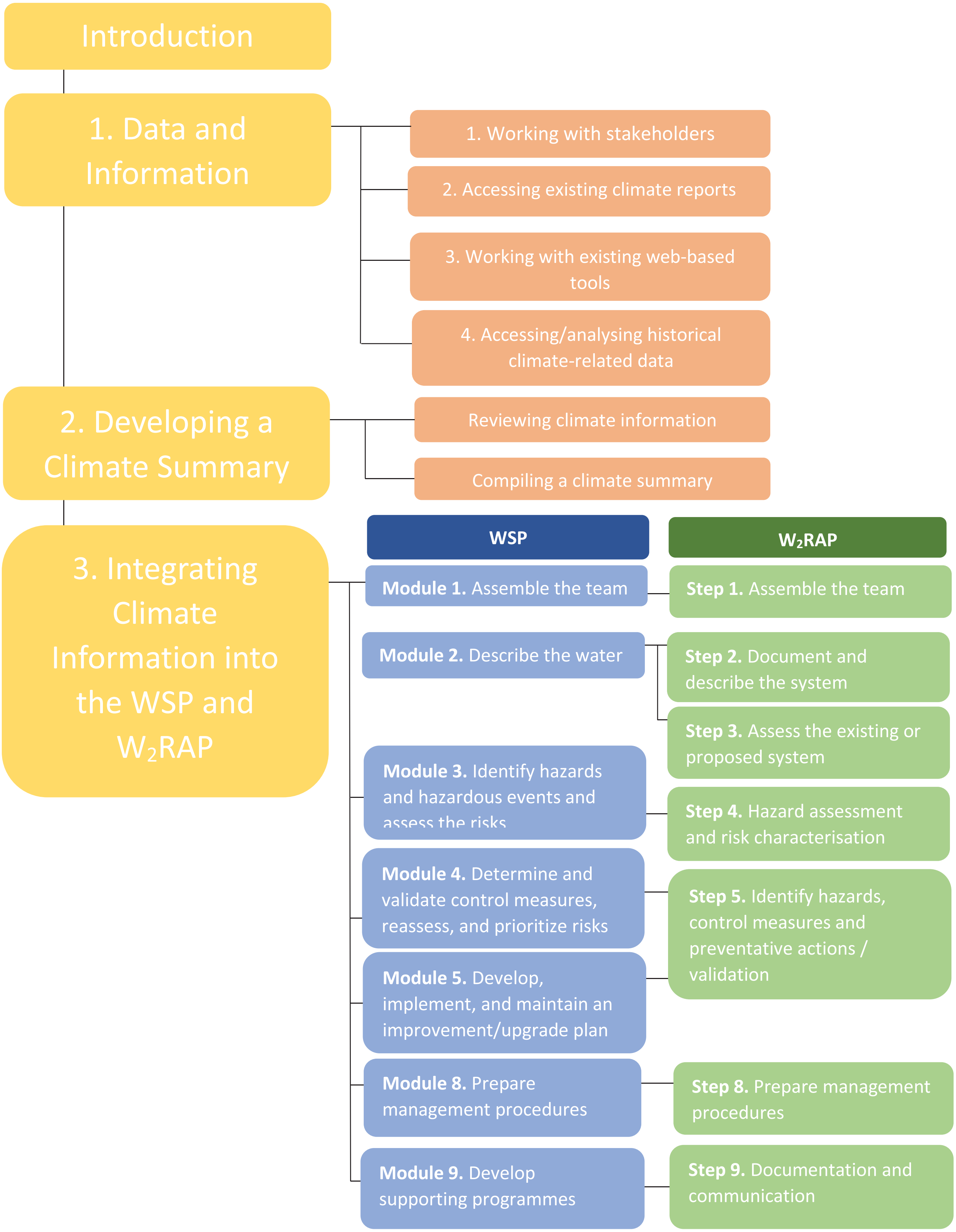
- Less rainfall reduces runoff within catchments, leading to less water availability in dams. This could result in reduced environmental/river health, increased water restrictions and/or increased water prices (e.g. due to need for more sophisticated technologies such as desalination).

- 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 particular concern.

WSIs, however, struggle to interpret and incorporate climate data/information into their 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.

This guidance note has been developed with WSIs in mind and fills the gap faced by these institutions through an easy-to-follow practical methodology. The methodology herein describes how to access, collate, interpret, summarise, and integrate climate information into the WSP and W_2RAP.

2. Guideline Roadmap



3. Data and Information

3.1 Sources, availability, accessibility, ease of use of climate data and information

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 of climate change 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, the availability, ease of access, and the ease of using that information to support WSP and W_2RAP. It is strongly advised that you first consider 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/models, 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 at least start simple (i.e. consider approach 1), and incrementally improve over time (i.e. consider approach 2, approach 3, or approach 4 – see overleaf).**

Table 1: Overview of each approach

Information type	Description	Target audience	Capacity/Resources required	Should we use this information?
Approach 1 – Working with stakeholders	Information is in the form of stakeholder interviews	Generalists	Low capacity required. Target audience only need a basic understanding of climate change and the effects of climate change. ***Ease of use: +***	This type of data and information should be used when you have little to no access to climate data or information. This information can be readily accessed through discussion and records with key stakeholders.
Approach 2 – Accessing existing climate reports	Summarised information is typically contained in an existing climate report/s. Information is readily available within the report and already 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: + +***	This type of data and information should be used when you have access to climate reports that are relevant to your area. These reports should be developed, ideally, at the local level but provincial level data and information may also be used.
Approach 3 – Working with existing web-based 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: + + +***	This type of data and information should be used when you have access to web-based tools and a team of technical specialists that understand and can interpret the data and information.
Approach 4 – Accessing/analysing historical climate-related data	Provides users with a starting point to collect data and information, especially where there is no / little data available, or data is inaccessible. You will need to setup monitoring stations/systems. Data from stations will have to be collated, verified, and analysed to generate associated information/intelligence.	Technical specialists	High level technical expertise required, with access to technology, to access and retrieve information ***Ease of use: + + +***	This type of data and information should be used when you have the skill, capacity, and tools as well as a team of technical specialists that understand and can interpret the data and information.

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, as well as ability to access, analyse and understand various types of information.

It is important that you consider each of the four approaches before deciding which approach suits your context the best. The team should, therefore, carefully study the climate resources information **(Appendix A).**

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.

4. Developing A Climate Summary

4.1 What is a climate summary?

The purpose of a climate summary is to collate climate data and information into a short but detailed overview of the current and climate as well as climate projections for an area. Changes in the observed climate – for ideally 30 years – depending on data/information availability. The climate summary also provides you with an indication as to how climate is expected to change in the form of climate projections. A climate summary also includes a list of threats that have occurred in the past, but also those treats that are likely to occur under the influence of climate change.

Climate information such as average temperature, rainfall projections, climate hazards and climate adaptation measures are available within the South African context. This information is available climate in reports, scientific literature, and web tools. You may have to consider the information from various sources as not all data / information will necessarily be found in one source. There are three basic processes to develop a climate summary, including:

- Accessing Information,
- Reviewing information, and
- Compiling the climate summary

4.2 Accessing climate data / information

Incorporating climate resilience into your WSP and W_2RAP processes requires an understanding of the historical climate, climate trends, climate projections (future scenarios) and climate hazards. 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. Table 2 provides suggested resources of and the data / information to be used when following the guidance provided in this document. It is recommended that you refer to the 'Suggested resource and where to source' column of Table 2, as the first source of data / information.

Please note that a more comprehensive list of data sources is provided in ***Appendix A****. It is recommended that you consult the comprehensive list only if the suggested data / information does not meet your needs, or when you need more sophisticated data / information sources.*

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 and W_2RAP 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.

Table 2: Data / Information type and the sources

Type of data	Source of data	Suggested resource and where to source (website or document)	Additional resource
Map of the Municipality	1. Municipal reports 2. Stakeholders 3. Websites and web-based tools	1. Integrated Development Plan (IDP) - *can be retrieved on the municipal website*	1. Greenbook - https://riskprofiles.greenbook.co.za/ 2. Municipalities of South Africa - https://municipalities.co.za/
Municipal Population	1. Municipal reports 2. Websites and web-based tools	*1.* IDP - *can be retrieved on the municipal website*	1. Municipalities of South Africa - https://municipalities.co.za/ 2. Stakeholders - *can be retrieved from the GIS department*
Number of Households within the municipality	1. Municipal reports 2. Websites and web-based tools	1. IDP - can be retrieved on the municipal website	1. Municipalities of South Africa - https://municipalities.co.za/ 2. Stakeholders - *can be retrieved from the GIS department*
Municipal average annual rainfall	1. Web-based tools, 2. Climate reports – Such as annual state of climate, 3. Municipal reports	1. Greenbook - https://riskprofiles.greenbook.co.za/	1. Climate systems analysis group (CSAG) - https://cip.csag.uct.ac.za/webclient2/datasets/africa-merged/ 2. South African Weather Service (SAWS) - www.weathersa.co.za 3. IDP - *can be retrieved on the municipal website*
Municipal minimum and maximum temperatures	1. Web-based tools 2. Climate reports	1. Greenbook - https://riskprofiles.greenbook.co.za/	1. CSAG - https://cip.csag.uct.ac.za/webclient2/datasets/africa-merged/ 2. South African Weather Service (SAWS) - www.weathersa.co.za 3. IDP - *can be retrieved on the municipal website*
Municipal climate trends	1. Web-based tools 2. Climate reports	1. Climate Information Platform (CIP)- https://cip.csag.uct.ac.za/webclient2/app/#datasets	1. South African Weather Service (SAWS) - www.weathersa.co.za; 2. Scientific Literature – *Journal articles*
Municipal Climate projections	1. Web-based tools 2. Climate reports	1. Greenbook - https://riskprofiles.greenbook.co.za/ 2. Long-term Adaptation Scenarios - https://www.environment.gov.za/sites/default/files/docs/climate_trends_bookV3.pdf	1. CSAG - https://cip.csag.uct.ac.za/ webclient2/datasets/africa-merged/ 2. National Climate Change Information System (NCCIS) - https://ccis.environment.gov.za/#/ 3. Department of Environmental affair LTAS - https://www.environment.gov.za/ 4. SAWS Climate Change Reference Atlas - https://www.weathersa.co.za/Documents/Climate/SAWS_CC_REFERENCE_ATLAS_PAGES.pdf
Municipal Climate hazards / threats	1. Web-based tools 2. Climate reports, 3. Stakeholders,	1. Greenbook - https://riskprofiles.greenbook.co.za/	1. Think Hazard - https://thinkhazard.org/en/report/227-south-africa/CF 2. NDMC Disaster Atlas App- https://gis-portal.ndmc.gov.za/portal/apps/webappviewer/index.html?id=700928590ea84665b234b038eb96c210 3. NCCIS - https://ccis.environment.gov.za/#/ 4. Long-term Adaptation Scenarios - https://www.environment.gov.za/sites/default/files/docs/climate_trends_bookV3.pdf

4.3 Reviewing the data / information and compiling the climate summary

In the previous section a curated table of suggested data / information sources was provided, which represents the minimum requirements to develop a climate summary for your municipality. This section will cover where / how to retrieve the information. As you progress through this section you will be guided on how to progressively develop your climate summary. This section provides a list of questions that must be asked of the data / information what needs to be taken from the suggested resource/s as per able 2. The questions are as follows:

- What is the geographic location of the local municipality within South Africa? Map, location, and climate description
- What is your municipality's population and number of households?
- What is the average annual rainfall observed within your municipality?
- What is the average maximum and minimum temperature for your municipality?
- During which months does your municipality experience the wet and dry seasons, respectively?
- What is the long-term (~30year) trend of extreme rainfall / temperature for your municipality?
- How is rainfall / temperature projected to change in the future for your municipality?
- Is rainfall / temperature expected to increase or decrease in the future for your municipality?
- How will the wet / dry season be affected i.e. are rainfall / temperature averages projected to increase or decrease?
- What are the typical threats for your municipality?

4.4 *What is the geographic location of the local municipality within South Africa?*

A map of the municipality can be easily retrieved from your municipalities Integrated Development Plan (IDP).

- When retrieving the map from the IDP, you are likely to find the map under the situational analysis or background section (or similar) within the IDP.

Figure 1: Example of a map of Lephalale Municipality as retrieved from the 2019-2020 IDP.

- Summarise the situational analysis, background, or climate section, as per the IDP, to provide a brief overview of the area as well the local climate.

- Population and household data, can be found under the demographics section of your municipalities IDP.

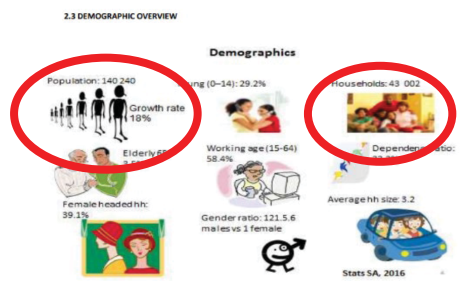


Figure 2: Demographic information

- The map, summary population and household should be included in the climate summary.

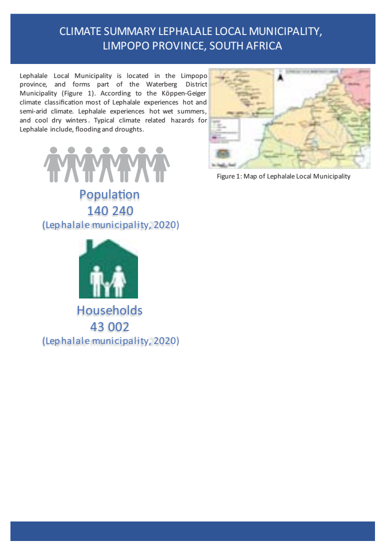


Figure 3: Updated climate summary

4.5 *Accessing climate information*

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 and services. Climate information can be analyzed 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. Climate information can be accessed from various sources, such as climate reports, scientific literature, and web-based tools. It is recommended that you consider web-based tools, as these tend to be updated more regularly. For this guidance note, **Green Book**, Climate Systems Analysis Group (CSAG) **Climate Information Platform** (CIP), **Think Hazard** and **Long-term Adaptation Scenarios** climate report will be referenced to access climate information. Using these information sources, the final climate summary for your area will provide a background of your area with a map and population and household information. The current climate for your area will also be described as well as the annual seasonal changes. The climate summary will also denote the long-term changes in rainfall and temperature, and how these have changed i.e. increased, or decreased over time. Climate projections will also be described, which is how temperature and rainfall is likely to change i.e. increase or decrease in the future. A list of hazards that are associated with your area and the impact that climate change will have on those hazards will also be described.

4.6 *Accessing Green Book*

- To access the climate information, visit Green Book at www.greenbook.co.za, and select the 'Risk Tool' option.

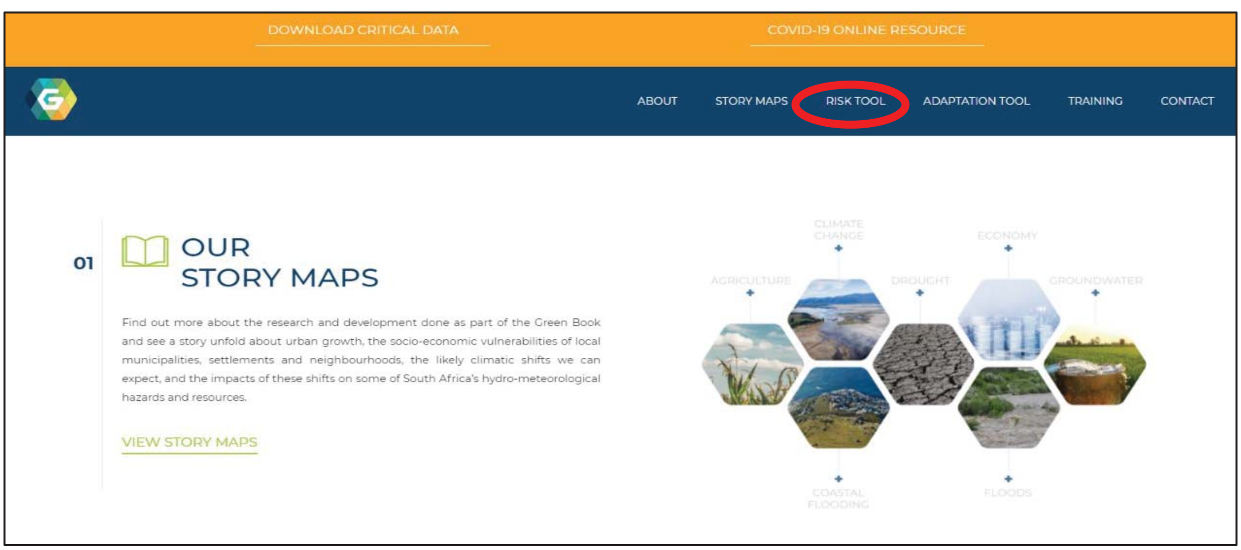


Figure 3: Greenbook home page

- You will be redirected to the Municipal Risk Profiles page, which displays a map showing the local municipalities across South Africa.

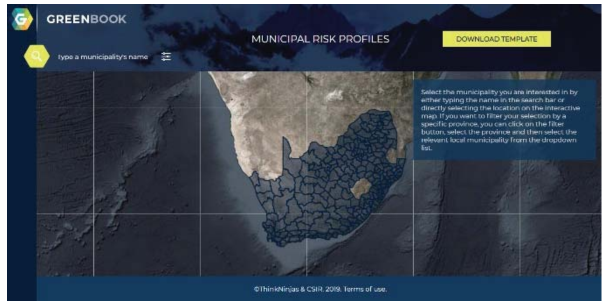


Figure 4: Greenbook municipal risk profiles page

- Select your municipality by clicking on the appropriate point on the map.

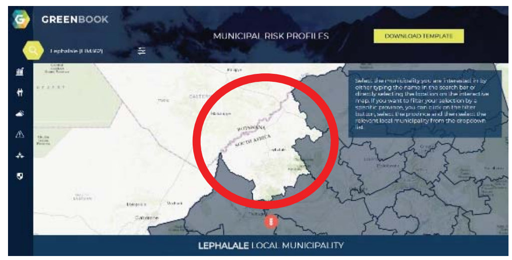


Figure 5: Selecting a municipality from the map

- You can also select your municipality by typing in the municipality's name, in the search bar.

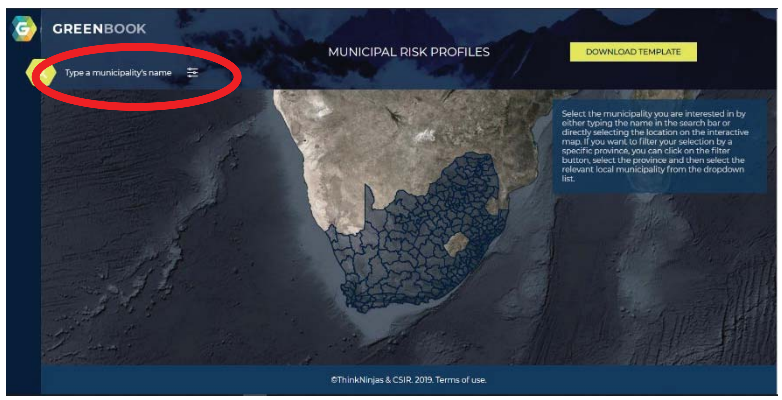


Figure 6: Selecting a municipality through the search

- After you have selected your municipality, you will be redirected to a page that displays your municipality's current vulnerability.

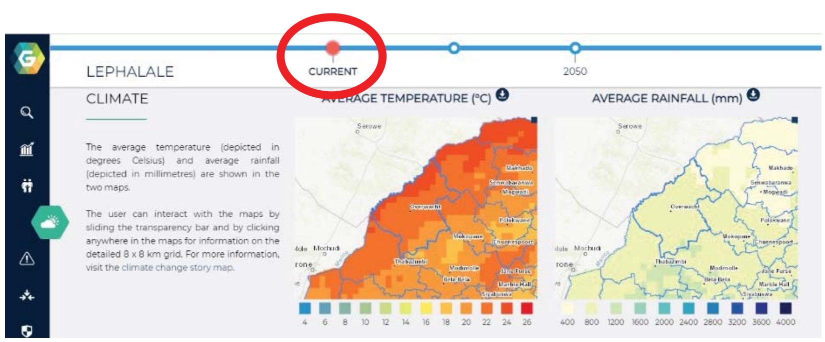


Figure 7: Current climate in the municipality

- Projected vulnerability can also be viewed by clicking the 2050 icon.

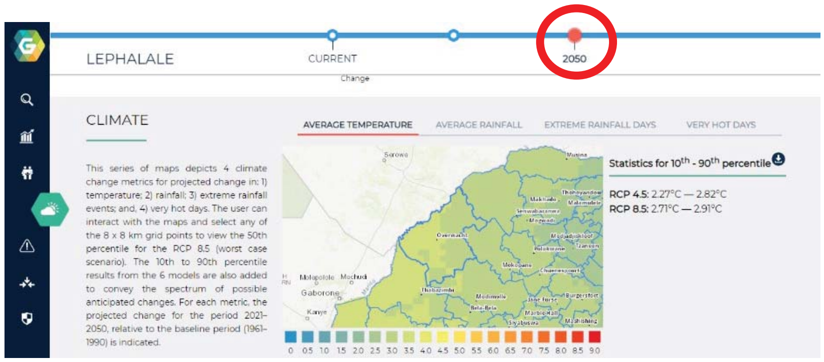


Figure 8: view projected climate for 2050

For the purposes of this guidance note, accessing only the climate related information (rainfall, temperature, hazards, and projections) will be covered.

4.7 What is the average temperature and rainfall observed within your municipality?

- When you have selected your municipality, two maps will be displayed showing average temperature (°C) and rainfall (mm) for your municipality.

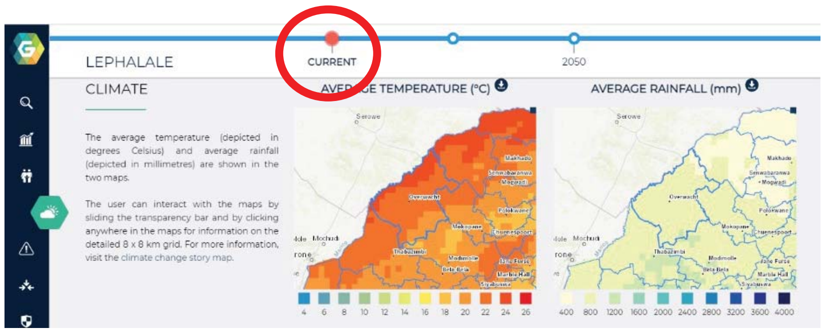


Figure 9: temperature and rainfall maps for the selected municipality

- Information in these maps are satellite data which are displayed in an 8 x 8 km grid. Therefore, clicking on the map will provide you with the average temperature / rainfall for a particular 8 x 8 Grid.

- To get the average temperature for your area click on the map, ideally at or near to the area where your system is located.

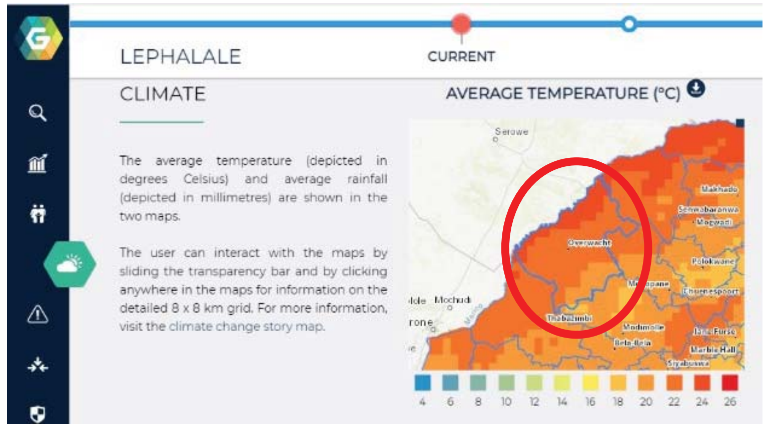


Figure 10: Selected municipality temperature map

- A small pop-up will appear in the top-right corner of the map. The pop-up in the temperature map, displays the minimum, maximum and average annual temperature for the selected grid.

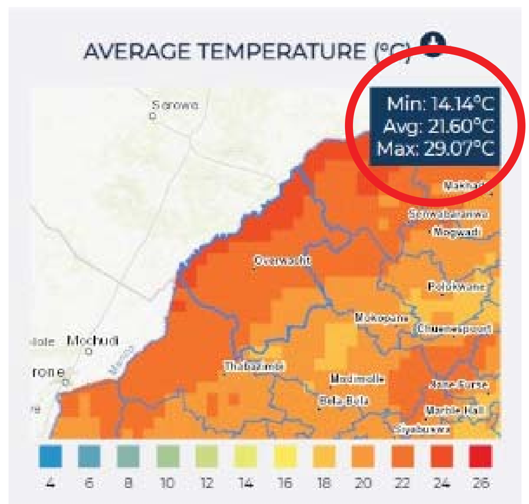


Figure 11: Temperature averages for the municipality

- To get the average rainfall for your area click on the map, ideally at or near to the area where your system is located.

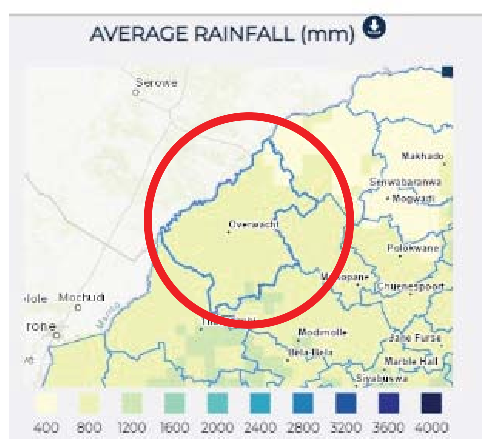


Figure 12: Selected municipality rainfall map

- A small pop-up will appear in the top-right corner of the map. The pop-up in the rainfall map, displays the average annual rainfall for the selected grid.

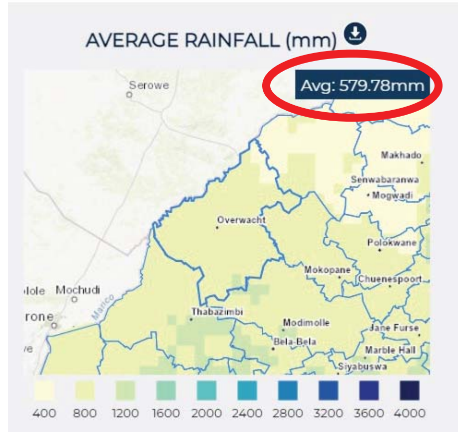


Figure 13: Rainfall averages for the municipality

- The temperature and rainfall information and map you retrieved from Greenbook should be recorded in your climate summary.

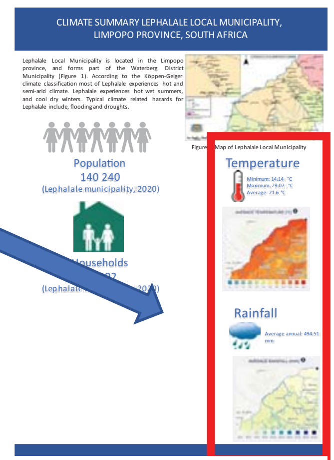


Figure 14: Updating the climate summary with temperature and rainfall averages

4.8 Accessing Climate Information Platform

- To access the climate trend information, visit the Climate Information Platform (CIP) at https://cip.csag.uct.ac.za/.

- To begin accessing the data / information, click "here" under the "How do I get started?" section.

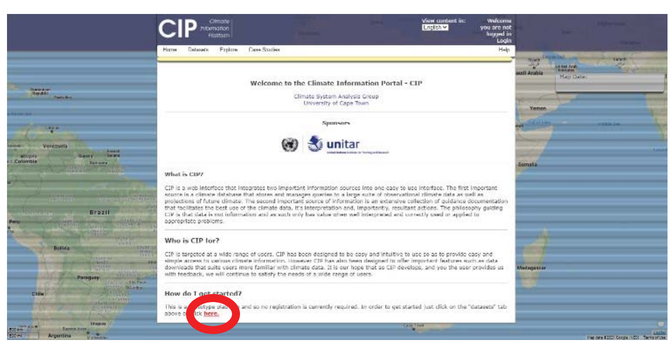


Figure 15: CIP homepage

- On the page that loads you are given the option to select between “African merged stations CMIP3” and “African merged stations CMIP5” data sources. The suggested option for this guideline document is the “African merged stations CMIP5.

Figure 16: Data / information selection

- You will be redirected to a page displaying satellite data and the location of weather stations across Africa.

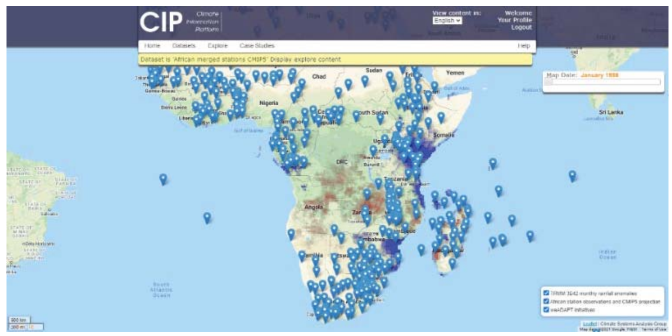


Figure 17: Weather stations across Africa

- To view the station data, you need to click on the station for your location. A list of information including long-term historical climate records, historical average seasonality and future climate projections.

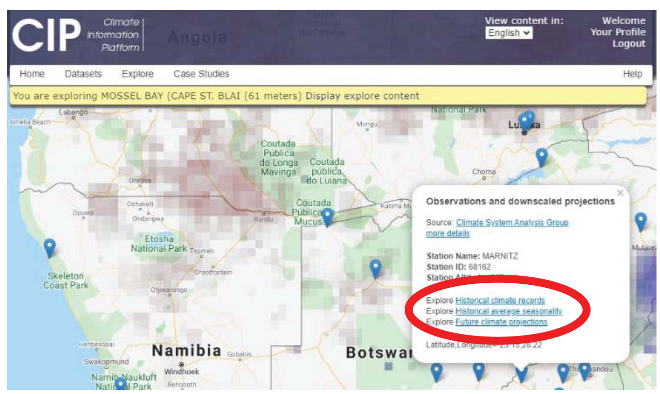


Figure 18: Selecting a station

Why should I use CMIP5 over CMIP3?

It is suggested that you use the CMIP5 dataset as the CMIP 3 provides climate projections for two time periods i.e. 2046-2065 and 2081-2100, and the does not consider the impact of reducing carbon emissions. Additionally, the CMIP3 only provides climate projections for rainfall. The CMIP5 dataset, however, provides climate projections for climate scenarios RCP 4.5 and RCP 8.5. The information also provides climate projections for both rainfall and temperature, as well as the projected extremes for both temperature and rainfall. The RCP 4.5 scenario represents a scenario whereby radiative forcing is stabilized before 2100 i.e. Greenhouse gas emissions are reduced; and RCP8.5 represents a scenario whereby greenhouse gas emissions continue to increase over time, and results in high concentrations of atmospheric greenhouse gases. Additionally, these emissions scenarios cover time periods from 1960 to 2090 (Chaturvedi *et al.,* 2012). Therefore, it is recommended that you use the CMIP5 dataset as it allows you to understand how climate is likely to change under two scenarios and allows you to plan for the appropriate scenario an extreme as required.

4.9 What is the seasonal and long-term (~30year) trend of extreme rainfall / temperature for your municipality?

- To get data for your area select the weather station in your area or the weather station nearest to your area.

- To determine the seasonality of your area i.e. the wet and dry season, select the "Historical average seasonality" option for the weather station.

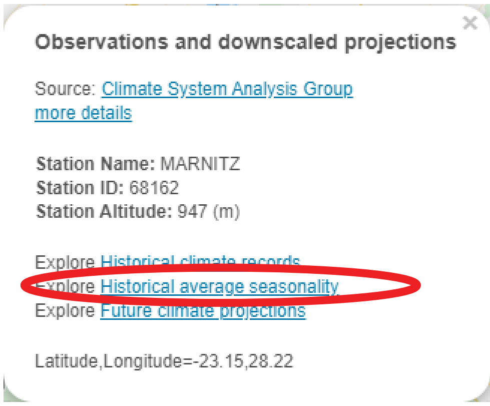


Figure 19: Selecting historical average seasonality

- The graph generated will display long-term monthly climatology of rainfall totals and monthly averaged minimum and maximum temperatures.

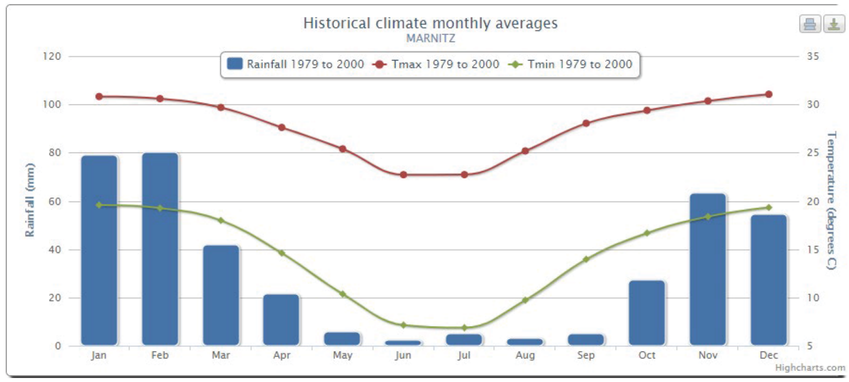


Figure 20: Annual trends in climate

- Download the graph by clicking the download button and selecting either .png or .jpg.

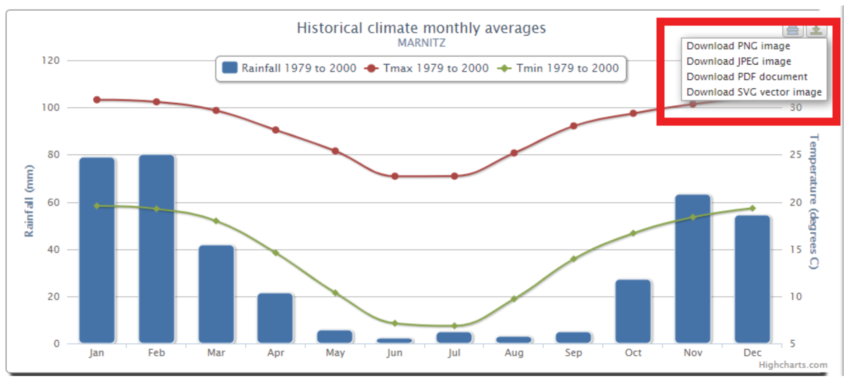


Figure 21: graph download

There is no station at my location, what Weather station should I use?

Weather stations are not available for every town or city across South Africa. However, weather stations are located such that the data collected from the weather station is representative for an area and its surrounds. Therefore, when selecting the weather station that is representative, it is recommended that you use the station closest to your area.

- The graph must be added to the climate summary and the seasons described.

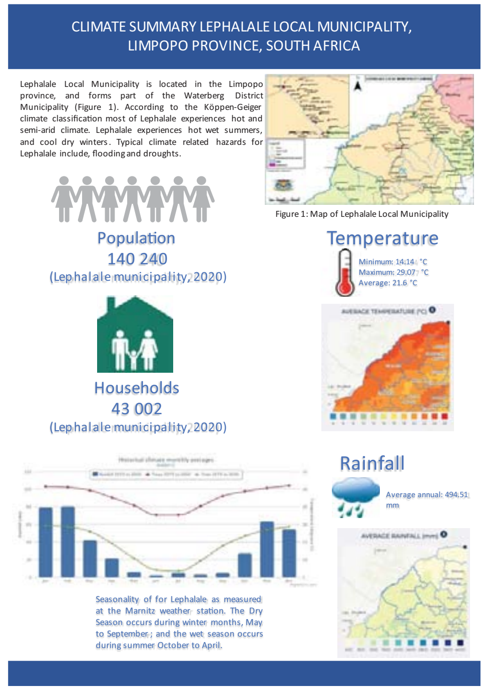


Figure 22: Climate summary updated with annual

- To determine the long-term trends of rainfall / temperature click on the station, closest to your area of interest.

- In the pop-up that appears click the "historical climate records", which will bring up a "total monthly rainfall" graph as a default.

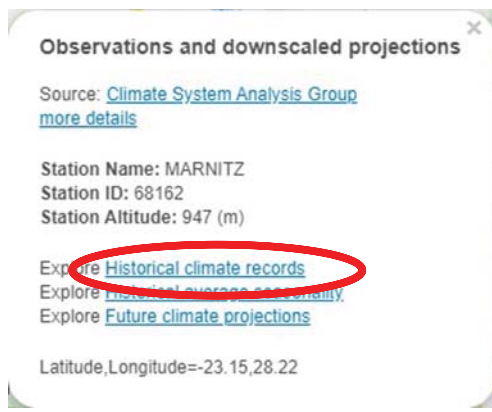


Figure 23: Selecting historical climate records

- There are three graphs that display long-term data these are the "Total monthly rainfall", Average maximum temperature" and "Average minimum temperature". These graphs will display the trends observed in rainfall and temperature.

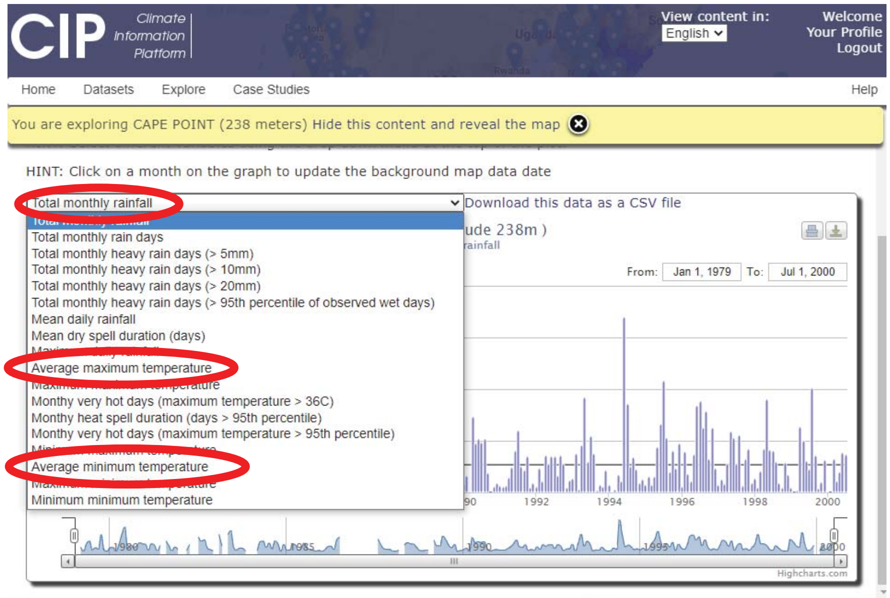


Figure 24: list of long-term data

- The rainfall graph that is loaded as a default is for "Total monthly rainfall" which should be downloaded, by clicking the download button and downloading as either a .png or .jpg file.

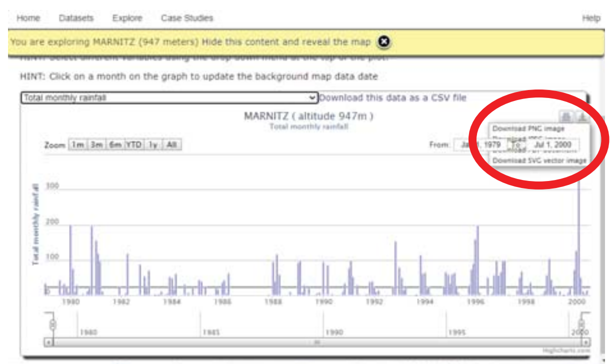


Figure 25: Long-term rainfall graph download

- To access the "Average maximum temperature" and "Average minimum temperature" graphs, click the drop-down and select the graphs.

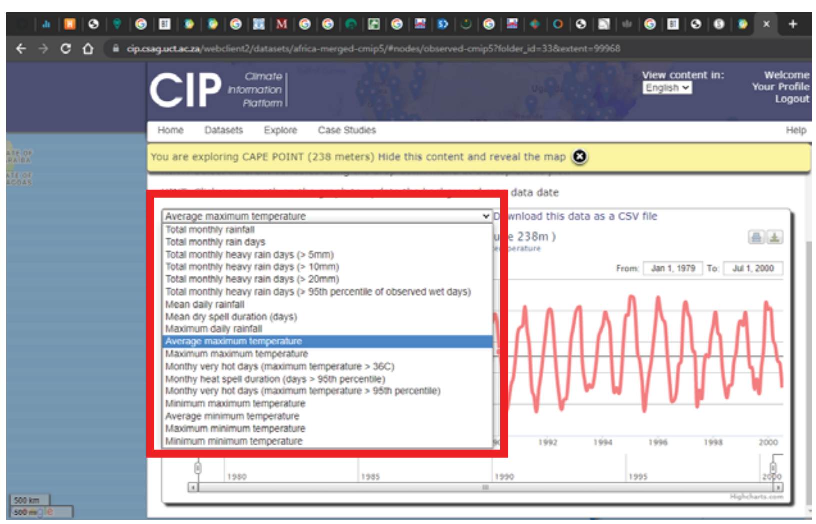


Figure 26: Selecting temperature graphs

- Download the temperature graphs by clicking the download button and downloading as either a .png or .jpg file.

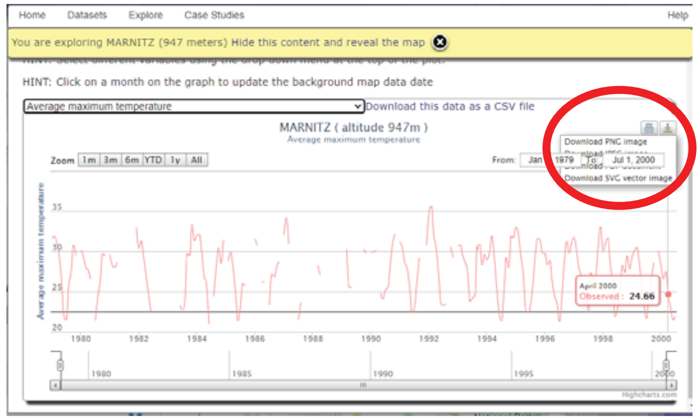


Figure 27: Downloading temperature graphs

- The downloaded graphs should be added to the climate summary and the observed trends should be described.

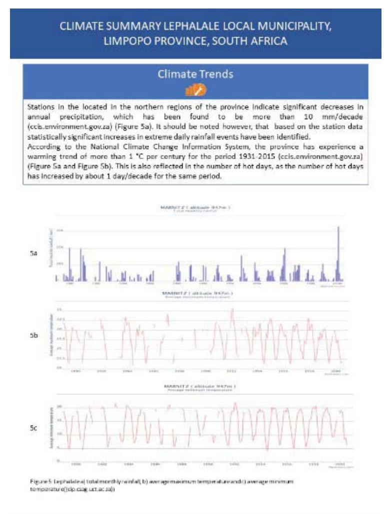


Figure 28: Updating the climate summary with the climate trends

I am not sure what the trend is for my area

It may be difficult to describe what the long-term (i.e. 30-year) trend in the data means. It is recommended that you consult your relevant WSP / W$_2$RAP team members to interpret the data and information. However, if your WSP / W$_2$RAP team does not yet include member/s that can interpret the graphs, the National Climate Change Information System provides an overview of what has occurred over time at the provincial scale.

4.10 How is rainfall / temperature projected to change in the future for your municipality?

In this section two sources of data will be described namely the web-based tool Greenbook, and long-term adaptation Scenarios report as published by DEA (2013). Greenbook provides you with climate projection up to 2050 at the municipal level for RCP 4.5 and RCP 8.5, however does not provide information beyond 2050. The Second National Climate Change Report provides projection from 1970 to 2099, however at the provincial scale.

- To access the climate information, visit Green Book at www.greenbook.co.za, and select the 'Risk Tool' option.

- You will be redirected to the Municipal Risk Profiles page, which displays a map showing the local municipalities across South Africa.

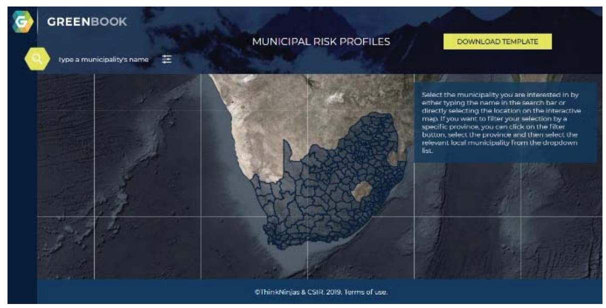


Figure 29: Municipal risk profiles

- Select your municipality by clicking on the appropriate point on the map, or by typing the name into the search bar.

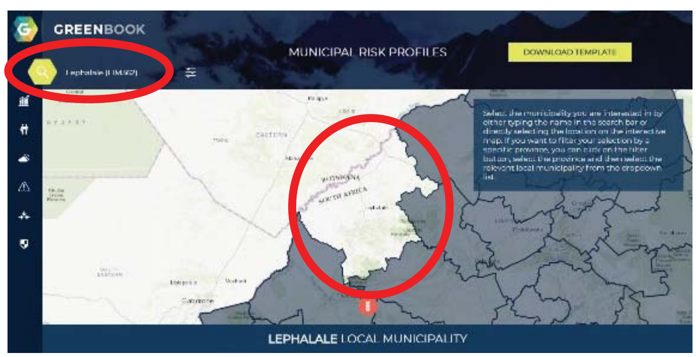


Figure 30: Selecting and searching for the municipality

- After you have selected your municipality, you will be redirected to a page that displays your municipality's current vulnerability. You need to select "2050" to access the projected vulnerability.

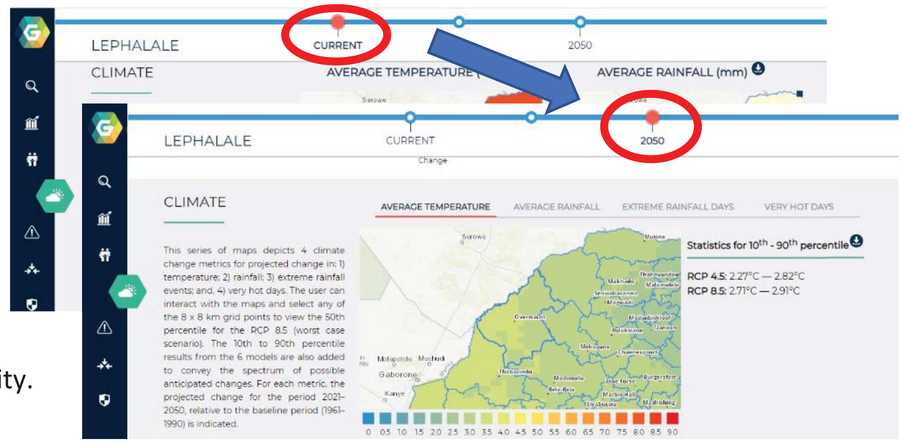


Figure 31: Switching from 'Current' to '2050' data / information

- You will be redirected to a page where your projected vulnerability for 2050 for Temperature under RCP 4.5 and RCP 8.5 will be displayed as a default.

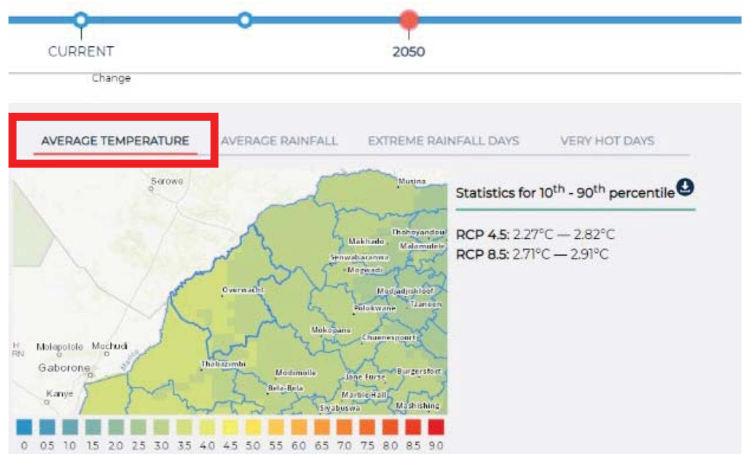


Figure 32: Default '2050' data / information

- Greenbook gives you information on how much your temperature and rainfall is expected to change and extreme events such as very hot days and extreme rainfall days.

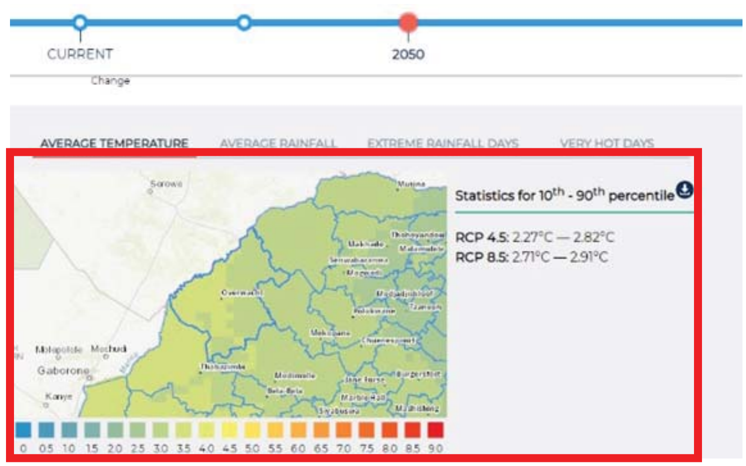


Figure 33: Temperature projections

For the purposes of this section on the Average temperature and Average rainfall projections will be covered, as the extreme events will be covered in the ***What is the climate change hazards for your area?*** *section.*

- Like the "Current" the information in these maps are satellite data which are displayed in an 8 x 8 km grid. Therefore, clicking on the map will provide you with the average temperature / rainfall for a particular 8 x 8 Grid.

- The average projected changes in temperatures for the municipality are displayed towards the right of the map, are given as a range between the 10th and 90th percentiles for both RCP 4.5 and RCP 8.5.

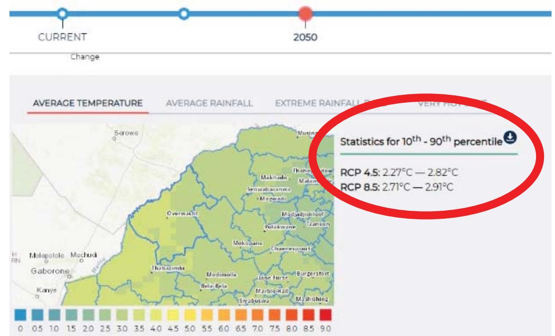


Figure 34: Temperature projections for two scenarios

- To get the average projected changes for a specific area within the municipality, click on the map. A small pop-up will appear in the top-right corner of the map.

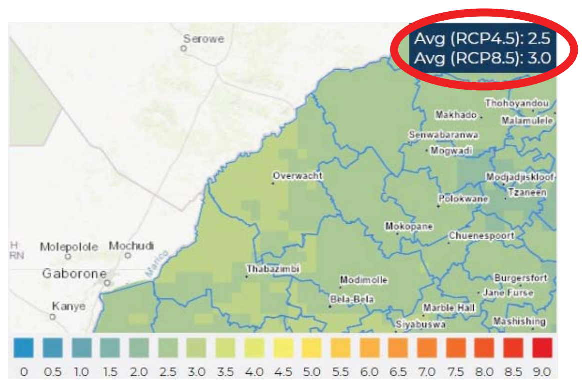


Figure 35: Median temperature projections for a selected point on the map

- The pop-up displays the projected change in temperature for the 50th percentile (Median) for the selected grid for both RCP 4.5 and RCP 8.5.

- To get the projected changes rainfall click the “Average Rainfall”.

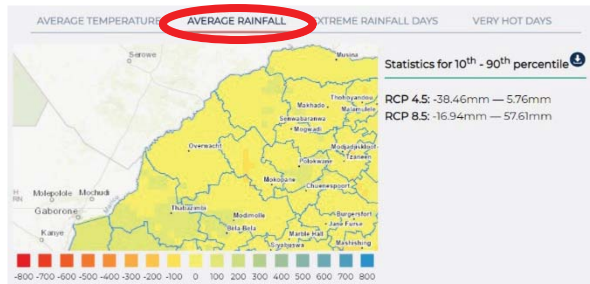


Figure 36: Switching to the average projected rainfall

- The average projected changes in rainfall for the municipality are displayed towards the right of the map, are given as a range between the 10th and 90th percentiles for both RCP 4.5 and RCP 8.5.

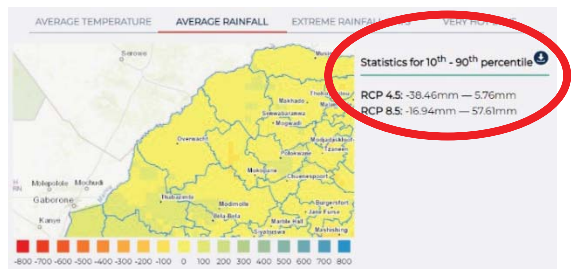


Figure 37: Rainfall projections for two scenarios

- To get the average projected changes for a specific area within the municipality, click on the map. A small pop-up will appear in the top-right corner of the map.

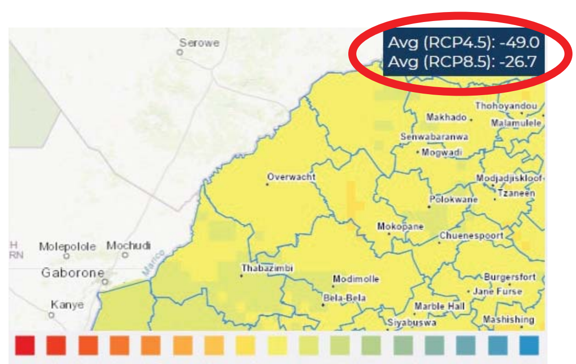


Figure 38: Median rainfall projections for a selected point on the map

- The pop-up displays the projected change in rainfall for the 50th percentile (Median) for the selected grid for both RCP 4.5 and RCP 8.5.

- If you require climate projections for longer time periods it is recommended that you consider using the Long-term Adaptation Scenarios accessible using the following link – https://www.environment.gov.za/sites/default/files/docs/climate_trends_bookV3.pdf

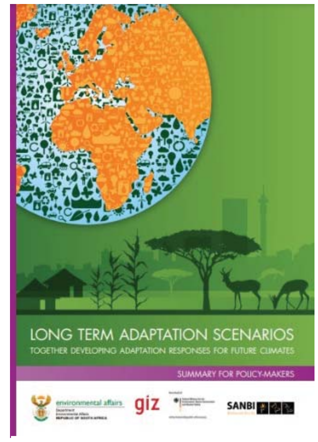


Figure 39: Long term adaptation scenarios

It is recommended that you review the whole document to get a clear understanding of the projected changes that are likely to occur in your province / hydrological zone. However, the key messages and findings are summarised in ***Chapter 6 – Key messages at national and sub-national scale.***

- Go to *Chapter 6 – Key messages at national and sub-national scale* in the long-term adaptation scenarios report.

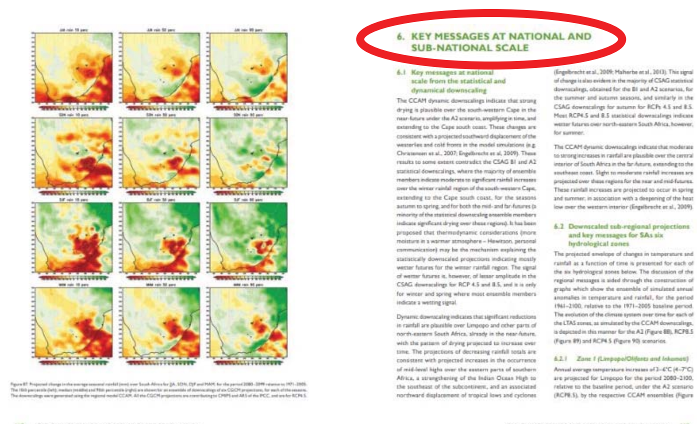


Figure 40: Long-term climate projections in the "Long-term adaptation scenarios"

- A discussion of the data around the expected changes in rainfall and temperatures is provided for both RCP 4.5 and RCP 8.5 scenarios.

- Summarise the discussion focussing on how temperature and rainfall are likely to increase / decrease Under RCP 4.5 and RCP 8.5, across various the various time periods i.e. 2015-2035; 2040-2060 and 2080-2100.

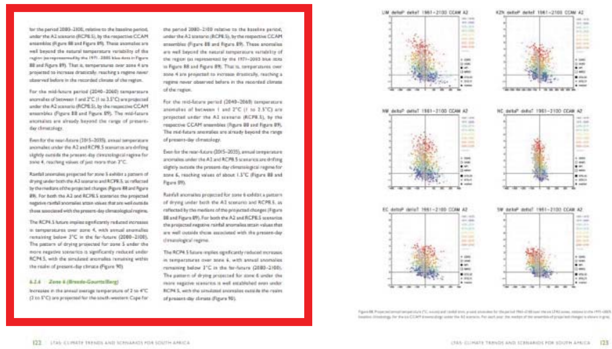


Figure 41: Description of climate projections in the Long-Term Adaptation Scenarios

Accessing climate projection information from the Climate Information Platform

The climate projections are based on the CMIP5 models for RCP 4.5 and RCP 8.5. This information set provides you with projection information for both temperature, rainfall, and extremes such as very days and very wet days, etc. The information can be accessed at the point scale (i.e. weather stations). The information shows the range of projected future changes for this location across 10 different statistically downscaled CMIP5 Global Circulation Models. Anomalies are currently calculated relative the historical period 1980-2000.

- The maps and graphs relevant to your area, must be included into your climate summary.

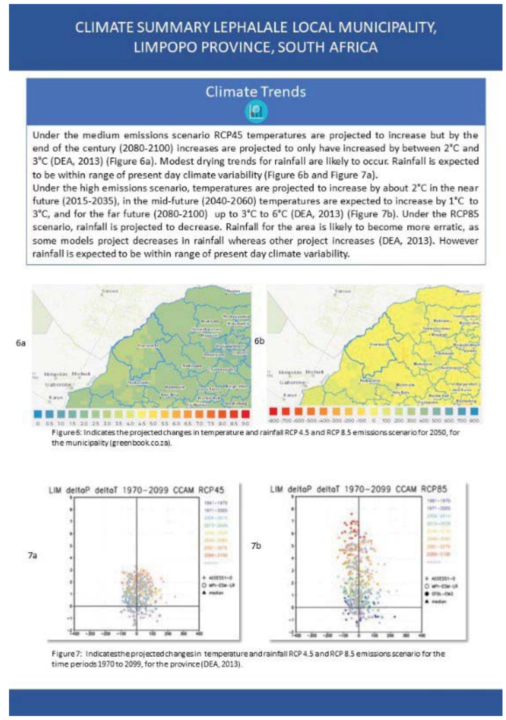


Figure 42: Climate summary updated with climate projection information

4.11 What is the climate change hazards for your area?

Climate threats for your area need to be identified and, the impact of the threats need to be determined especially under the impact of climate change. Climate change may increase the instances whereby the hazard occurs and / or the areas affected by the hazard. Climate threats can be retrieved from various sources as covered in Table 2 (and **Appendix A**), however for the purposes of this section Greenbook will be discussed.

- To access hazard information, visit Greenbook at https://riskprofiles.greenbook.co.za/

- You will be redirected to the Municipal Risk Profiles page. The overview page displays a list of hazards and a map of South Africa.

Figure 43: Municipal risk profiles page

- Select the province that your municipality is in, by clicking on the map or by typing in the municipality name.

Figure 44: Selecting and searching for the municipality

- After you have selected your municipality, you will be redirected to a page that displays your municipality's current vulnerability. The hazards can be accessed by scrolling down to the "Hazards" section.

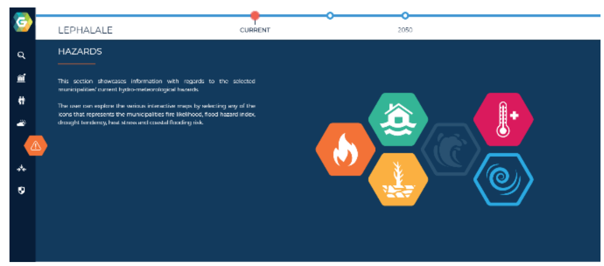


Figure 45: Current municipal hydro-meteorological hazards

- Click on the icons to view the areas that are likely to be affected by the hazards. A map will be generated that displays the areas that will be affected by the hazard (fire hazards), the hazard index (floods and droughts) or the number of days a hazard is experienced.

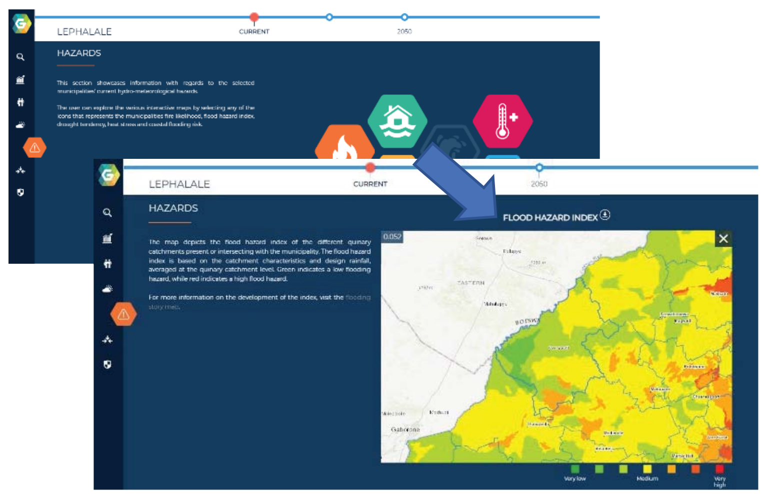


Figure 46: Map displaying the Flood hazard index for the municipality

- Click on the map to view the hazard index for an 8 km x 8 km grid. The hazard index / number of days will be displayed in the top left corner of the map

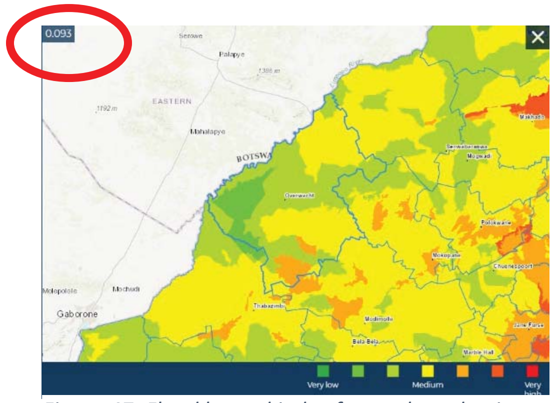


Figure 47: Flood hazard index for a selected point on the map.

- To view the impact of climate change on hazard click on the “2050” icon.

Figure 48: Change from current hazards to 2050 hazards

- Click on the icons to view the areas that are likely to be affected by the hazards. Two maps will be generated that displays the hazard risk under the RCP 8.5 and the settlements that will be affected.

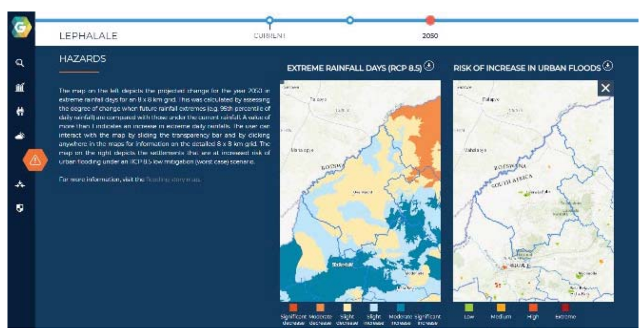


Figure 49: Maps displaying 2050 hazards

- Maps are interactive, so clicking on the maps will provide you with a hazard index or number of days a hazard is likely to occur.

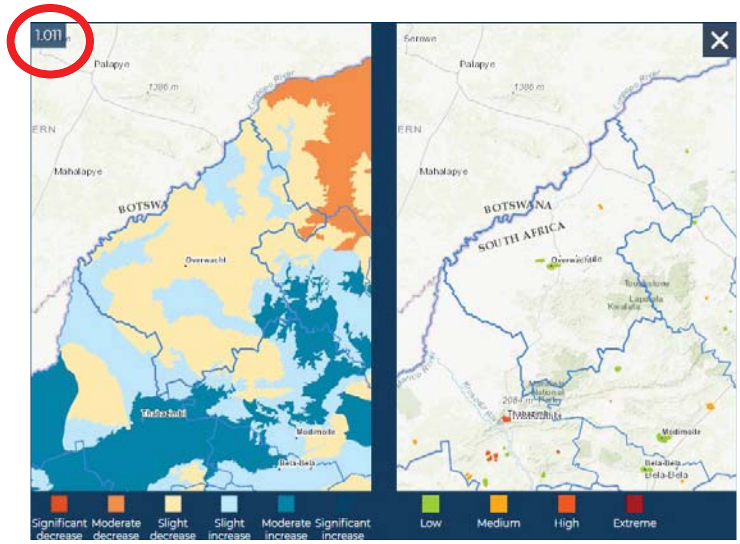


Figure 50: 2050 flood hazard index for a selected point on the map.

- An overview of the resources can be viewed under the “Current” section. You can explore sectors including agriculture, economy, groundwater and surface water availability.

Figure 51: Resources whereby the “Current” status can be viewed

- Clicking on the icons provides you with information which includes maps and / or graphs of the current status quo of resources.

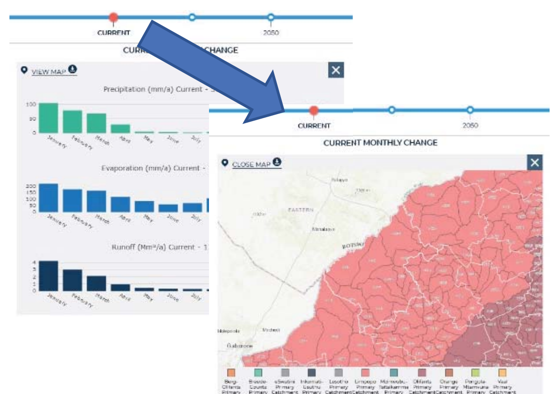


Figure 52: Graphs and maps for the current status quo

- The impact of climate change can be viewed by changing from "Current" to 2050. The 2050 provides information on more resources than are covered in the "Current" section.

Figure 53: Change from current status quo of resources to the impact of climate change by 2050

- Clicking on the icons provides you with information which includes maps and / or graphs, of how climate change will impact a given resource.

Figure 54: Impact of climate change on a resource

- Summarise the information in a table focussing on the change in climate, impact of change in climate, climate hazard, the impact of hazard on water supply systems.


CLIMATE SUMMARY LEPHALALE LOCAL MUNICIPALITY, LIMPOPO PROVINCE, SOUTH AFRICA

Figure 55: Table with climate hazards

- Your final climate summary should look like Figure 56 (**Appendix B**).

Figure 56: Completed climate summary

Hazard information using Think Hazard

Think Hazard provide you with information related to a hazard, based both the present and future vulnerability. The probability of each hazard occurring is highlighted, as well as the need to ensure that projects planning across all phases need to account for the hazard. Additionally, it indicates possible indirect causes of damage because of the hazard occurring. The impact of climate change on the hazard is also noted. By way of example, in the case of wildfires it is noted that the weather that induces wildfires i.e. high temperatures are likely to proliferate due to this the affected by wildfires is likely to expand. Think Hazard also provides you with a list of recommendations that you can use to assist you in developing and taking appropriate action to reduce the impacts of the hazard. In addition to the recommendations a contact list of state-owned and parastatal institutions (e.g. Disaster Management Institute of South Africa, National Disaster Management Centre, or South African Weather Service, etc.) is provided. These institutes or members thereof can form part of a team that assist in providing control measures to potentially reduce the impact of a hazard should it occur (refer to **Assembling the CR-WSP and CR-W$_2$RAP teams** for more information). Accessing climate information is presented as an alternative below:

- To access hazard information, visit Think Hazard at https://thinkhazard.org/en/report/227-south-africa
- You will be redirected to the overview page for South Africa. The overview page displays a list of hazards and a map of South Africa.

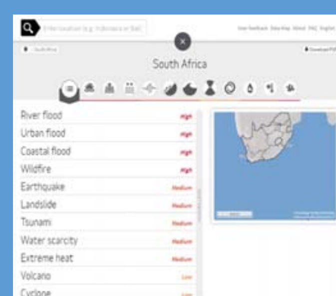


Figure 57: Think Hazard homepage

- Select the province that your municipality is in, by clicking on the map.

Figure 58: Selecting a province by clicking on the map

- You will be redirected to a map of the province showing the District Municipalities in your Province.

Figure 59: Selecting the District municipality

- To access information at your district municipality level, click on the relevant district municipality on the map.

Figure 60: District municipality

The lowest level of information is available at the District Municipal level on Think Hazard, and therefore Local Municipal information is unavailable. However, this information is still very useful.

- After you have selected your District Municipality, you will be able to view your vulnerability to various hazards

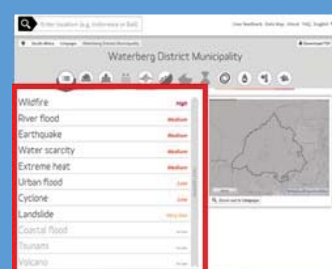


Figure 61: List of hazards for the district municipality

- Clicking on the hazard name (or relevant icon), will provide you with more information on that hazard

- Summarise the information in a table focussing on the change in climate, impact of change in climate, climate hazard, the impact of hazard on water supply systems (Figure 55).

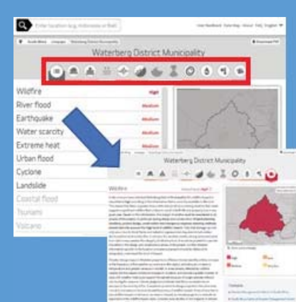


Figure 62: Hazard information

Accessing/analyzing historical climate-related data

The type of data/information accessible and available as described in the above approaches will assist audiences with at least a 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)

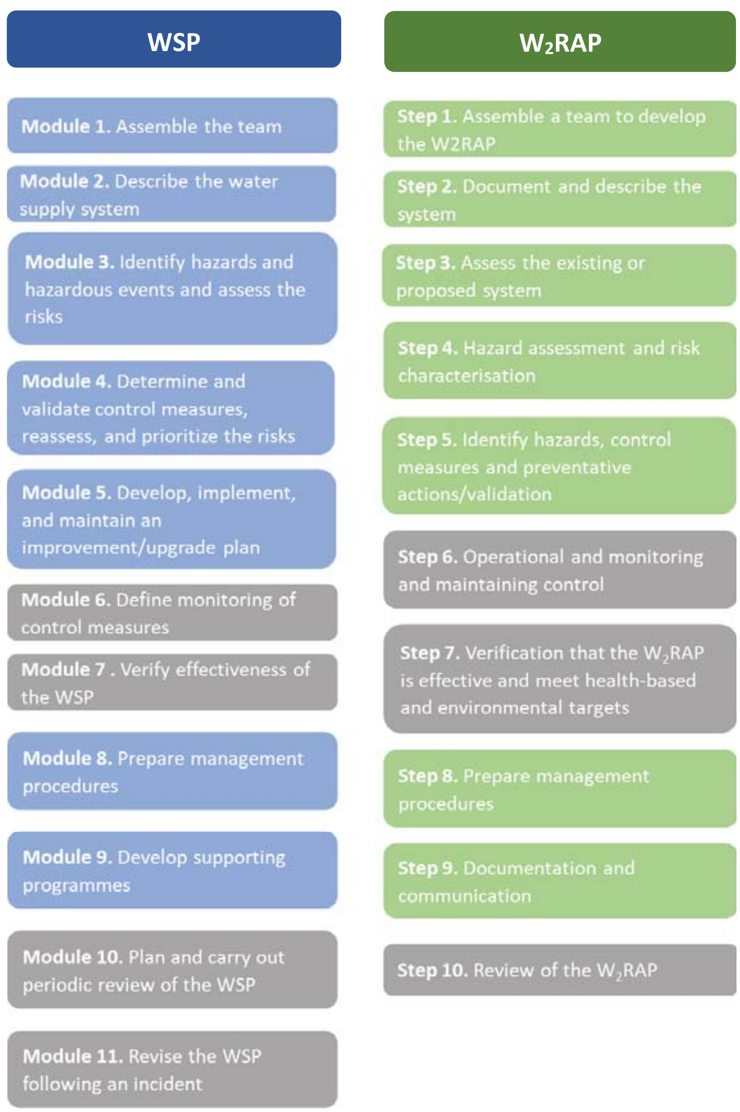
However, development of the above can only be done at a high level of technical expertise and resources. Additionally, meaningful trends may take a long time to develop (at least 10 years) (i.e. these are not short-term actions). In the early stages, it will be challenging to analyze the data with the 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.

The data / information that can be accessed is similar to the above approaches described herein. However, it may be more localized to your specific area (i.e. station data). 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 summarized using descriptive statistics, and data should be plotted on graphs or maps.

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 descriptive statistics (Mean, Median, Minimum, Maximum, etc.). 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.

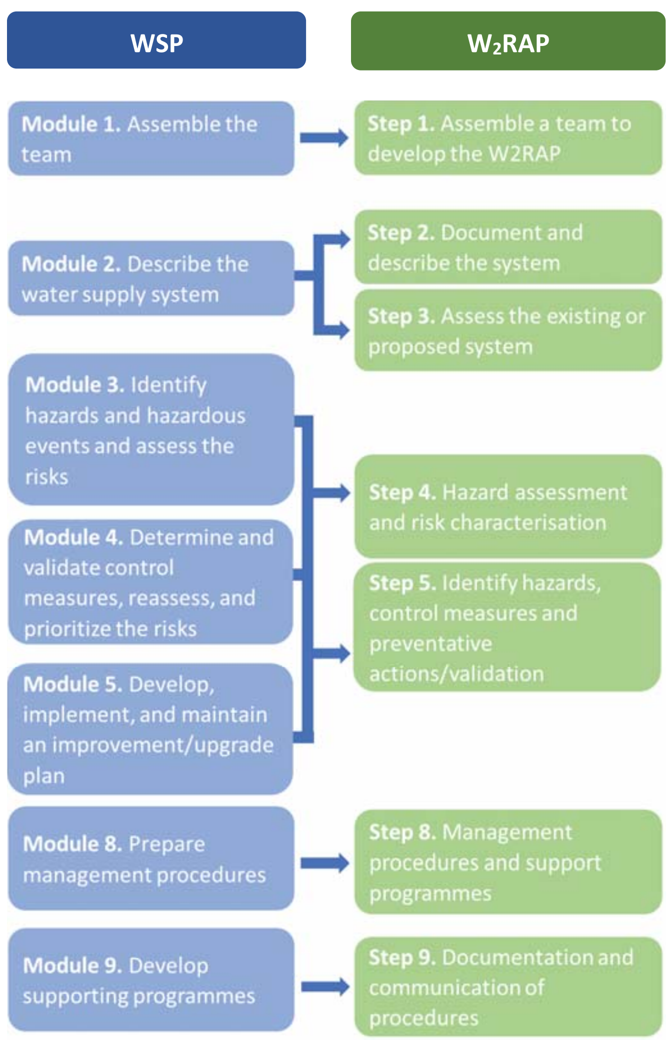
5. INTEGRATING CLIMATE INFORMATION INTO THE WSP AND W_2RAP

The purpose of this section is to provide municipalities/water suppliers/water utilities with guidance on amending the WSP modules and W_2RAP steps that are impacted by climate change. This section is in no way meant to replace the WHO/IWA WSP manual (2009), WRC W_2RAP guideline (2011) or the WHO CR-WSP manual (2017), and water utilities are encouraged to consult each guide when preparing their WSP/ W_2RAP and CR-WSP/ W_2RAP. Not all modules require amending for climate resilience. Rather only 7 WSP and 7 W_2RAP steps require amendment. The below Figure provides an indication of which WSP modules (blue) and W_2RAP steps (green) need to be amended for climate resilience**. NOTE:** Modules and steps that do not need to be amended are in grey boxes:

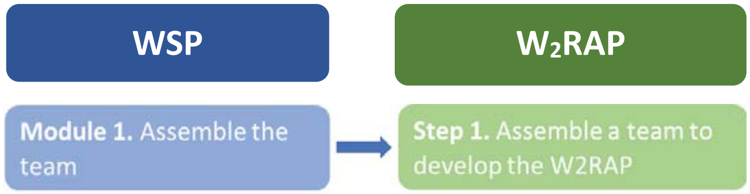


“For those modules not covered in this document, it is expected that appropriate consideration of climate-related issues will follow from explicit consideration of climate issues in the modules addressed in this document, with no additional guidance necessary for these modules. For example, additional control measures required to manage climate-related risks are explicitly addressed in this document (part of module 5 and Step 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.”

The WSP and W_2RAP processes are very similar, but not entirely aligned. By way of example the process covered in WSP module 2 are covered in W_2RAP steps 2 and 3. Therefore, the below in the sections links some modules and steps and are addressed under one heading. The figure below provides an indication as to which modules and steps are linked.



5.1 Assembling the CR-WSP and CR-W_2RAP teams



This requires a multi-disciplinary team with an understanding of the water / wastewater treatment systems. The team members should typically be comprised of members that are involved in various stages of the water / wastewater value chain. The team will be responsible for developing and implementing the WSP / W_2RAP. In terms of climate resilience, the WSP / W_2RAP team should include sector professionals that understand climate information, wastewater system knowledge, authority figures and supporting members. The below table provides suggested key team members and departments that should form part of your WSP and W_2RAP, respectively (Table 3):

Table 3: Example of WSP and W_2RAPteam members

WSP Module 1: assemble the team	**W_2RAP Step 1: assemble the team to develop the W_2RAP**
Typical WSP 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	**Typical W_2RAP members** • Technical Director • Wastewater Engineers and Technicians • Sewer Network personnel • Water Works Superintendents and Senior Process Controllers • Human Resources Departments • Financial Department • Catchment Management and water services managers, • Wastewater 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

WSP Module 1: assemble the team	W_2RAP Step 1: assemble the team to develop the W_2RAP
• Water utility personnel with knowledge of drinking water related issues • Water utility personnel with knowledge of natural water resources **Possible CR-WSP members** • Climatologists and meteorologists (local weather services) • Hydrologists and geohydrologists • Geographical Information System Scientists • Oceanographers • Experts on disaster and risk reduction and identification • Maintenance teams • Other key role players	**Possible CR-W_2RAP members** • Experts on disaster and risk reduction and identification • Climatologists and meteorologists (local weather services) • Hydrologists and geohydrologists • Geographical Information System Scientists • Oceanographers • Research Institution/Centre's – Universities, NGO research entities, etc. • Infrastructure planning • Municipal Energy Champions / Managers • Change Managers • Maintenance teams • Financing agents such as the GCF, new DBSA WRP • Other key role players

If you are unsure as to which sector professionals you should include, Think Hazard may be a good starting point. Think hazard provides you with a list of contact organizations for each of the hazards, of which members from these organizations could form part of your WSP / W_2RAP teams. Additionally, there are recommendations for technical experts that can assist in further understanding and analysing data / information about the hazards.

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 analyzing climate related information:

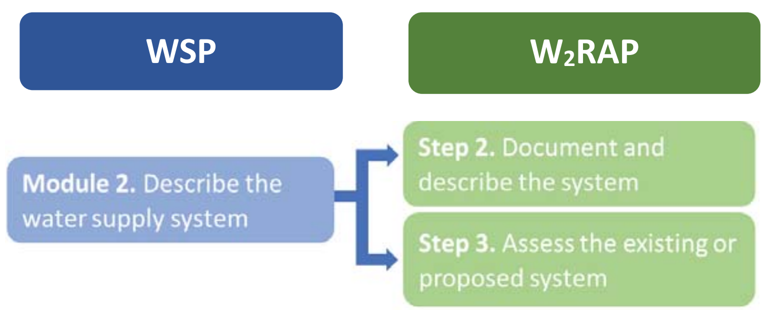
- Team members must perform data analysis and tasks according to their expertise (i.e. climatologists must review climate graphs and maps, hydrologists must review hydrological graphs).

- 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 4)

Table 4: Example of defined roles for each team member

Name	*Job title*	*Organization*	*Role*	*Contact information*
Ms. X	Manager operations	Municipality	WSP / W_2RAP team leader	Tel.: (021) 4543 1234
Mr. Y	Water quality & risk specialist	Treatment works	Water quality risk management	Tel.: 3454 1234
Ms. W	Catchment liaison officer	Catchment authority	Catchment user liaison	Tel.: 5443 1234
Mr. C	Professor of climate sciences	University	Auxiliary Member	Tel.: 3544 1234

5.2 Describing, documenting, and assessing the water and wastewater systems



It is the responsibility of the WSP / W_2RAP team to describe the water supply / wastewater system. The description should include relevant documentation such as an updated flow diagram of the water treatment works / wastewater 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. The WSP / W_2RAP team members that form part of the municipalities/water suppliers/water utility, should have access to this documentation and data. The climate summary you developed in the first part of this guideline should the climate information you will need to update the system description and diagrams.

The system description should be updated to incorporate, climate resilience with the following considerations:

- Climate information (e.g. historical v. projected rainfall, temperature, etc.),
- Sea-level rise (where applicable),
- Flooding zones,
- River flows,
- Aquifer recharge rates, yield vs. demand,
- Water quality challenges,
- Alternative water sources,
- Catchment land-use,
- New development,
- Population growth,
- Urbanization

This information should be captured in a system diagram, which can be overlaid with key climate information. Where a water treatment works (Figure 64) and wastewater treatment works (Figure 65) is present, a separate and more detailed schematic of the facility should also be included.

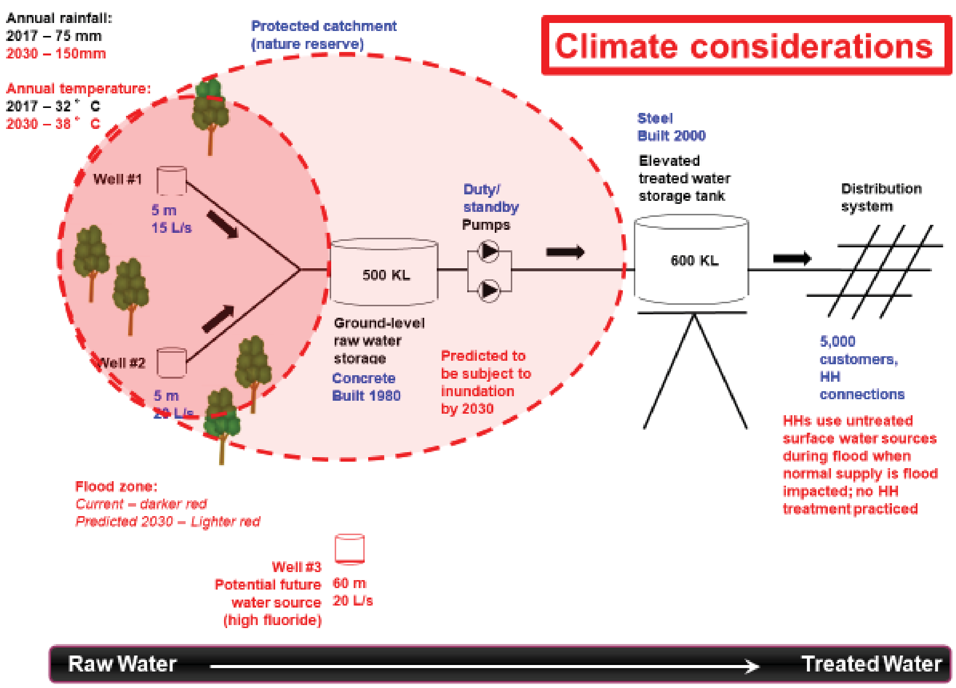


Figure 63: WTW updated system diagram

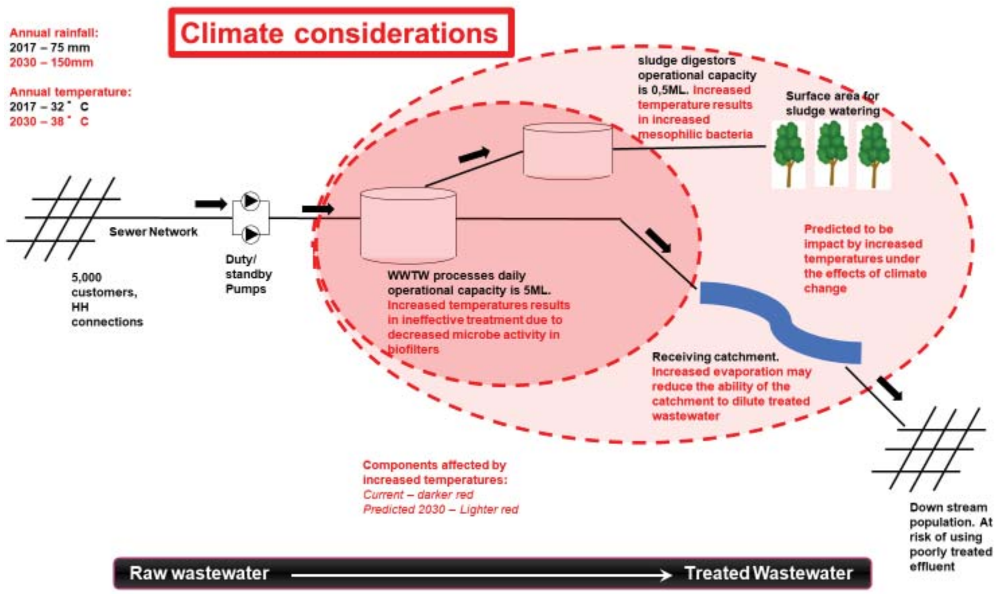
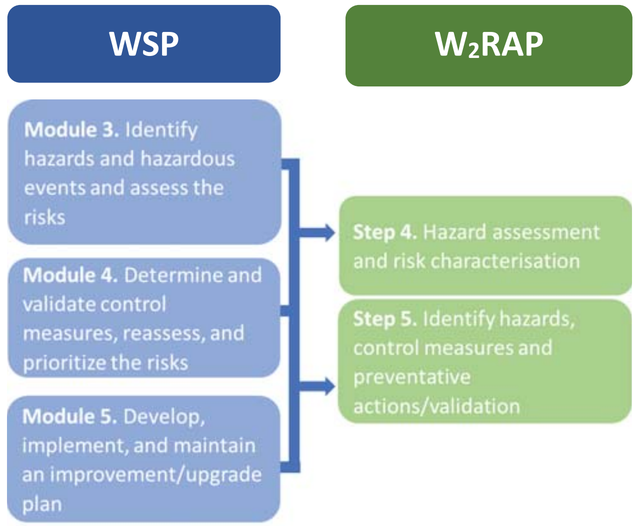


Figure 64: WWTW updated system diagram

Other supporting information could 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.

5.3 Identifying climate related hazards, hazardous events, assessing the risks and control measures



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 / wastewater value chain.

According to WSP and W_2RAP terminology, a hazard is any **Biological, Chemical, Physical,** or **Radiological** agent that has the potential to cause harm to the system, consumers, or the receiving environment. 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 for water supply systems 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**)

Hazardous events for sanitation/wastewater systems 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)

Examples:

- Catchment becomes faecally contaminated (**X**) because of discharge of poorly treated wastewater release from the WWTW (**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 and consumer to environment). The risk associated with each hazard and hazardous event, should be calculated for new risks, and re-calculated to determine impacts of climate change (only to applicable to those risks that are affected by 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 and descriptions are presented in Table 5 and Table 6, respectively. The application of the application of the hazard and hazardous event as well as the risk scoring are presented in Table 7 and Table 8.

***Note**: Not all hazards and hazardous events are affected by climate change. Therefore, not all hazards and hazardous events need to be recalculated for climate change. By way of example hazards and hazardous events that are unaffected by climate change may include those related to power supply and control, staffing or laboratory services, etc.

Table 5: Risk Matrix

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

Likelihood is determined by "how often' or "how likely" a hazard or a hazardous event occurs. It must consider hazards that have occurred in the past and their likelihood of re-occurrence and must predict the likelihood of hazards and events that have not occurred to date

Consequence looks at the severity of the results of the hazard/hazardous event and the seriousness or intensity of the impact of the hazard. When dealing with impact we are concerned with human health only.

RISK RATING = LIKELIHOOD X CONSEQUENCE

Risk Rating
Low
Medium
High

Table 6: Description of risk profiles and scores

Score	Risk profile	
0-10	Low	These are systems that operate with minor deficiency and usually meet the quality specifications set by the relevant authority (SABS, DWS, DEA, etc.). It is unlikely that this level of risk is harmful to human and environmental health. Aesthetically and/or physical non-compliance can be expected for short periods.
11-20	Medium	These are systems with deficiencies which individually or combined pose a moderate risk to humans and the environment. 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 treatment plant and disinfection process is likely.
21-25	High	These are systems with deficiencies which individually or combined pose a high risk to human health or the environment, which 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.

Table 7: Example of a climate risk for a WTW

Risk No.	Risk Description (hazardous event)	Hazard Type	Likelihood	Consequence	Risk rating	Risk Levels
PROCESS STEP: INLET WORKS						
1	Increased water availability at the WTW due to high intensity short duration rainfall	Phys	3	5	15	M

Table 8: Example of a climate risk for a WWTW

Risk No.	Risk Description (hazardous event)	Hazard Type	Likelihood	Consequence	Risk rating	Risk Levels
PROCESS STEP: PUMPING STATIONS						
1	Micro-organisms in biofilters die off, due to increased atmospheric and wastewater temperatures	Phys	3	5	15	M

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

As part of South Africa's Blue and Green Drop programmes comprehensive questionnaires have been developed to assess each of the process steps within WTW / WWTW system. The questionnaires cover multiple aspects such as appearance of the works, primary mains, sewer network reservoirs, boosting stations, pump stations and disinfection but to name a few. The questionnaires can be used to assess WTWW / WWTW with any combination of processes. However, the questionnaire does not yet cover questions related to climate change. Therefore, when trying to incorporate climate resilience into your WSP / W_2RAP you need to develop a list of generic questions that can be asked at each of the process. Table 9 provides you the list of generic question that can be added to the site inspection questionnaire.

Table 9: Examples of generic climate change questions

	Generic climate change questions
1	How will extreme heat affect this process?
2	How will wildfires impact this process?
3	How will this process be affected by heavy rainfall?
4	How will this process be affected be during water scarce periods?
5	How is this process affected by flooding?

5.3.1 Determine and validate control measures, reassess, and prioritize the risks

Existing and potentially new/additional control measures must 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 need to be implemented. Control measures must be validated through regular monitoring, and after an incident occurs. Where control measures are not effective, new control measures must be identified and implemented. The risk associated with each hazard and hazardous event must 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 10 and Table 11 below can be used to determine the risk of a hazard and hazardous event, before and after considering the impacts of climate change.

Not sure what control measures should be applied to a hazard and hazardous event?

Two of the web-tools covered in this guidance document, Greenbook and Think Hazard, can be used as a starting point to determine the applicable control measures. Each of these web-tools, provide you with adaptation actions and recommendations that, if applied, may assist you in mitigating the impact of a hazard. Additionally, consulting the sector experts that from part of your teams is recommended, as they are likely to know which control measures are best suited to mitigate the hazard and hazardous event.

Table 10: Control measure effectiveness for the WSP

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?**		
Risk No.	**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)*
PROCESS STEP: INLET WORKS																		
1	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 11: Control measure effectiveness for the W_2RAP

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?**		
Risk No.	**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)*
PROCESS STEP: PUMPING STATIONS																		
1	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		✓	---

5.3.2 Develop, implement, and maintain an 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 Table 13 and Table 14.

Using short-term and long-term control measures

Sometimes a stepwise or incremental approach towards 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 (i.e. 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 (i.e. 5 years (or more) to be fully implemented), and substantial 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 12).

Table 12: 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

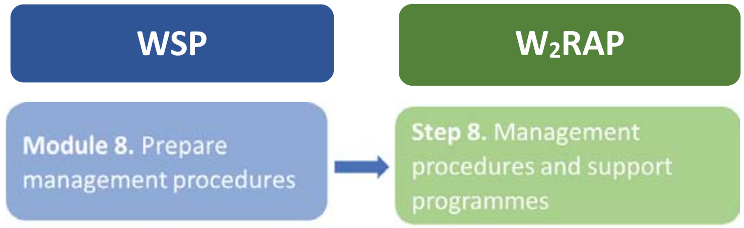
Table 13: WSP improvement plan

Risk No.	Risk Description (hazardous event)	Hazard Type	Risk Levels	Existing Control Measures	Corrective Action	Efficacy of Control Measures	Discussion Plan		
							Who?	When?	Budget
PROCESS STEP: POLICIES, PLANS AND PROCEDURES									
1	Increased water availability at the WTW due to high intensity short duration rainfall	Phys	Medium	Reduce flow of raw water, during rain events	Increase WTW capacity to cope with increased periods of increased flows	Monitoring of flow at the inlet works	Asset Manager	June 2023	R40 mil

Table 14: W_2RAP improvement plan

Risk No.	Risk Description (hazardous event)	Hazard Type	Risk Levels	Existing Control Measures	Corrective Action	Efficacy of Control Measures	Discussion Plan		
							Who?	When?	Budget
PROCESS STEP: POLICIES, PLANS AND PROCEDURES									
1	Micro-organisms in biofilters die off, due to increased atmospheric and wastewater temperatures	Phys	Medium	Require industry to reduce wastewater temperatures before release into the system	Installation of temperatures gauges and temperature control mechanisms	Monitoring of temperatures Monitoring of temperatures across the system	Asset Manager	June 2023	R200,000

5.4 Preparing management procedures



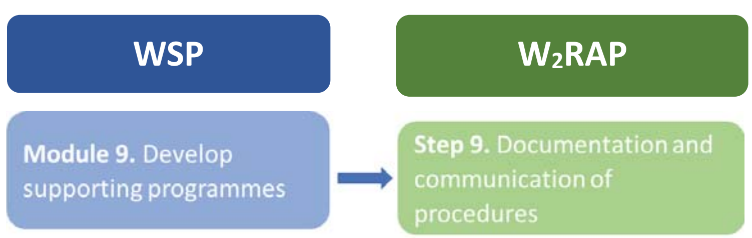
Management procedures should be developed that define the actions required when the system is running optimally and/or when an incident occurs. These actions should be documented as each process is routinely monitored or corrected during an incident. More experienced staff/team members should oversee 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 / W_2RAP effectiveness. These records are essential as they provide auditors with an indication of the adequacy of the WSP / W_2RAP, 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 must 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 come into contact with each other.

5.5 Developing 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.
- 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.

The WSP / 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 WSP / W_2RAP and associated water / 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 (Figure 66).

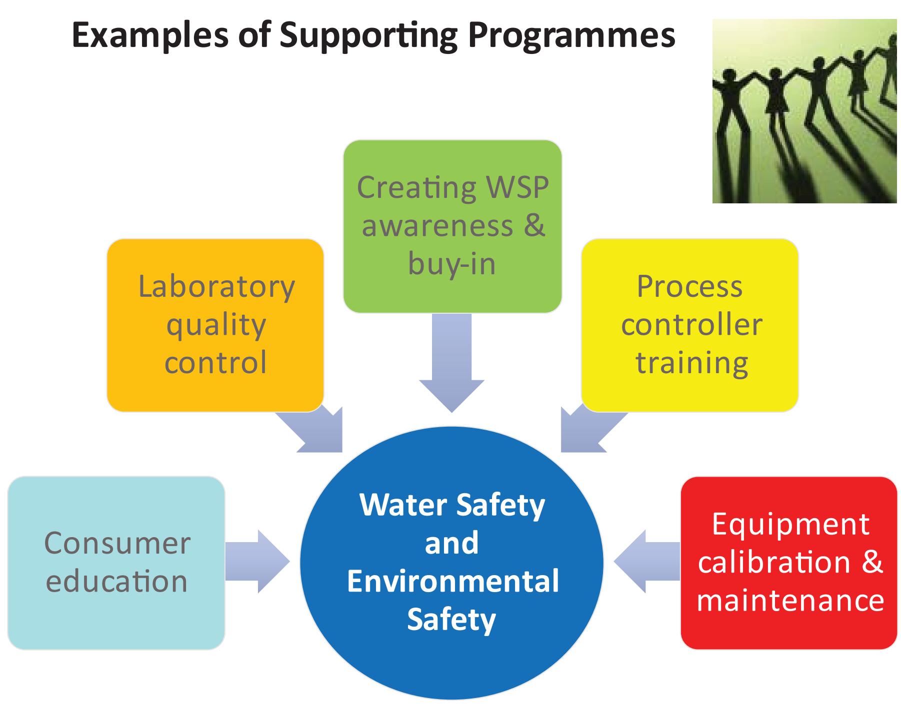


Figure 65: Supporting programmes that can help improve the WSP / W_2RAP processes

5.6 Implementation of the CR-WSP and CR-W_2RAP

The methodology described herein needs to be implemented by WSIs, so that they can start the process of identifying climate threats and implementing climate resilience to their water and sanitation systems.

Although we have referred to CR-WSP and CR-W_2RAP throughout this document, it is important to note that the inclusion of climate resilience into the WSP and W_2RAP processes should be seen as an extension or refinement of the current risk management approaches, and not necessarily the development of a new or separate document.

The current WSP and W_2RAP are therefore improved by continuing to include a broader spectrum of risks. Applying this methodology to improve and update the existing WSPs and W_2RAPs, and more importantly the implementation of the plans will show commitment to the processes. The key is to start simple and incrementally improve your approach as the technical expertise of your WSP / W_2RAP teams and other resources (e.g. financial) improve.

CR-WSP vs. WSP?

You can call it CR-WSP or just WSP – what's more important is that you have considered climate threats and included this into your risk management processes.

As new threats materialise, they need to be considered and addressed (e.g. COVID-19/pandemic related). This doesn't necessarily we are going to change the title of the WSP to "pandemic considered WSP".

It is important to consider both climate change and non-climate change related hazardous events (i.e. don't forget the basics and only concentrate on "climate issues" – a holistic assessment and improvement approach is key.

Consideration must also be given to prioritizing climate change related risks, with an understanding of what is already changing now, and what is predicted to change in the future. This will assist with first implementing short-term inexpensive control measures that can be readily implemented until the resources become available (and uncertainty is reduced) to implement more long-term control measures.

6. References

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7. Appendices

7.1 Appendix A: Expanded list of 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/
		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*
What is the							

<table>
<tr><td rowspan="8">pattern of extreme temperatures (both hot and cold weather)?</td><td></td><td></td><td></td><td></td><td></td><td></td><td>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</td></tr>
<tr><td rowspan="6">Regional Meteorological and Hydrological services</td><td>Station data</td><td rowspan="2">Individual locations</td><td rowspan="6">Regional</td><td rowspan="2">Technical specialists</td><td rowspan="2">Free</td><td rowspan="2">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</td></tr>
<tr><td>(Time series or summary statistics)</td></tr>
<tr><td rowspan="2">Monthly or seasonal summary reports</td><td>Individual locations Sub-national (regions, districts)</td><td rowspan="4">Generalists</td><td rowspan="4">Free</td><td>Tokyo Regional Climate Centre (http://ds.data.jma.go.jp/tcc/tcc/)</td></tr>
<tr><td>National</td><td rowspan="3">African Centre of Meteorological Applications for Development (ACMAD)
http://acmad.net/rcc/</td></tr>
<tr><td>Short-term forecasts</td><td rowspan="2">Regional</td></tr>
<tr><td>Seasonal forecasts</td></tr>
<tr><td>International databases or services</td><td>Station data (time series or summary statistics)</td><td>Individual locations</td><td>International</td><td>Technical specialists</td><td>Free</td><td>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</td></tr>
</table>

							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.*
		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 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	National Meteorological and Hydrological Services (or other	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

the future?	government bodies)						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*
	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 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 precipitation?	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
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/

	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
		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 Seasonal 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.
		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
							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							Let's respond toolkit – Department of Environmental Affairs http://www.letsrespondtoolkit.org/

precipitation patterns change in the futures?	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.*
	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$_2$RAPs 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/
	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? *What are the levels of extreme peak flows?* *How long do low flows last?*	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* SA Risk and Vulnerability Atlas http://sarva2.dirisa.org/
	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* Global River Discharge Database (available at 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/#/
How might this pattern change in the future?	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.*
How long do floods last?	Newspapers	Newspaper reports	Various	National / local		*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 does flood occur?	National hydrological services	Various	Catchments and regions	National	Generalists	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 data feeds 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/
	International databases	Reports and statistics	Catchments and regions	International			Dartmouth Flood Observatory https://floodobservatory.colorado.edu The Global Flood Detection System

How might this change in the future							http://www.gdacs.org/flooddetection/
							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				

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 hydrologic al 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 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*

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
							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
							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	Water utilities	Station data	Individual locations	Nationals	Technical specialists	Free	Measured by WTW and WWTW available on request

body temperatures? (Rivers, lakes, and reservoirs)	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
			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
	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/Local	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/
	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

							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/

7.2 Appendix B: Climate Summaries for three pilot municipalities

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 (Figure 1). 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.

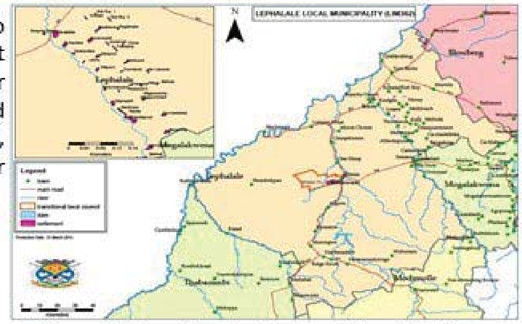


Figure 1: Map of Lephalale Local Municipality (Lephalale municipality, 2020)

Population
140 240
(Lephalale municipality, 2020)

Households
43 002
(Lephalale municipality, 2020)

Temperature

Minimum: 14.14 °C
Maximum: 29.07 °C
Average: 21.6 °C

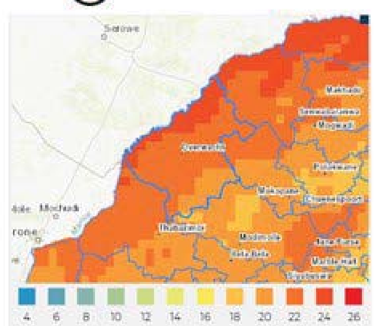


Figure 2: Temperature across Lephalale (greenbook.co.za)

Rainfall

Average annual: 494.51 mm

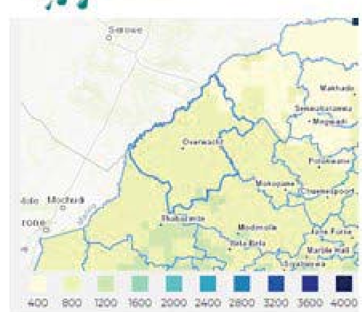


Figure 4: Rainfall across Lephalale (greenbook.co.za)

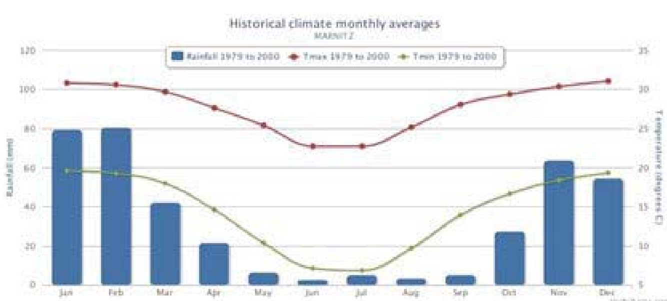


Figure 3: Seasonality of for Lephalale (cip.csag.uct.ac.za)

Seasonal average rainfall and temperature Lephalale as measured at the Marnitz weather station (Figure 3). The Dry Season occurs during winter months, May to September; and the wet season occurs during summer October to April.

Climate Trends

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) (Figure 5a). It should be noted however, that based on the station data statistically significant increases in extreme daily rainfall events have been identified.

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 (ccis.environment.gov.za) (Figure 5a and Figure 5b). 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.

5a

5b

5c

Figure 5: Lephalale a) total monthly rainfall, b) average maximum temperature and c) average minimum temperature((cip.csag.uct.ac.za))

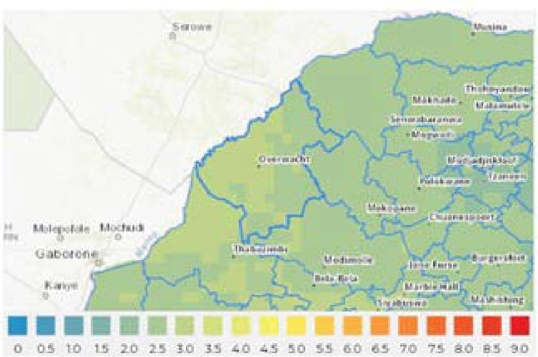
CLIMATE SUMMARY LEPHALALE LOCAL MUNICIPALITY, LIMPOPO PROVINCE, SOUTH AFRICA

Climate Trends

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) (Figure 6a). Modest drying trends for rainfall are likely to occur. Rainfall is expected to be within range of present day climate variability (Figure 6b and Figure 7a).

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) (Figure 7b). 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.

6a



6b

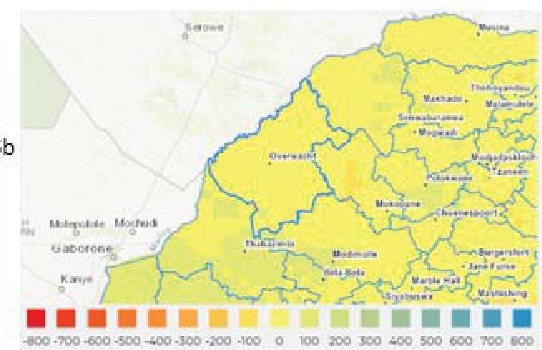
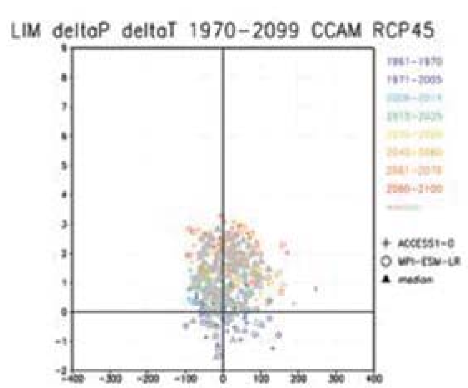


Figure 6: Indicates the projected changes in temperature and rainfall RCP 4.5 and RCP 8.5 emissions scenario for 2050, for the municipality (greenbook.co.za).

7a



7b

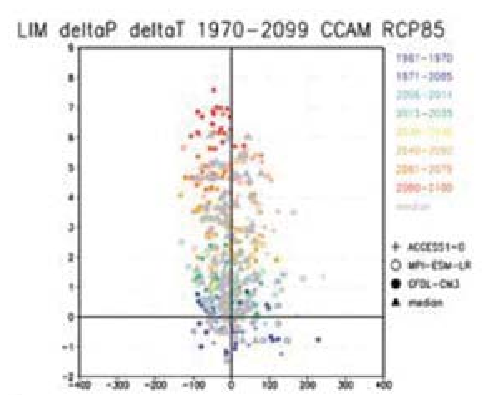


Figure 7: Indicates the projected changes in temperature and rainfall RCP 4.5 and RCP 8.5 emissions scenario for the time periods 1970 to 2099, for the province (DEA, 2013).

CLIMATE SUMMARY LEPHALALE LOCAL MUNICIPALITY, LIMPOPO PROVINCE, SOUTH AFRICA

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

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4. https://ccis.environment.gov.za/#/cic-trends-provincial
5. https://riskprofiles.greenbook.co.za/
6. https://thinkhazard.org/en/report/227-south-africa/

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

Uthukela District Municipality is located in the KwaZulu-Natal Province, South Africa (Figure 1). 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.

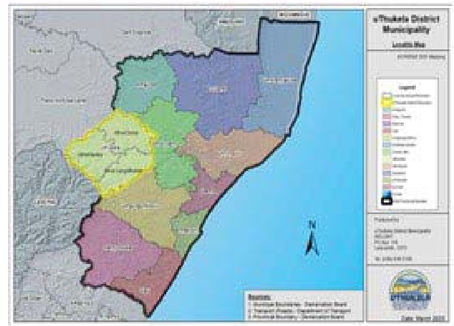


Figure 1: Location of Uthukela Municipality (Uthukela Municipality, 2019)

Population

706 589

(Uthukela Municipality, 2019)

Households

161 788

(Uthukela Municipality, 2019)

Temperature

Minimum: 3°C
Maximum: 30°C

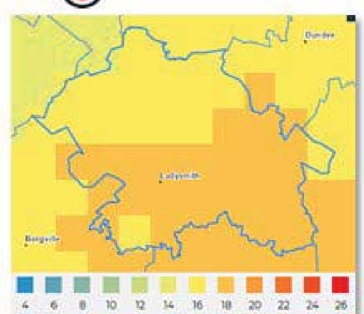


Figure 2: Temperatures across Ladysmith, Uthukela municipality (greenbook.co.za)

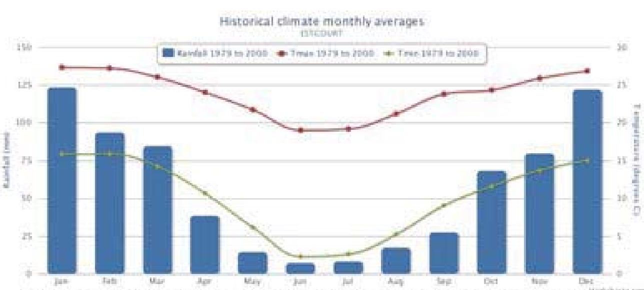


Figure 3: Seasonality of for Ladysmith (cip.csag.uct.ac.za)

Seasonal average rainfall and temperature Ladysmith as measured at the Estcourt weather station (Figure 3). The Dry Season occurs during winter months, May to September; and the wet season occurs during summer October to April.

Rainfall

Average annual: 700mm

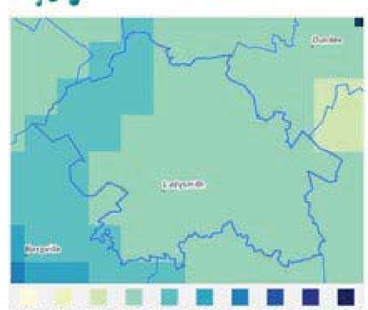


Figure 4: Rainfall across Ladysmith, Uthukela municipality (greenbook.co.za)

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

Climate Trends

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 (Figure 5a). Temperature for the area has shown an overall warming trend, with observed increase being as much as 2°C per century (Lakhraj-Govender, 2017). Maximum daily temperatures have also shown an increase over time (Figure 5b and Figure 5c). 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.

5a
5b
5c

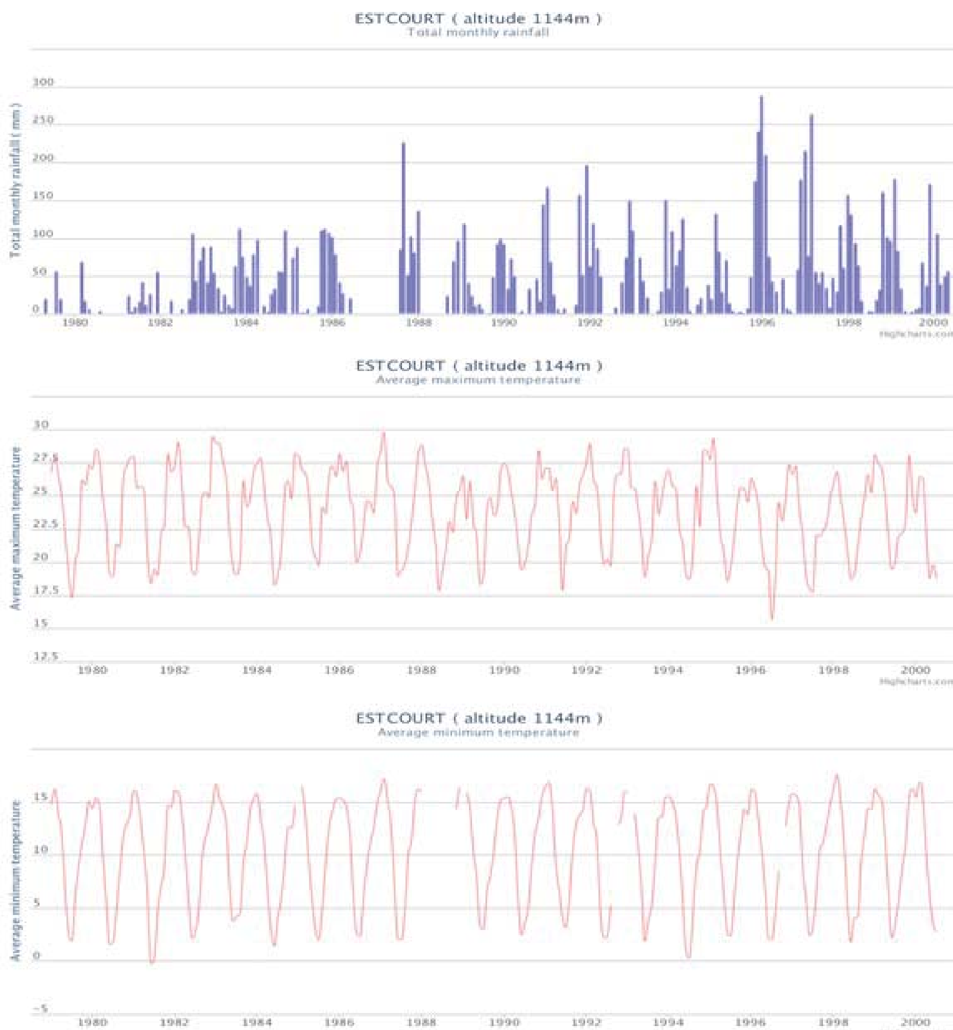


Figure 5: Ladysmith a) total monthly rainfall, b) average maximum temperature and c) average minimum temperature((cip.csag.uct.ac.za))

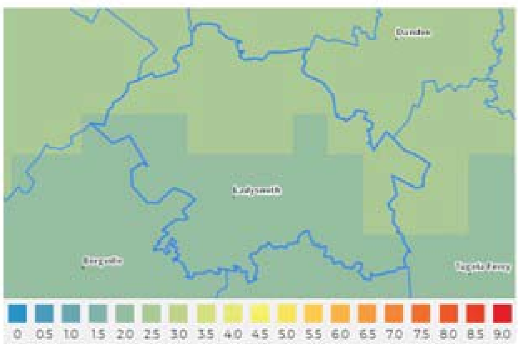
CLIMATE SUMMARY UTHUKELA DISTRICT MUNICIPALITY, KWAZULU-NATAL, SOUTH AFRICA

Climate Trends

Under the medium emissions scenario RCP45 temperatures are projected to increase between 1.89°C and 2.33°C (Figure 6a) but by the end of the century (2080-2100) increases are projected to only have increased by between 1°C and 3°C. Modest wetting trends for rainfall are likely to occur, with increases ranging between 2.52mm – 185mm by 2050 (Figure 6b) .

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 (Figure 7a) (DEA, 2013). Under the RCP85 scenario, rainfall is projected to decrease (Figure 7b). The projected rising temperatures and decrease in rainfall, is likely to result in heatwaves, fires, and droughts (DEA, 2013).

6a



6b

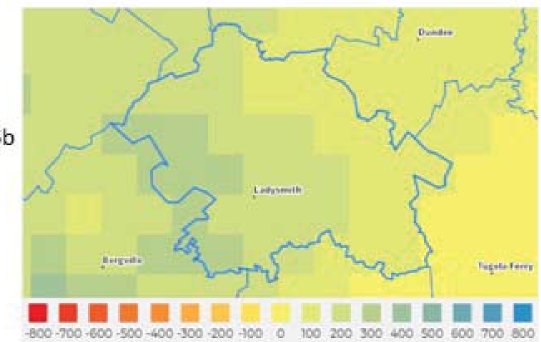
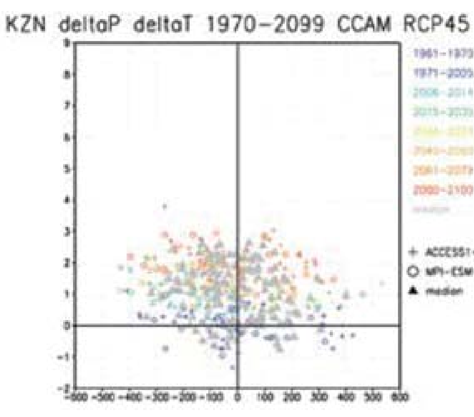


Figure 6: Indicates the projected changes in temperature and rainfall RCP 4.5 and RCP 8.5 emissions scenario for 2050, for the municipality.

7a



7b

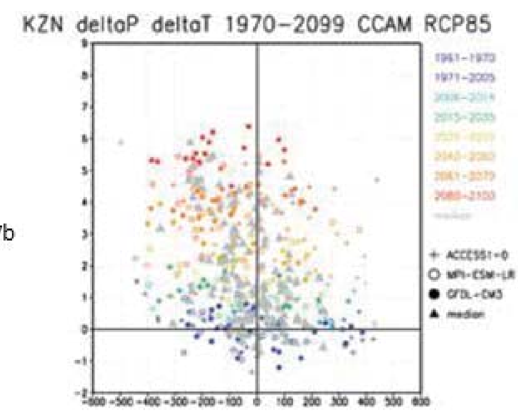


Figure 7: Indicates the projected changes in temperature and rainfall RCP 4.5 and RCP 8.5 emissions scenario for the time periods 1970 to 2099, for the province (DEA, 2013).

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

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

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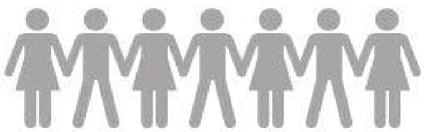
8. https://riskprofiles.greenbook.co.za/
9. https://thinkhazard.org/en/report/227-south-africa/

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 (Figure 1). 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.

Figure 1: Location of Witzenberg Municipality (Witzenberg Municipality, 2020)



Population

130548

(Witzenberg Municipality, 2017)

Households

35 976

(Witzenberg Municipality, 2017)

Temperature

Minimum: 4.3 °C

Maximum: 29.2 °C

(Witzenberg Municipality, 2017)

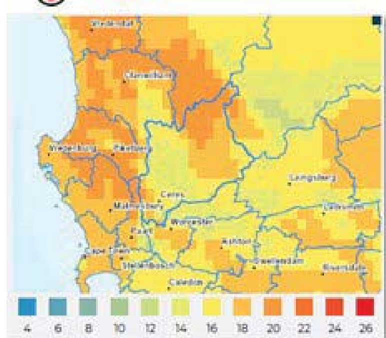


Figure 2: Temperature across Witzenberg (greenbook.co.za)

Rainfall

Average annual: 588,75mm

(Witzenberg Municipality, 2017)

Figure 4: Rainfall across Witzenberg (greenbook.co.za)

Figure 3: Seasonality of for Witzenberg (cip.csag.uct.ac.za)

Season average rainfall and temperatures as measured at the Robertson weather station (Figure 3). Rainfall is experienced year-round. However, most rainfall occurs during April to July.

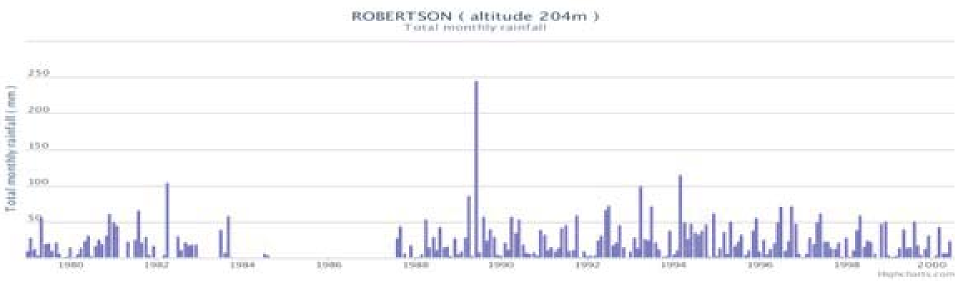
CLIMATE SUMMARY WITZENBERG LOCAL MUNICIPALITY, WESTERN CAPE, SOUTH AFRICA

Climate Trends

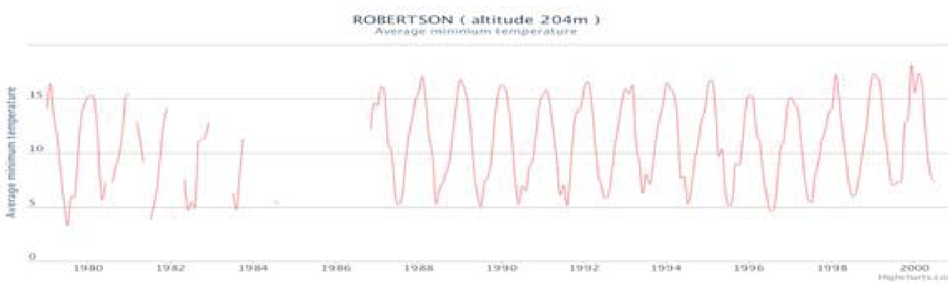
The analysis of quantitative rainfall data for the Western Cape indicate that rainfall has by an average of 13,53 mm/decade between 1987 to 2017 (Lakhraj-Govender and Grab, 2019). The number of rainfall days has also shown a decrease especially in the dry season (November –April), whereas the rainy season (typically May – October) is starting later each year (Figure 5a).

Temperatures for the province indicate an increasing trend in minimum, maximum and mean temperature (Figure 5b and Figure 5c). Temperature over the past decade has increased by about 1°C (Lakhraj-Govender, 2017). 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 has increased by 0.03°C/yr (Jury, 2017)

5a



5b



5c

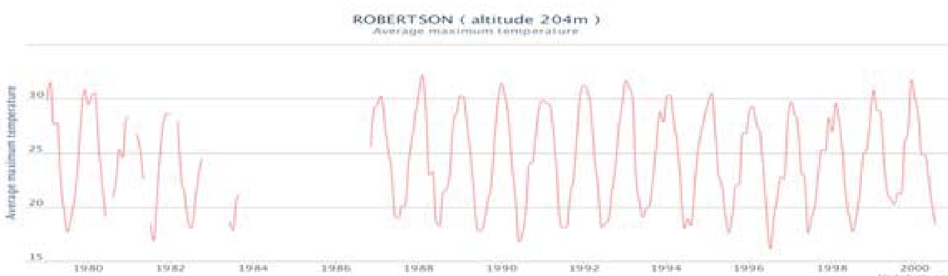


Figure 5: Witzenberg a) total monthly rainfall, b) average maximum temperature and c) average minimum temperature((cip.csag.uct.ac.za))

CLIMATE SUMMARY WITZENBERG LOCAL MUNICIPALITY, WESTERN CAPE, SOUTH AFRICA

Climate Trends

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 (DEA, 2013) Figure 6a). 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 (DEA, 2013) (Figure 6 b and Figure 7a) .

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 (DEA, 2013) (Figure 7b). 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 (DEA, 2013).

6a 6b

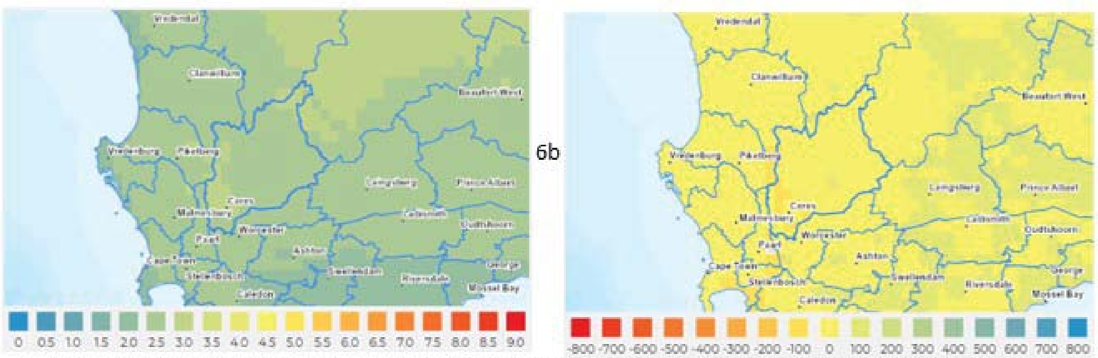


Figure 6: Indicates the projected changes in temperature and rainfall RCP 4.5 and RCP 8.5 emissions scenario for 2050, for the municipality (greenbook.co.za).

7a 7b

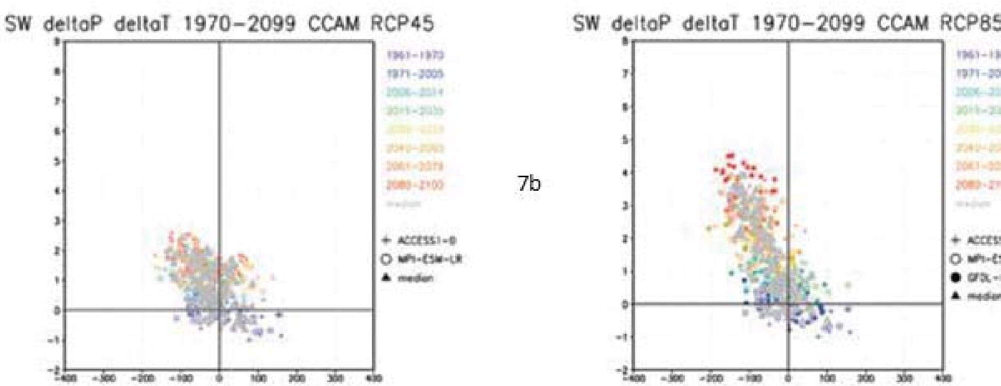


Figure 7: Indicates the projected changes in a) temperature and rainfall RCP 4.5 and b) RCP 8.5 emissions scenario for the time periods 1970 to 2099, for the province (DEA, 2013).

CLIMATE SUMMARY WITZENBERG LOCAL MUNICIPALITY, WESTERN CAPE, SOUTH AFRICA

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

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