

Flood and Drought Management Tools Project

Guideline for Interpreting Climate Information for Application in Water Safety Planning



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List of Acronyms

CO₂ – Carbon Dioxide

CRU – Climatic Research Unit

GCM – General Circulation Model

GEF - Global Environment Facility

GIS – Geographical Information System

GPM – Global Precipitation Measurement

IW – International Waters

IWA – International Water Association

IWRM – Integrated Water Resources Management

RCP – Representative Concentration Pathways

SDG – Sustainable Development Goal

SOP – Standard Operating Procedures

TRMM – Tropical Rains Measuring Mission

UN – United Nations

WHO – World Health Organization

WQA – Water Quality Assurance

WSP – Water Safety Plan

1. Introduction

This serves as a guidance document to assist water utilities to analyse climate related data and incorporate those findings into their water safety planning processes. Methods of analysis include frequency analysis and simple averaging to determine if the physical condition within the water utility is wetter or drier. The analysis is not intended to be too intensive or complex, so as to encourage water utilities to use the Flood and Drought Portal and the methods of analysis presented within this guidance document. The Portal provides water utilities with access to an array of tools (e.g. Data and Information, Drought Assessment, Flood Assessment, Water Safety Planning) to assist with decision-making. The aim is to identify the changes in likelihood and severity of the hazards and hazardous events associated with floods and droughts, and subsequently mitigate these. Detailed instructions have been provided within this guidance document to facilitate conclusions which can be used within water safety planning processes. This will help utilities to review and amend current risks by considering the impacts of climate change, and subsequently prioritize these risks. Incorporating the new risk ratings in the water safety plan is discussed in detail within this guidance document. Subsequently, if identified actions are implemented, the water utility will be more resilient to climate change impacts, including that associated with floods and droughts.

2. Background

Climate change is an atmospheric phenomenon that can either be the result of natural causes or, as observed over the last few decades, induced by human activities that increase atmospheric carbon dioxide (CO₂) and other greenhouse gases (Narimisa and Narimisa, 2018). The United Nations Framework Convention on Climate Change (1992) defines climate change as “change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods”. The most notable effect of the change in atmospheric composition is global warming due to increases in CO₂ and other greenhouse gases. Carbon dioxide acts as a blanket over the atmosphere of the Earth, trapping heat and increasing surface temperatures (Ramanathan and Feng, 2009).

Temperature affects weather conditions; therefore, an increase in surface temperatures will cause changes in climate. Evidence of the effects of climate change include glacier retreat (Kaser *et al.*, 2003), changes in streamflow records (Leith and Whitfield, 1998), increased frequency of flooding and prolonged droughts (Spence *et al.* 2011; Rankoana, 2018). Even though climate change is a global phenomenon, the impact to regions will vary spatially and temporally. It is expected that wet regions will get wetter, whereas dry regions will get drier (WHO, 2017).

The changes that occur in meteorological variables is one of the more profound impacts of climate change (including, for example, the changes seen in precipitation frequency, event extent and intensity). These changes in precipitation frequency and intensity occur as a result of increased surface temperatures which increase the vapour holding capacity of the atmosphere (WHO, 2017). Therefore, more water can be evaporated due to the increased holding capacity of the atmosphere. This results in changes in precipitation frequency, event extent such as rainfall or snowmelt, and intensity which may affect the water storage of an area. High rainfall intensities or rapid snowmelt may lead to flooding, consequently if rainfall or snowmelt becomes infrequent, this may lead to the occurrence of droughts.

Climate change can have a major impact on water utilities, and as a result some water utilities may not be ready for the changes in occurrence of floods and droughts. Floods and droughts affect the ability of water utilities to both supply water and maintain the appropriate water quality. It is therefore necessary for water utilities to be prepared for floods and droughts, by anticipating and predicting the changes in likelihood and severity of hazards and hazardous events and incorporating these findings into their planning and amending daily operations.

Many organizations have developed climate change, flood and/or drought related tools. These tools are generally aimed at assessing the impact of climate change and the risk of floods, droughts and other events, while also indicating which areas are prone to disasters at a global, country, local or water utility scale. These scales of assessment vary between climate models. Climate tools use various sources of data such as environmental, climate projections, disaster risk, socio-economic and historical datasets. These tools aim to educate various stakeholders (such as policy makers, researchers, water utilities and the media) about climate change and an improved understanding of vulnerabilities, adaptation needs and climate readiness, thereby informing decision making and aiding utility resilience. There is a large focus within climate change models on assessing the impacts of climate change on both water quality and quantity. The outputs may be displayed on maps, charts or in tables. Climate tools also exist in various platforms including web-based, spreadsheet-based models, or various software such as MIKE from DHI and others.

3. Flood and Drought Portal

A number of land and water managers have recognised the impacts of climate change, the changes in the predictability of floods and droughts, and the need to develop climate resilience and adaptation within river basins and water management plans. In order to address this, the Flood and Drought Portal was developed through the Flood and Drought Management Tools project by the Global Environment Facility (GEF), International Waters (IW) and implemented by UN Environment (together with the International Water Association (IWA) and DHI as the executing agencies).

The Portal provides water utilities with access to a “methodology with tools to facilitate the inclusion of information on floods and droughts, and future scenarios into Integrated Water Resources Management (IWRM) planning, and Water Safety Planning (WSP). The approaches are used to support planning from the transboundary basin to water utility level” (Flood and Drought Management Tools, 2018). The Flood and Drought Portal is expected to be used globally, and was piloted in three basins, namely Lake Victoria Basin (East Africa), Volta Basin (West Africa) and the Chao Phraya Basin (Thailand). These basins were selected as they are prone to both floods and droughts, have varied levels of technical capacity, and different approaches to decision making.

The Flood and Drought Portal is a freely available web-portal source with a number of applications. The Portal uses a variety of data types and sources which are accessible through the data and information application. The types of data include different climate variables, climate forecast data, climate change data, and drought related indices and flood related data. The Portal provides water utilities with a platform to access different types of data that are spatially and temporally distributed. Datasets are updated in near real time (from 48 hours) and can be downloaded, so that users have the option of analysing the data using their own techniques and tools. This will assist decision makers and planners to both improve flood and drought related planning and readiness, and to assist with the recovery following such events. According to the Global Status Report on Water Safety plans (2017), there is need for an increased attention to water supply system management that focuses on improved and safe supplies. As a result, policy and planning has to take into account “monitoring data showing unsafe drinking-water” (Global Status Report on Water Safety plans, 2017). Water safety planning is therefore a useful tool for policy-makers and practitioners. Water Safety Planning is seen as a tool for implementation of Sustainable Development Goal 6 (SDG 6). Sustainable Development Goal 6, seeks to ensure the availability and sustainable management of water and sanitation for all. The Flood and Drought Portal assists in improving water safety plans which will ultimately assist countries to report on SDG 6.

4. Guideline Purpose

The purpose of this guideline is to provide water utilities with a simple methodology that they can use to access and use datasets, and incorporate findings from these datasets into their water safety planning activities. The availability of near real-time data, allows water utilities to do baseline assessments which can facilitate impact assessments and planning.

The benefits of using flood and drought data include:

- Early detection especially in the case of droughts where the onset is not always clear
- Planning for disasters, early awareness and response time
- Protection of water infrastructure
- Improved risk management (hazard identification, prevention and mitigation of risks associated with floods and droughts)
- Early warning to specific areas that may be affected by a disaster, requisite incident management protocol activated

5. Identifying Hazards Associated with Wet and Dry Conditions

An Important step for using this guidance document, is a review of the hazards and hazardous events as identified in the water utility's current WSP. This is required as the methodology for amending the risk and risk rating of hazards and hazardous events, only considers those hazards and hazardous events that are affected by either wetter conditions, drier conditions or both. In some cases, hazards and hazardous events may not be affected by either wetter or drier conditions, and need not be amended using the methodology presented in this guidance document.

The WSP team should do a literature review to identify hazards and hazardous events that the water utility may become susceptible to under the effects climate change. The literature review will further assist the WSP team to develop a climate resilient WSP with a comprehensive list of hazards and hazardous events, that takes into account the effects of climate change. The hazards and hazardous events should be categorised into those hazards and hazardous events that are affected by i) wetter, ii) drier, iii) both wetter and drier conditions or iv) neither wetter and drier conditions. Categorising hazards and hazardous events requires knowledge from the WSP team and in some cases may require expert advice from consultants or academics, in order to understand the physical conditions under which the identified hazards and hazardous events occur. A basic example of how to categorise hazards and hazardous events is presented below:

- Review your current WSP
- Look at your current hazards/hazardous events
 - Will these events be affected by climatic conditions being 'drier' or 'wetter'?
 - Affected by wet conditions?
 - Affected by dry conditions?
 - Affected by both wet and dry conditions?
 - Unaffected by either wet or dry conditions?

- Is my list of events comprehensive?
 - Literature review – e.g. WHO
- Does my list of events consider climate resiliency?
 - Amend/expand current list of events

Hazards and hazardous events should be described using the below method:

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 over- or under-dosed with chlorine (X), because of insufficient operator training (Y)

Table 1 provides examples of hazards and hazardous events

Table 1: list of hazards and hazardous events

Hazardous event	Hazard type
Increases in temperature and shifting of precipitation patterns will alter seasonal runoff and storage of water as snow. Earlier peak runoff flows may strain the capacity of reservoirs to hold large earlier peak flow volumes.	Physical
Increases in temperature and decreases in mean annual precipitation, leads to reduced runoff and higher loss of water through evapotranspiration.	Physical
Under wetter conditions - Projected sea level rise will increase inundation and salinity in coastal areas. Under drier conditions - Over abstraction of groundwater in coastal areas especially during dry periods, leads to reduced groundwater table.	Physical and Chemical
The building size is not according to legislation for the chlorine content being kept in the chlorine building.	Chemical
Intense precipitation events may occur more frequently, concentrating the annual total rainfall into episodes that challenge current infrastructure for water management and flood control.	Physical
Under wet conditions - Reduced energy production due to increased flows and rises in water levels. Under dry conditions - Due to reduced water levels, energy production may not be possible.	Physical
Increased animal activity at open reservoirs. Increased animal activity and leads to faecal contamination due to droppings of birds and other small animals such as frogs etc.	Microbial
Lower precipitation will lead to lower streamflow in many locations, which may lead to diminished water quality due to little flushing of pollutants taking place.	Microbial

- The WSP team should categorise each hazard and hazardous event into one of four categories which include (Table 2):
 - hazards affected by wet conditions
 - hazards affected by dry conditions
 - hazards affected by both wet and dry conditions
 - hazards affected by neither wet or dry conditions

Table 2: Categorised hazards and hazardous events

Hazardous event	Hazard	Physical Conditions
Increases in temperature and shifting of precipitation patterns will alter seasonal runoff and storage of water as snow. Earlier peak runoff flows may strain the capacity of reservoirs to hold large earlier peak flow volumes.	Physical	Wetter
Increases in temperature and decreases in mean annual precipitation, leads to reduced runoff and higher loss of water through evapotranspiration.	Physical	Drier
Under wetter conditions - Projected sea level rise will increase inundation and salinity in coastal areas. Under drier conditions - Over abstraction of groundwater in coastal areas especially during dry periods, leads to reduced groundwater table.	Physical and Chemical	Wetter or Drier
The building size is not according to legislation for the chlorine content being kept in the chlorine building.	Chemical	Unaffected by wetter or drier conditions
Intense precipitation events may occur more frequently, concentrating the annual total rainfall into episodes that challenge current infrastructure for water management and flood control.	Physical	Wetter
Under wet conditions - Reduced energy production due to increased flows and rises in water levels. Under dry conditions - Due to reduced water levels, energy production may not be possible.	Physical	Wetter or Drier
Increased animal activity at open reservoirs. Increased animal activity and leads to faecal contamination due to droppings of birds and other small animals such as frogs etc.	Microbial	Unaffected by wetter or drier conditions
Lower precipitation will lead to lower streamflow in many locations, which may lead to diminished water quality due to little flushing of pollutants taking place.	Microbial	Drier

6. Getting Started with the Flood and Drought Portal

6.1 Register and Login

Access the Flood and Drought Portal using the following URL: <http://www.flooddroughtmonitor.com>. In order to use the Portal and access the datasets the user will be required to register and setup login information. Click login in the top right corner of the screen, this should bring up a login dialog (Figure 1).

- In the login dialog click on the dropdown (under select user-group)
- Choose water-utility, and click register

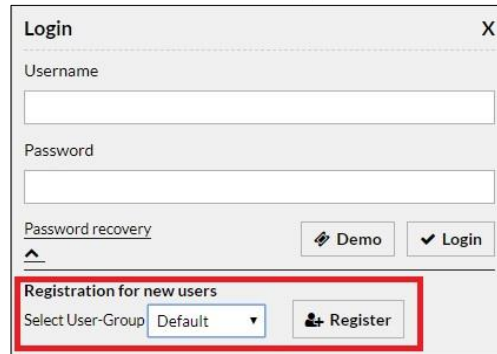


Figure 1: Login screen

The user should complete the registration dialog, and click register (Figure 2). The user should receive a registration email from the DHI-group. It should be noted that if the requested basin is unavailable, the user may need to wait up to three (3) days for the basin and information to become available. When the basin and information becomes available the user will be notified via email. For more information on logging in and registration the user can find more info at: [User guide](#)

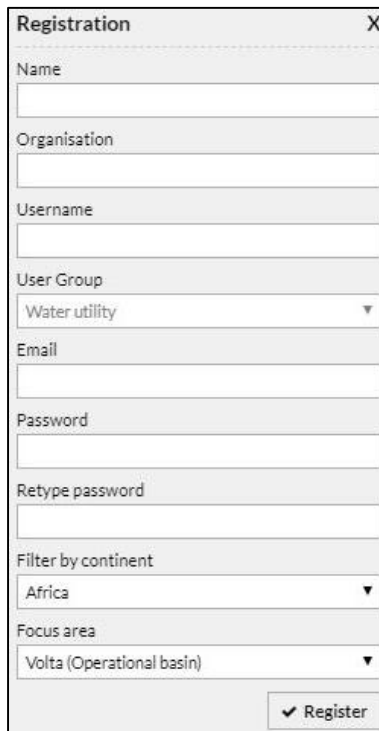


Figure 2: Utility registration form

6.2 Data Review

When the user has logged in, a menu will appear displaying various tools within the Portal. Each of these tools allows the user to conduct different assessments. For the purposes of this guideline, only the use of the “Data and Information” and “water Safety Planning” tools are described (Figure 3).

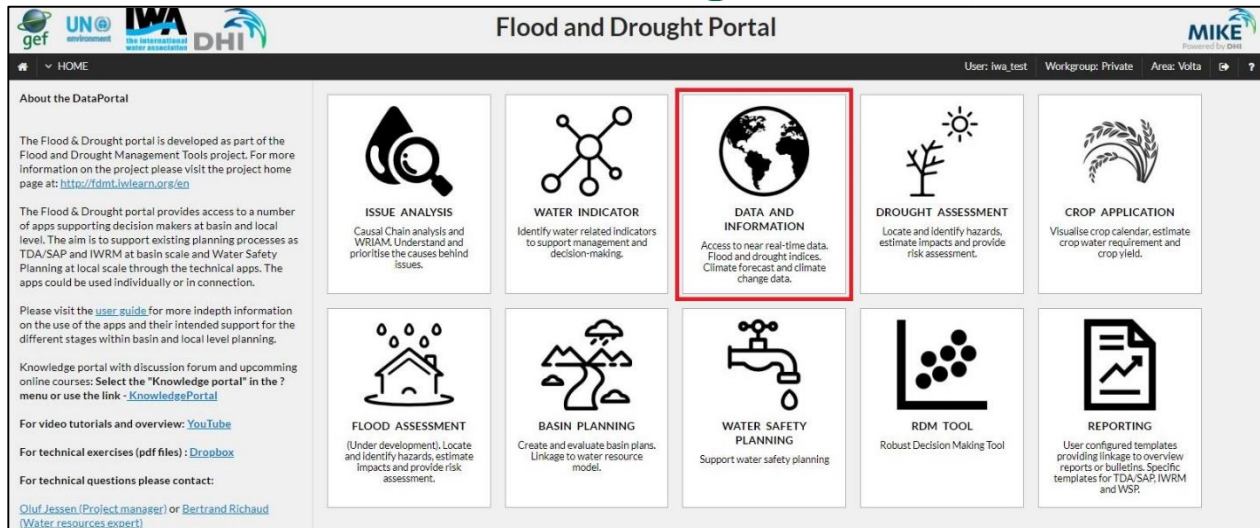


Figure 3: Basic functionality of the Flood and Drought Portal

Select the “Data and information” tool. This will show the water utility region and basin of interest highlighted in green, and the dataset dialog to the left (Figure 4). Above the dataset dialog two options are available “Status” and “GIS layers”. “Status” indicates the last time step of all datasets (i.e. when datasets were last updated). “GIS layers” will download the available shapefiles for your basin which are accessible using a GIS (ARCGIS, QGIS, Whitebox etc.).



Figure 4: Data and information application with no datasets added

In order to view the list of datasets:

- Click “Select” above the dataset dialog, this opens the “Favourite Data” dialog.
- The “Favourite Data” dialog shows a list of the various datasets (as listed in Table 3).

NOTE: Available datasets may change as new datasets come online and other datasets are retired.

Table 3: List of datasets

Name	Description	Name	Description
Rainfall (CHIRPS)	Historical ensemble	Vegetation NDVI (5600 m)	NDVI deviation rel. (5600 m)
	Monthly mean		NDVI deviation (5600 m)
Rainfall (TRMM)	Historical ensemble (TRMM)		Vegetation Condition Index (VCI)
	Monthly mean (TRMM)	Soil water index (SWI)	SWI percentile
	SPI 1 month		SWI percentile change (10-day)
	SPI 3 month		SWI percentile change (20-day)
	SPI 6 month		SWI percentile change (30-day)
	Rainfall deviation 30-day (TRMM)	Vegetation Health Index (VHI)	VHI
	Effective drought Index (EDI)	Agricultural Stress Index (ASI)	ASI Seasonal (season 1)
	Effective flood Index (EFI)		ASI Seasonal (season 2)
Rainfall (GPM)	Rainfall deviation 30-day (GPM)		ASI Seasonal (season 3)
	SPI 1 month		ASI Annual (season 1)
	SPI 3 month		ASI Annual (season 2)
	SPI 6 month		ASI Annual (season 3)
Rainfall (PERSIAN)	Monthly mean (PERSIAN)	Combined Drought Index (CDI)	CDI
	SPI 1 month	Evapotranspiration	PET (0.1mm/8day)
	SPI 3 month		ET (0.1mm/8day)
	SPI 6 month	Evapotranspiration	CRU PET mm/day
Rainfall (CRU)	Rainfall (mm/month) (CRU)	Temperature	Temperature deviation
Rainfall (GHCN)	Rainfall daily (GHCN)		Temperature Condition Index (TCI)
	Rainfall monthly (GHCN)		
Rainfall forecast	Seasonal forecast <ul style="list-style-type: none"> Forecasted SPI 1 month (Raw) Forecasted SPI 3 month (Raw) Seasonal forecast (Corrected) <ul style="list-style-type: none"> Forecasted SPI 1 month Forecasted SPI 3 month 	Temperature	CRU Temperature C
Chlorophyll	Chlorophyll	Climate change	PET rcp45 2016-2035
Lakes and reservoirs	JASON		PET rcp85 2016-2035
Medium Range Rainfall Forecast	GFS025		PET rcp45 2081-2100

Name	Description	Name	Description
	EGFS10		PET rcp85 2081-2100
Global Surface Water	Maximum water extent (1984 -2015)	Climate Change (continued)	TEMP rcp45 2016-2035
	Water seasonality		TEMP rcp85 2016-2035
	Annual water recurrence (1984-2015)		TEMP rcp45 2081-2100
	Water occurrence (1984-2015)		TEMP rcp85 2081-2100
	Water occurrence change		Precip. rcp45 2016-2035
	Water transitions		Precip. rcp85 2016-2035
			Precip. rcp45 2081-2100
			Precip. rcp85 2081-2100
Flood Index	HAND		Dry days/month rcp45 2016-2035
Physical and socio-economic data	Socio-economic <ul style="list-style-type: none"> • Population (A1B1) • Gross Domestic Product • Night Light (2006) • Night Light (2010) • Drought Mortality Risk • Flood Mortality Risk • Infant Mortality Rate (2000) • Urban expansion (2030) • Child under weight (percentage) 		Dry days/month rcp85 2016-2035
Physical and socio-economic data	Agriculture <ul style="list-style-type: none"> • Irrigated areas • Crop Dominance • Crop Mask • Soil Map • Pasture 		Dry days/month rcp45 2081-2100
Physical and socio-economic data	Drought related <ul style="list-style-type: none"> • Drought exposure economic • Drought exposure physical • Drought Mortality Risk (2000) 		Dry days/month rcp85 2081-2100
Physical and socio-economic data	Flood related <ul style="list-style-type: none"> • Flood Hazard 25yrp • Flood Hazard 50yrp • Flood Hazard 100yrp • Flood Exposure economic 		

Name	Description	Name	Description
	<ul style="list-style-type: none"> Flood exposure physical Flood risk 		
River discharge	River Discharge		
Flash Flood	Flash Flood Potential Index (FFPI)		
Water Bodies	Water Body (10 day)		

In order to get a feel for using the Data and Information tool, a brief example using the “Rainfall TRMM” dataset is presented below.

Example 1: Making a dataset part of your favourites

- In the “Favourite data” dialog click on the “Rainfall TRMM” and view the dataset description (Figure 5).
- View the Descriptions of other datasets to get an understanding of the various datasets available.
- After viewing the various dataset descriptions, add the dataset “Rainfall TRMM” by checking the box next to it.
- Click on “Update” at the bottom right corner of the “Favourite data” dialog.

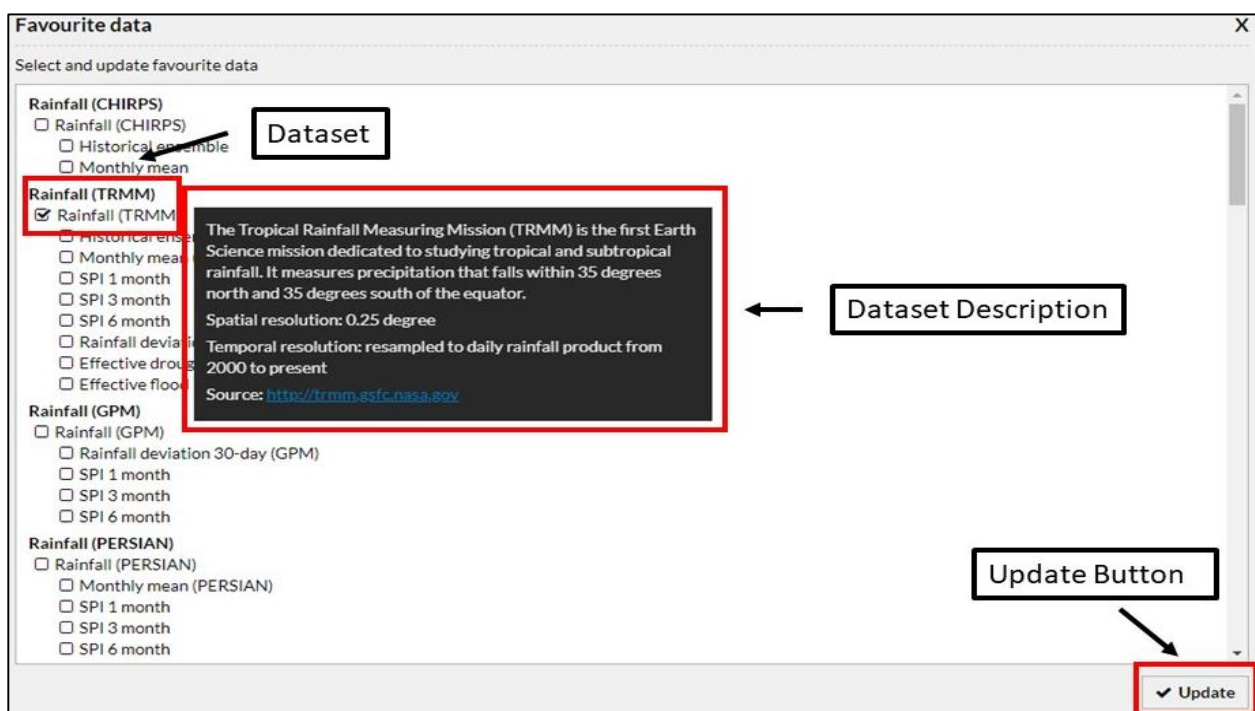


Figure 5: Favourite data dialog

- The dataset will appear in the dataset dialog.
- Select the dataset “Rainfall TRMM” in the dataset dialog, this will load the data on the map with the legend and below the dataset dialog (Figure 6).

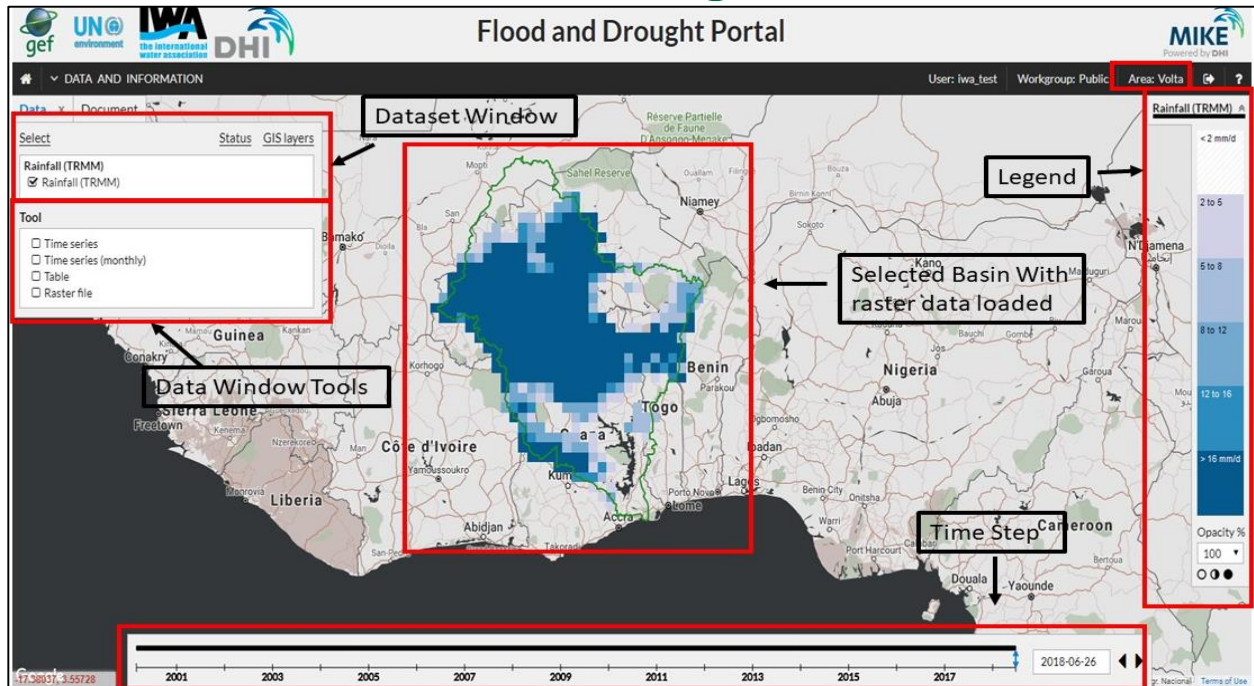


Figure 6: Overview of data functionality and Rainfall distribution for the Volta Basin

- A tools dialog will appear: these tools include time series data, table data and raster files which are available for download and can be processed in excel or a GIS.
- The tools for data types may vary between datasets, as some datasets may include additional tools such as envelope plots and others may only include raster files.
- The map generated shows the last time step available for each dataset, however the “time step” slider, at the bottom of the screen, can be moved to see the weather conditions of a basin over time.

Example 2: Viewing the data – Part 1

- Select the dataset “Rainfall TRMM”.
- The tools dialog should open.
- In the tools dialog select “Time Series”.
- The graph displaying the rainfall data will appear (Figure 7) (**Note:** this graph is specifically for the Volta basin).
- Zoom into a specific year or time step by dragging your mouse over the period on the graph, this will display data for that year/time step in more detail.

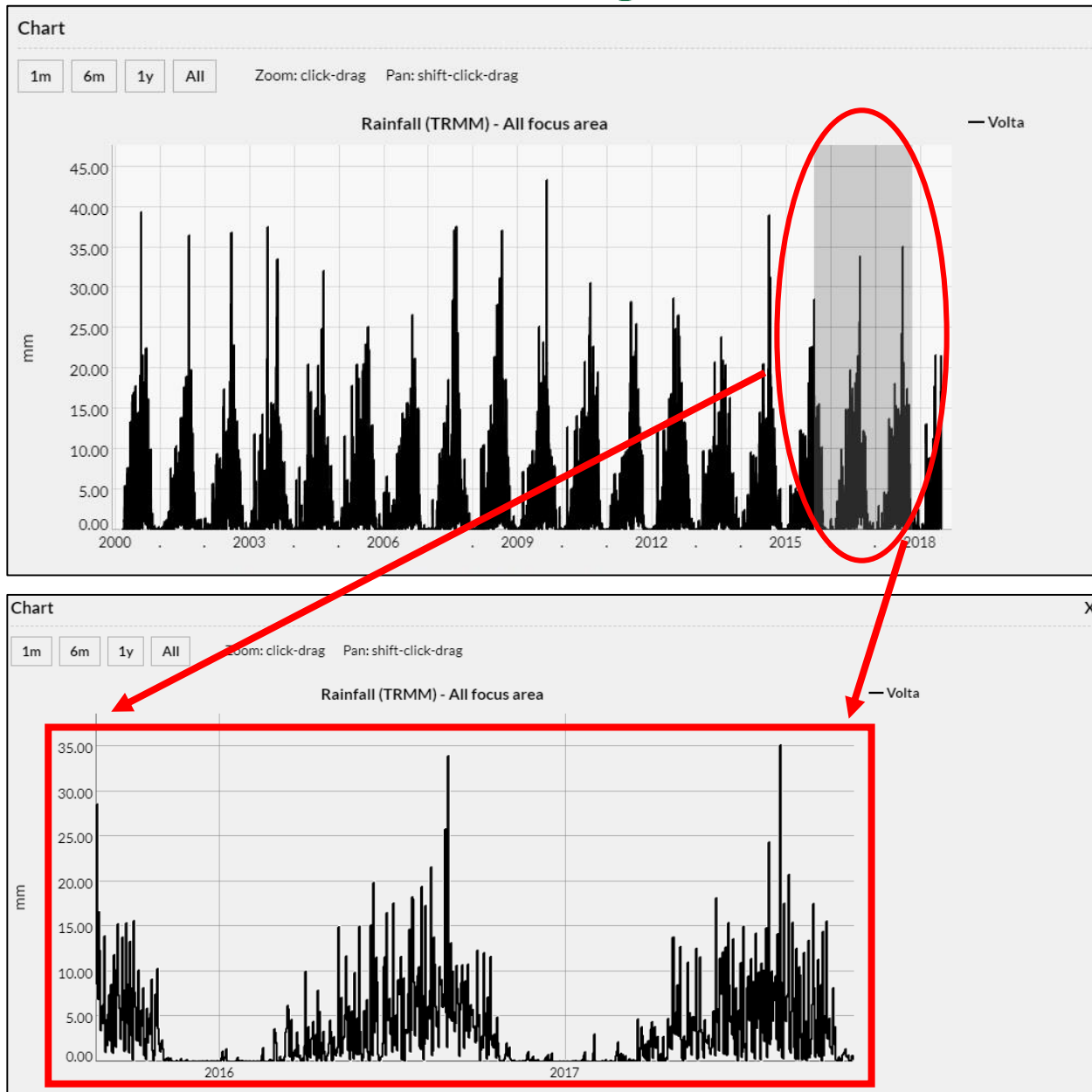


Figure 7: The graph at the top indicates the rainfall for the entire TRMM, while the graph at the bottom indicates a zoomed in section

Example 3: Viewing data – Part 2

- Select the “Time Series (monthly)” in the tools menu.
- Click “New Chart”.
- The graph generated shows a monthly time series plot (in black) and the long-term average/mean for the dataset (in red) (Figure 8). This graph is useful as it indicates the months where rainfall exceeded the mean.

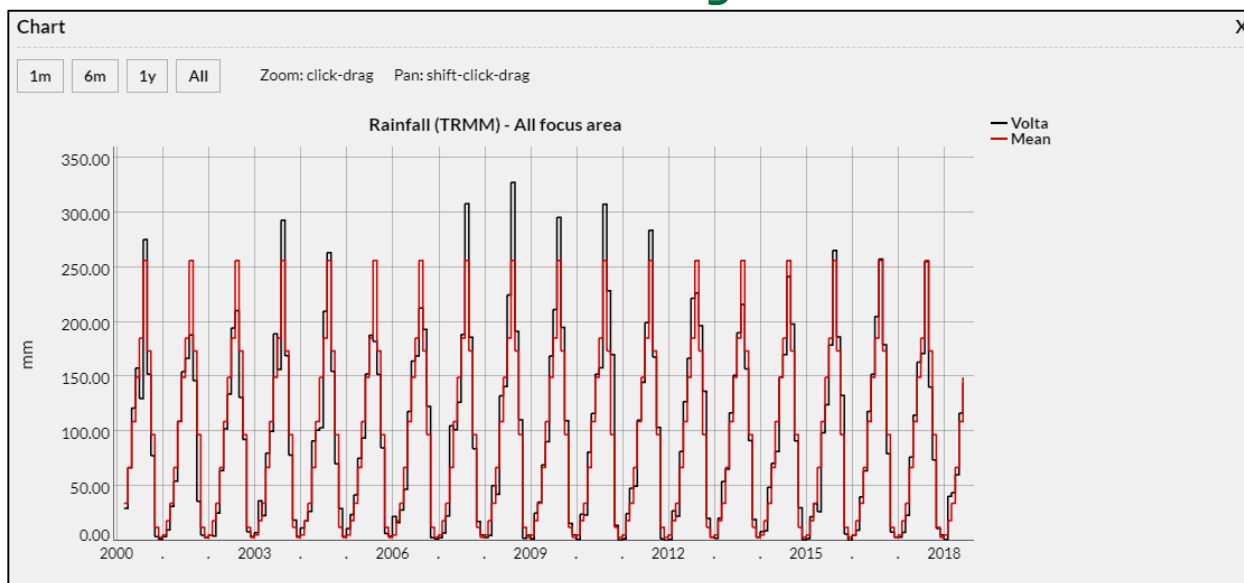


Figure 8: Monthly time series graph with averages/ means displayed in red.

- Select the “Table” option, the dataset (Figure 9)

Time	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg.	Min.	Max.
2000			29.7	66.7	121.3	157.8	129.9	275.4	152.1	77.9	3.9	1.5	101.6	1.5	275.4
2001	3.7	10.0	31.5	54.5	109.1	154.5	166.9	188.0	146.2	36.2	5.0	2.8	75.7	2.8	188.0
2002	5.3	4.5	25.3	64.1	102.4	133.9	194.4	210.2	131.0	92.6	8.2	4.0	81.3	4.0	210.2
2003	7.5	36.5	23.0	80.1	99.9	189.1	156.7	293.0	169.0	78.2	18.9	3.9	96.3	3.9	293.0
2004	11.8	18.2	26.7	91.4	101.1	103.4	209.9	263.2	154.8	70.4	29.4	3.8	90.4	3.8	263.2
2005	11.3	24.0	42.0	75.4	94.0	152.3	187.8	182.0	151.9	85.0	6.7	4.0	84.7	4.0	187.8
2006	22.3	16.7	28.2	47.1	118.1	164.2	168.8	212.5	193.1	122.8	2.9	1.7	91.5	1.7	212.5
2007	2.9	7.1	22.8	105.1	101.5	126.7	188.6	308.0	185.9	84.1	17.6	5.5	96.3	2.9	308.0
2008	3.2	4.8	50.3	42.6	132.5	141.0	224.7	327.5	191.3	110.5	2.4	5.0	103.0	2.4	327.5
2009	1.8	25.3	35.3	69.3	90.6	168.7	211.4	295.5	194.9	109.6	15.9	5.4	102.0	1.8	295.5
2010	1.3	24.4	23.5	81.1	116.5	152.1	158.0	307.4	228.5	170.0	14.0	0.8	106.5	0.8	307.4
2011	1.7	24.9	48.2	49.8	110.1	144.9	199.4	283.6	167.8	103.6	1.9	0.5	94.7	0.5	283.6
2012	1.4	27.4	22.5	81.6	127.2	166.8	221.6	226.4	196.4	136.7	20.4	3.4	102.7	1.4	226.4
2013	2.3	20.8	54.2	65.5	117.0	151.2	190.1	215.9	157.0	91.5	19.5	3.3	90.7	2.3	215.9
2014	8.5	9.1	48.9	70.8	81.5	149.6	170.0	241.4	198.0	91.3	30.3	0.8	91.7	0.8	241.4
2015	2.1	21.9	34.1	26.7	98.7	124.4	178.9	265.4	186.2	132.8	6.2	0.5	89.8	0.5	265.4
2016	5.1	9.8	40.1	63.8	118.2	152.1	205.0	257.4	179.1	79.5	7.9	3.4	93.4	3.4	257.4

Figure 9: Monthly averages/means in tabular format.

The datasets can be downloaded and viewed in Excel. There is also an option to download the raster data which the user may view using a GIS. The user is strongly encouraged to spend some time looking at the other datasets available within the Portal, and using the available data tools to view them. To assist the user further, the Portal also provides a quick overview of a basin (Figure 10).

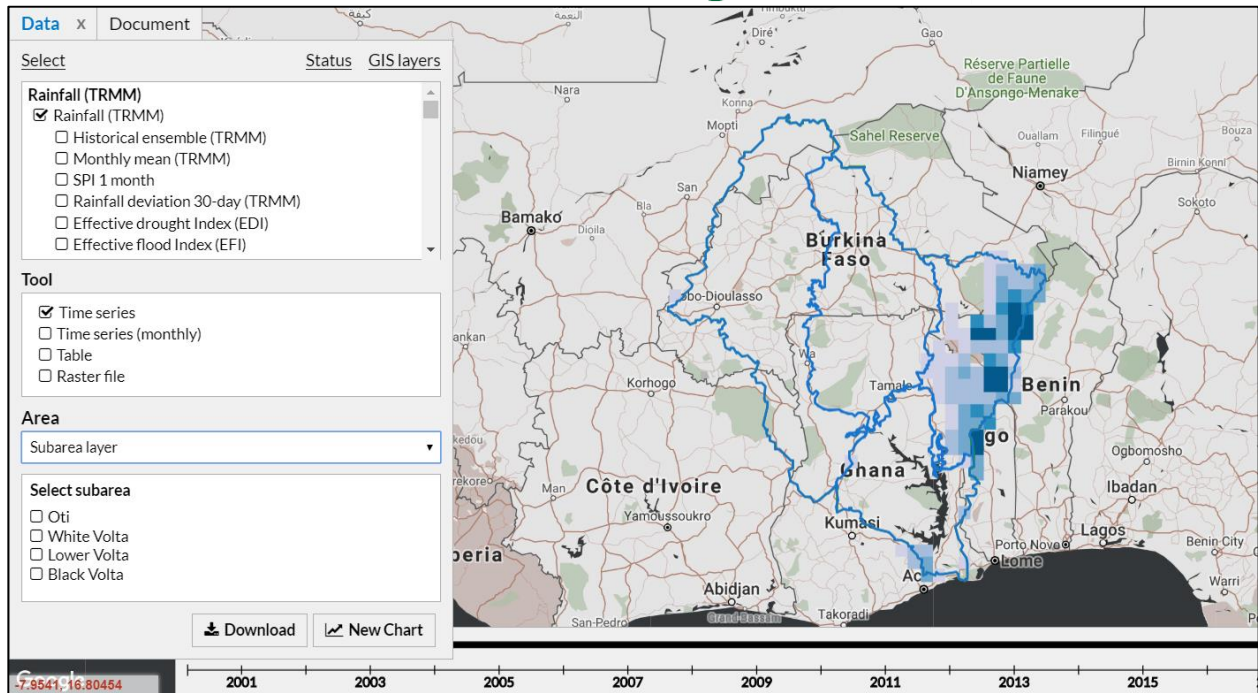


Figure 10: Data and map view in the Portal

More information on the datasets and the different data tools can be found in the IWA guiding documents. These documents are found by following the link: [Flood and Drought Portal Documents](#).

Example 4: Viewing data – Part 3

When viewing a dataset in the Portal, the default spatial scale is at the basin scale. However, the user can view the datasets at different spatial scales. These scales are described below:

- All focus area: Weighted time values for the whole basin
- User location: Weighted values for a user specified location
- Subarea layer: Weighted values for a selected sub-basin
- Point layer: Weighted values for a selected station (point location)

In order to view data for different spatial scales:

- Select Rainfall TRMM in the Data dialog
- When the tool dialog appears select the “Tool” of choice either Time series, Table and Envelope plot (where available)
- When the “Tool” is selected, another dialog will appear called “Area”
- In the “Area” dialog select the spatial scale that is useful to the water utility (Figure 11).

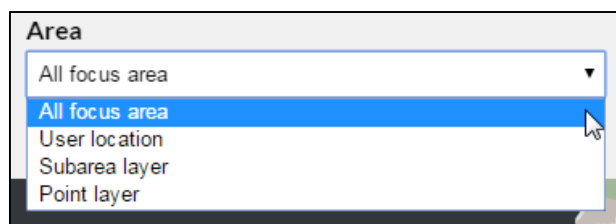


Figure 11: List of spatial scales that data can be viewed at within the Portal.

- The different spatial scales will appear differently on the map
- When selecting “Subarea layer”, the different sub-basins will appear
- When selecting “Point layer”, different points on the map will appear with in the basin
- In both cases the “Subarea” and “Point layer” can be selected by, i) clicking on the subareas or points on the map, or ii) from the list that is generated when choosing the spatial scale

7. Overview of Selected Datasets

For the purposes of this guidance document, six (6) datasets were selected to determine if physical conditions are expected to be wetter or drier. Two (2) datasets were selected for a short-term analysis, while four (4) datasets were selected for a long-term analysis. These datasets were selected based on (1) feasibility of use, and (2) ease of use/understanding and applicability to utilities for data analysis. Datasets which (1) do not provide a clear indication of how the graphs/data can be read, (2) produce graphs/data with too much information (cluttered), or (3) provide insufficient data (data gaps or only provide raster files) were firstly eliminated (Table 4).

Table 4: List of selected datasets for short or long-term climate analysis

Short-Term Climate Analysis Datasets		Long-term Climate Analysis Datasets	
1.	Rainfall (TRMM)	1.	Rainfall (CRU) – Rainfall (mm/month) (CRU)
2.	Temperature (MOD11A1)	2.	Precip. RCP45 2016-2035
		3.	Temperature – CRU Temperature C
		4.	TEMP RCP45 2016-2035

Short-Term Datasets

- **Rainfall (TRMM)** - The preferred data for rainfall is the Tropical Rains Measuring Mission (TRMM). It provides the probable rainfall changes for 1 month, 3 months and 6 months, taking into account the

historical rainfall. It is recommended that the historical ensemble data be downloaded and evaluated in Excel, as the graphs on the Portal can be confusing for novice users.

Note: The user should note that although Rainfall (TRMM) dataset is still available, there is currently a project to reprocess the TRMM-era multi-satellite datasets (TMPA) with GPM-era algorithms to create a continuous record with the GPM IMERG multi-satellite dataset that will cover 1998 to the present. This reprocessing is currently scheduled to take place in April to June 2018.

More information can be found at the following links:

[How to Access TRMM & GPM Precipitation Data](#)

OR

[PPS is Reprocessing TRMM PR Data as TRMM GPM](#)

- **Temperature (MOD11A1)** - Temperature is one of the first indicators of a drought, with prolonged periods of high temperatures exceeding the mean indicating drought conditions. The dataset is based on the 1 km MOD11A1 product. The product is resampled to a 5 km resolution with an 8-day temporal resolution.

Long-Term Datasets

- **Rainfall (CRU) Rainfall (mm/month) (CRU)** - CRU rainfall data covers the period 1901-2013, and covers all land areas except Antarctica at a resolution of 0.5°. The dataset indicates month-by-month climate variations.
- **Temperature CRU Temperature C** – CRU temperature data covers the period 1901-2015, and covers all land areas except Antarctica at a resolution of 0.5°. The dataset indicates month-by-month climate variations.
- **TEMP, Precip.RCP45 2016 to 2035** - RCP datasets consist of a range of possible changes in future anthropogenic greenhouse gas emissions and aims to represent their atmospheric concentrations. The RCP values are consistent with certain socio-economic assumptions, providing flexible descriptions of possible futures. The datasets provide predictions of temperature and precipitation, where the estimations are for the medium radiation forcing scenario RCP45 and the extreme radiation forcing scenario RCP85. The recommended RCP dataset is RCP45, which estimates that the CO₂-emissions will peak around the year 2040, and then decline, due to less usage of fossil fuels. The data provides various change factor outputs, indicating if there is an increase or decrease in temperature and precipitation.

8. Step-by-step Guidance on How to Determine the Risk of Wetter or Drier Conditions

The following section is divided into two parts, namely **short-term analysis** and **long-term analysis**. Various methods will be used to determine whether the utility will be experiencing wetter or drier conditions in the short- and long-term. This will include downloading of relevant datasets, and processing the data using a spreadsheet (e.g. Excel). The information that this analysis yields will be incorporated into the water safety planning process. **The short-term analysis should be done every six months, whereas the long-term analysis should be done annually, e.g. Water utilities should do the analysis before the financial cycle so that the water utility may secure the necessary funding to implement control measures.** To assist the user with analysing the datasets, worked examples have been prepared. These are available as an accompanying Excel file named “Short-term analysis for rain/temperature” and “Long-term analysis for rain/temperature”.

8.1 Short-Term Climate Analysis

A short-term analysis of climate data can assist utilities in determining immediate risks and addressing noted concerns through appropriate immediate/short-term interventions. In order to perform a short-term analysis, the utility will have to download and process the required datasets and use the Portal to **determine if they are experiencing wetter or drier conditions**. This analysis is not intended to indicate whether the utility is experiencing floods or droughts, but rather to determine whether the utility is experiencing a wetting or drying trend. This will be based on the analysis of recent data for a 1-year period and determining whether rainfall or temperature is above or below the average. Analysis of climate data can assist in short-term planning and implementation of control measures that may reduce the impacts of climate related disasters to the utility. The datasets required for a short-term analysis include (Table 5):

Table 5: List of datasets for short-term climate analysis

Short-Term Climate Analysis Datasets	
1.	Rainfall (TRMM)
2.	Temperature (MOD11A1)

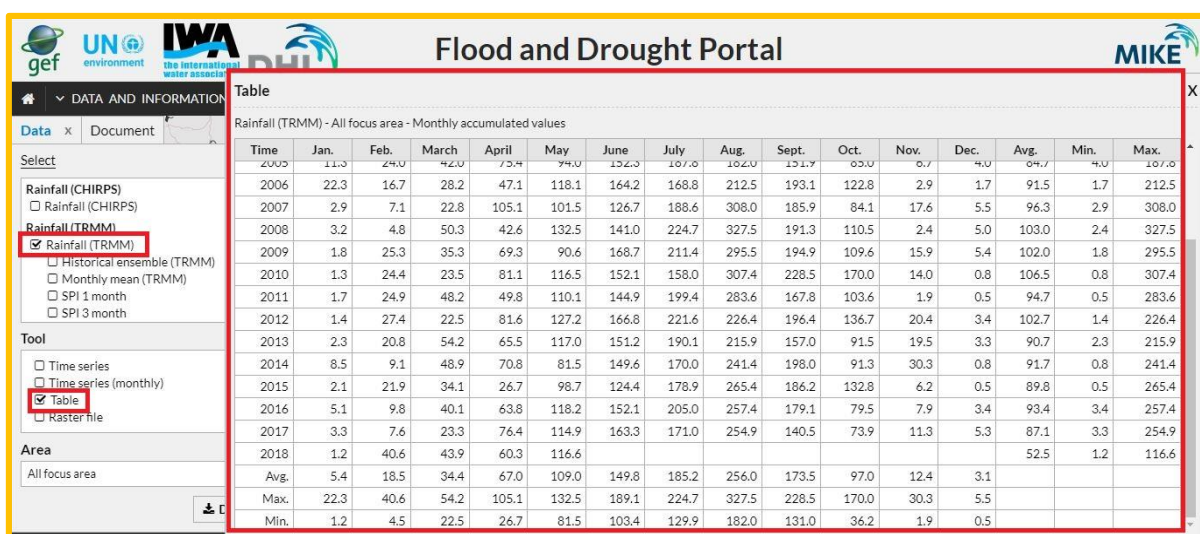
The datasets listed in Table 5 should be added to the dataset dialog (as explained in Section 2.2: Data review). To get a general idea of what the basin data looks like, the user should view the graphs, maps and tables for each dataset.

The purpose of the following analysis is to determine if the amount of rainfall in the year is above or below the long-term mean, and therefore to indicate if conditions are wetter or drier than normal.

Note: The analysis conducted should not be interpreted as a weather forecast and are only intended to be used to facilitate improved planning.

8.1.1 Steps for analysing short-term rainfall data

- In the dataset dialog select the Rainfall (TRMM).
- In the “Tool” dialog select the “Table” option and download the table data for the dataset (Figure 12), the downloaded data will be in “.csv” format and can be accessed using Microsoft excel.



Flood and Drought Portal

Table

Rainfall (TRMM) - All focus area - Monthly accumulated values

Time	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg.	Min.	Max.
2005	11.3	24.0	42.0	73.4	94.0	132.3	107.0	102.0	131.7	63.0	0.7	4.0	64.7	4.0	107.0
2006	22.3	16.7	28.2	47.1	118.1	164.2	168.8	212.5	193.1	122.8	2.9	1.7	91.5	1.7	212.5
2007	2.9	7.1	22.8	105.1	101.5	126.7	188.6	308.0	185.9	84.1	17.6	5.5	96.3	2.9	308.0
2008	3.2	4.8	50.3	42.6	132.5	141.0	224.7	327.5	191.3	110.5	2.4	5.0	103.0	2.4	327.5
2009	1.8	25.3	35.3	69.3	90.6	168.7	211.4	295.5	194.9	109.6	15.9	5.4	102.0	1.8	295.5
2010	1.3	24.4	23.5	81.1	116.5	152.1	158.0	307.4	228.5	170.0	14.0	0.8	106.5	0.8	307.4
2011	1.7	24.9	48.2	49.8	110.1	144.9	199.4	283.6	167.8	103.6	1.9	0.5	94.7	0.5	283.6
2012	1.4	27.4	22.5	81.6	127.2	166.8	221.6	226.4	196.4	136.7	20.4	3.4	102.7	1.4	226.4
2013	2.3	20.8	54.2	65.5	117.0	151.2	190.1	215.9	157.0	91.5	19.5	3.3	90.7	2.3	215.9
2014	8.5	9.1	48.9	70.8	81.5	149.6	170.0	241.4	198.0	91.3	30.3	0.8	91.7	0.8	241.4
2015	2.1	21.9	34.1	26.7	98.7	124.4	178.9	265.4	186.2	132.8	6.2	0.5	89.8	0.5	265.4
2016	5.1	9.8	40.1	63.8	118.2	152.1	205.0	257.4	179.1	79.5	7.9	3.4	93.4	3.4	257.4
2017	3.3	7.6	23.3	76.4	114.9	163.3	171.0	254.9	140.5	73.9	11.3	5.3	87.1	3.3	254.9
2018	1.2	40.6	43.9	60.3	116.6								52.5	1.2	116.6
Avg.	5.4	18.5	34.4	67.0	109.0	149.8	185.2	256.0	173.5	97.0	12.4	3.1			
Max.	22.3	40.6	54.2	105.1	132.5	189.1	224.7	327.5	228.5	170.0	30.3	5.5			
Min.	1.2	4.5	22.5	26.7	81.5	103.4	129.9	182.0	131.0	36.2	1.9	0.5			

Figure 12: Rainfall (TRMM) table data

Note: When opening the downloaded files, the data may appear in one single column. It is very important that the data be separated, before the analysis starts (Figure 13). This may not always occur and it is largely dependent on the Version of the Microsoft Office software on your computer.

	A	B	C	D	E	F	G	H
1	description==Monthly accumulated values							
2	Time,Jan.,Feb.,March,April,May,June,July,Aug.,Sept.,Oct.,Nov.,Dec.,Avg.,Min.,Max.							
3	2000, , ,29.7,66.7,121.3,157.8,129.9,275.4,152.1,77.9,3.9,1.5,101.6,1.5,275.4							
4	2001,3.7,10.0,31.5,54.5,109.1,154.5,166.9,188.0,146.2,36.2,5.0,2.8,75.7,2.8,188.0							
5	2002,5.3,4.5,25.3,64.1,102.4,133.9,194.4,210.2,131.0,92.6,8.2,4.0,81.3,4.0,210.2							
6	2003,7.5,36.5,23.0,80.1,99.9,189.1,156.7,293.0,169.0,78.2,18.9,3.9,96.3,3.9,293.0							
7	2004,11.8,18.2,26.7,91.4,101.1,103.4,209.9,263.2,154.8,70.4,29.4,3.8,90.4,3.8,263.2							
8	2005,11.3,24.0,42.0,75.4,94.0,152.3,187.8,182.0,151.9,85.0,6.7,4.0,84.7,4.0,187.8							
9	2006,22.3,16.7,28.2,47.1,118.1,164.2,168.8,212.5,193.1,122.8,2.9,1.7,91.5,1.7,212.5							
10	2007,2.9,7.1,22.8,105.1,101.5,126.7,188.6,308.0,185.9,84.1,17.6,5.5,96.3,2.9,308.0							
11	2008,3.2,4.8,50.3,42.6,132.5,141.0,224.7,327.5,191.3,110.5,2.4,5.0,103.0,2.4,327.5							
12	2009,1.8,25.3,35.3,69.3,90.6,168.7,211.4,295.5,194.9,109.6,15.9,5.4,102.0,1.8,295.5							
13	2010,1.3,24.4,23.5,81.1,116.5,152.1,158.0,307.4,228.5,170.0,14.0,0.8,106.5,0.8,307.4							
14	2011,1.7,24.9,48.2,49.8,110.1,144.9,199.4,283.6,167.8,103.6,1.9,0.5,94.7,0.5,283.6							
15	2012,1.4,27.4,22.5,81.6,127.2,166.8,221.6,226.4,196.4,136.7,20.4,3.4,102.7,1.4,226.4							
16	2013,2.3,20.8,54.2,65.5,117.0,151.2,190.1,215.9,157.0,91.5,19.5,3.3,90.7,2.3,215.9							
17	2014,8.5,9.1,48.9,70.8,81.5,149.6,170.0,241.4,198.0,91.3,30.3,0.8,91.7,0.8,241.4							
18	2015,2.1,21.9,34.1,26.7,98.7,124.4,178.9,265.4,186.2,132.8,6.2,0.5,89.8,0.5,265.4							
19	2016,5.1,9.8,40.1,63.8,118.2,152.1,205.0,257.4,179.1,79.5,7.9,3.4,93.4,3.4,257.4							
20	2017,3.3,7.6,23.3,76.4,114.9,163.3,171.0,254.9,140.5,73.9,11.3,5.3,87.1,3.3,254.9							
21	2018,1.2,40.6,43.9,60.3,116.6,167.6,210.3, , , , ,91.5,1.2,210.3							
22	Avg.,5.4,18.5,34.4,67.0,109.0,150.7,186.5,256.0,173.5,97.0,12.4,3.1, , ,							

Figure 13: Data appearing in one column

If your data appears in one column, the data can be separated into multiple columns using the following steps:

- Select column A in the spreadsheet then click the “Data” tab in excel.
- In the data tools Select “Text to Columns”.
- In the Window that opens choose “Delimited”, then click next.
- In delimiters check the box marked “Comma” and uncheck the “Tab” box.
- Click “Finished”.

The data should be separated into individual columns (Figure 14).

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Time	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg.	Min.	Max.
2	2000			29.7	66.7	121.3	157.8	129.9	275.4	152.1	77.9	3.9	1.5	101.6	1.5	275.4
3	2001	3.7	10.0	31.5	54.5	109.1	154.5	166.9	188.0	146.2	36.2	5.0	2.8	75.7	2.8	188.0
4	2002	5.3	4.5	25.3	64.1	102.4	133.9	194.4	210.2	131.0	92.6	8.2	4.0	81.3	4.0	210.2
5	2003	7.5	36.5	23.0	80.1	99.9	189.1	156.7	293.0	169.0	78.2	18.9	3.9	96.3	3.9	293.0
6	2004	11.8	18.2	26.7	91.4	101.1	103.4	209.9	263.2	154.8	70.4	29.4	3.8	90.4	3.8	263.2
7	2005	11.3	24.0	42.0	75.4	94.0	152.3	187.8	182.0	151.9	85.0	6.7	4.0	84.7	4.0	187.8
8	2006	22.3	16.7	28.2	47.1	118.1	164.2	168.8	212.5	193.1	122.8	2.9	1.7	91.5	1.7	212.5
9	2007	2.9	7.1	22.8	105.1	101.5	126.7	188.6	308.0	185.9	84.1	17.6	5.5	96.3	2.9	308.0
10	2008	3.2	4.8	50.3	42.6	132.5	141.0	224.7	327.5	191.3	110.5	2.4	5.0	103.0	2.4	327.5
11	2009	1.8	25.3	35.3	69.3	90.6	168.7	211.4	295.5	194.9	109.6	15.9	5.4	102.0	1.8	295.5
12	2010	1.3	24.4	23.5	81.1	116.5	152.1	158.0	307.4	228.5	170.0	14.0	0.8	106.5	0.8	307.4
13	2011	1.7	24.9	48.2	49.8	110.1	144.9	199.4	283.6	167.8	103.6	1.9	0.5	94.7	0.5	283.6
14	2012	1.4	27.4	22.5	81.6	127.2	166.8	221.6	226.4	196.4	136.7	20.4	3.4	102.7	1.4	226.4
15	2013	2.3	20.8	54.2	65.5	117.0	151.2	190.1	215.9	157.0	91.5	19.5	3.3	90.7	2.3	215.9
16	2014	8.5	9.1	48.9	70.8	81.5	149.6	170.0	241.4	198.0	91.3	30.3	0.8	91.7	0.8	241.4
17	2015	2.1	21.9	34.1	26.7	98.7	124.4	178.9	265.4	186.2	132.8	6.2	0.5	89.8	0.5	265.4
18	2016	5.1	9.8	40.1	63.8	118.2	152.1	205.0	257.4	179.1	79.5	7.9	3.4	93.4	3.4	257.4
19	2017	3.3	7.6	23.3	76.4	114.9	163.3	171.0	254.9	140.5	73.9	11.3	5.3	87.1	3.3	254.9

Figure 14: Data separated into individual columns

Steps for analysing short-term rainfall data:

- Download the TRMM rainfall data for short-term rainfall analysis (Figure 14)
- The datasets will download in “.csv” format, which can be accessed using Excel.
- Data will appear in columns A to P of your spreadsheet.
- Before the data is processed, add the following headings (we suggest starting from column “R1” to Column “U1”):

R1 - Month and year

S1 – Rainfall total for month (mm/month)

T1 – Average monthly rainfall (mm/month)

U1 - Percent of normal (%)

- Select the cells starting from “R1” to “R13” and “U1” to U13” and add borders to create a table (Figure 15). To add a border, go to the “Home” tab and under “font” click the drop-down arrow next to “borders” and choose “all borders”.
- In the “month and year” column add the dates for the previous 12 months (e.g. see Figure 15 – data downloaded in June 2018). In the “rainfall total for month” column, copy the data for previous 12 months from the long-term data and paste it next to the corresponding month in the table.
- The long-term average monthly rainfall for the dataset should be copied and added to the table (**Note:** when copying the average values make sure to paste it in the correct cell i.e. paste the average for June next to the recorded value for June).

	R	S	T	U
1	Month and year	Rainfall total for month (mm/month)	Average monthly rainfall (mm/month)	Percent of normal (%)
2	Jun 17	163.3	149.8	
3	Jul 17	171	185.2	
4	Aug 17	254.9	256	
5	Sep 17	140.5	173.5	
6	Oct 17	73.9	97	
7	Nov 17	11.3	12.4	
8	Dec 17	5.3	3.1	
9	Jan 18	1.2	5.4	
10	Feb 18	40.6	18.5	
11	Mar 18	43.9	34.4	
12	Apr 18	60.3	67	
13	May 18	116.6	109	
14			Average Percent of Normal for previous 12 months (%)	

Figure 15: Table displaying short-term data

In order to determine the likelihood of conditions being more or less than the average, the number of times the projected conditions are above or below the long-term monthly average should be counted. However, the user has to determine the number of times the observed monthly average is above the long-term monthly average/mean. In order to do this the “percent of normal” should be calculated.

The “percent of normal” will be calculated for each month. This will indicate to the user if observed monthly rainfall was more than, less than or equal to the long-term monthly average/mean (the long-term average monthly rainfall in this case is considered “normal rainfall”). The average percent (%) of normal of the 12 months will be determined to get an overall idea of what the rainfall was like during that period.

- In order to calculate the “percent of normal” insert the following equation into excel:

$$= (S2/T2) * 100$$

- where S2 is the recorded rainfall total for the month, and T2 is the long-term average monthly rainfall. Multiplying by 100 will give the answer as a percentage.

- Calculate the average of the “Percent of normal” for the last 12 months using the equation below:

$$= \text{Average} (U2:U13)$$

Where U2:U13 is the range of percent of normal calculated for January to December.

- The final table should then look as per Figure 17.

	R	S	T	U
1	Month and year	Rainfall total for month (mm/month)	Average monthly rainfall (mm/month)	Percent of normal (%)
2	Jun 17	163.3	149.8	109.01
3	Jul 17	171	185.2	92.33
4	Aug 17	254.9	256	99.57
5	Sep 17	140.5	173.5	80.98
6	Oct 17	73.9	97	76.19
7	Nov 17	11.3	12.4	91.13
8	Dec 17	5.3	3.1	170.97
9	Jan 18	1.2	5.4	22.22
10	Feb 18	40.6	18.5	219.46
11	Mar 18	43.9	34.4	127.62
12	Apr 18	60.3	67	90.00
13	May 18	116.6	109	106.97
14			Average Percent of Normal for previous 12 months (%)	107.20

Figure 16: Final table with all calculations for rainfall

The “Percent of normal (%)” calculates the percentage increase or decrease observed in rainfall relative to the and long-term average monthly rainfall. In the case of the above example, rainfall has increased to 107.2% of average/mean. Values **below 100%** indicate that rainfall was **less** than the average/mean, while **values above 100%** indicate that rainfall was **more** than the average/mean. In the above example, the observed rainfall during the analysis period increased (i.e. 107.2%). Using table 6 below, the physical conditions experienced by the water utility can be determined.

Is there information on changes in rainfall intensity in the system?

The Portal does not have any indicator related to rainfall intensity. The main reason is that rainfall data within the Portal focuses on daily rainfall where the intensity is not as relevant. It is possible to look at half-hourly and 3-hourly rainfall for some of the rainfall products (e.g. TRMM) and in that case the intensity would be a very relevant parameter. It should be noted that, the Portal will not include rainfall products with datasets related to rainfall intensity on a global scale, due to the large data size of these products.

Table 6: Range of dry and wet spells expressed as a percentage (%) (Table adapted from Awange et al., 2007).

Percentage of rainfall relative to average/mean (%)	Physical conditions
>175	Extremely Wet
150 – 175	Very Wet
125 – 150	Moderately Wet
100 – 125	Mildly Wet
100	Normal
75 – 100	Mildly Dry
50 – 75	Moderately Dry
25 – 50	Very Dry
<25	Extremely Dry



MILDLY WET

Considering the above Table 6, we can see that the utility in the example experienced a “Percentage of rainfall relative to average/mean” rainfall between 100-125, indicating “mildly wet” physical conditions.

Note: In the Portal and within the Rainfall (TRMM) dataset, there is a sub-dataset called “Rainfall deviation 30-day (TRMM)”. The dataset provides the user with the deviation in rainfall for the last 30 days. The deviation is calculated as the difference between accumulated TRMM rainfall and the long-term mean. The data is only available in raster format. This dataset is particularly useful to see how rainfall has deviated from the long-term mean for the entire basin, and which parts of the basin experienced rainfall conditions either above or below the mean. An example is the below map for the Volta basin (Figure 17). Based on the below image, most of the Volta basin experienced conditions that exceeded the mean (blue cells), whereas areas mostly the eastern parts of the basin experienced conditions below the mean (red cells). Only some parts of the basin experienced conditions that were equal to the mean (empty cells). **The categories used in table 6 differ from the categories used in the Portal (Figure 17). This is because the categories in table 6 are in percentage (%), and the categories in Figure 17 are in millimetres (mm).**

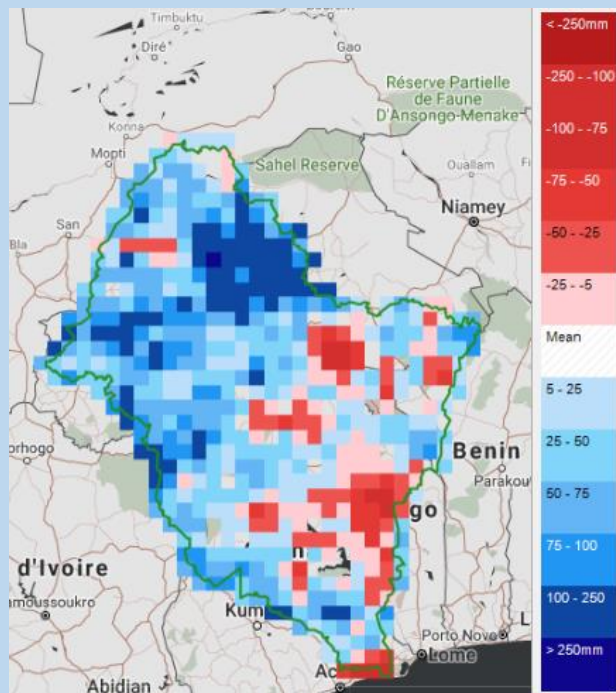


Figure 17: An example of a rainfall deviation in raster format

8.1.2 Steps for analysing short-term temperature data

- In the dataset dialog select the Temperature (MOD11A1).
- In the “Tool” dialog select the “Table” option and download the table data for the dataset (Figure 18), the downloaded data will be in “.csv” format and can be accessed using Microsoft excel.



Time	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg.	Min.	Max.
2005	32.1	33.3	33.4	37.0	35.3	31.7	29.0	31.0	30.9	33.0	30.2	30.7	34.2	29.0	39.0
2006	35.8	39.0	38.4	41.0	39.3	31.7	30.8	29.0	29.9	34.1	35.9	35.1	35.0	29.0	41.0
2007	33.3	38.1	38.5	39.2	34.7	32.9	30.9	29.5	31.3	34.2	35.0	35.0	34.4	29.5	39.2
2008	33.4	37.1	39.3	39.0	38.5	32.6	31.1	29.4	29.2	32.4	35.6	34.8	34.4	29.2	39.3
2009	33.8	36.5	38.6	39.4	36.0	32.5	30.8	30.3	29.6	33.5	34.0	37.4	34.4	29.6	39.4
2010	38.4	39.6	35.6	36.4	33.4	32.6	28.7	28.9	30.3	31.6	34.6	35.3	33.8	28.7	39.6
2011	33.8	38.7	38.3	41.6	36.6		31.8	30.6	32.5	33.2	36.4	34.7	35.3	30.6	41.6
2012	35.3	35.8	36.5	35.5	34.2	31.2	29.8	29.2	31.1	33.9	35.1	34.7	33.5	29.2	36.5
2013	35.1	38.5	41.6	37.5	35.6	32.3	31.7	30.0	31.3	34.0	37.3	34.8	35.0	30.0	41.6
2014	35.8	37.6	40.5	40.9	37.4	32.1	31.2	29.4	31.7	34.3	35.4	34.9	35.1	29.4	40.9
2015	34.2	38.5	37.8	37.9	38.1	32.6	33.0	29.8	30.8	33.3	35.5	32.3	34.5	29.8	38.5
2016	34.5	38.3	40.3	38.9	34.9	32.3	30.3	31.1	30.8	34.0	35.5	33.9	34.6	30.3	40.3
2017	35.6	36.7	41.2	37.3	34.9	32.0	31.0	29.9	30.5	33.4	35.9	33.3	34.3	29.9	41.2
2018	33.3	38.6	37.9	37.3	34.3	30.7							35.3	30.7	38.6
Avg.	34.8	37.8	38.9	38.7	36.1	32.3	30.9	30.0	30.7	33.5	35.5	35.2			
Max.	38.4	39.6	42.3	41.6	39.3	34.1	33.0	32.0	32.5	35.1	37.3	37.8			
Min.	32.1	35.3	35.5	35.5	33.4	30.6	28.7	28.9	29.2	31.6	34.0	32.3			

Figure 18: Temperature data in tabular format

- The datasets will download in “.csv” format which can be accessed using Excel.
- The data may need to be separated, use the same steps as described above to separate the data (see short-term rainfall analysis).
- Expand the table using the same steps as described earlier (see short-term rainfall analysis). The labels for each column should be as follows:

R1 - Month and year

S1 – Average temperature for the month (°C)

T1 - Average monthly temperature (°C)

U1 – Deviation (°C)

- Select the cells starting from “R1” to “R13” and “U1” to “U13” and add borders to create a table (Figure 19). To add a border, go to the “Home” tab and under “font” click the drop-down arrow next to “borders” and choose “all borders”.
- In the “month and year” column add the dates for the previous 12 months (e.g. see Figure 19 – data downloaded in June 2018). In the “Average temperature for the month” column, copy the data for previous 12 months from the long-term data and paste it next to the corresponding month in the table months (Figure 19).

- The long-term average monthly temperature for the dataset should be copied and added to the table (**Note:** when copying the average values make sure to paste it in the correct cell i.e. paste the average for June next to the recorded value for June):

	R	S	T	U
1	Month and year	Average Temperature for the month (°C)	Average monthly temperature (°C)	Deviation (°C)
2	Jun 17	32	32.3	
3	Jul 17	31	30.9	
4	Aug 17	29.9	30	
5	Sep 17	30.5	30.7	
6	Oct 17	33.4	33.5	
7	Nov 17	35.9	35.5	
8	Dec 17	33.3	35.2	
9	Jan 18	33.3	34.8	
10	Feb 18	38.6	37.8	
11	Mar 18	37.9	38.9	
12	Apr 18	37.3	38.7	
13	May 18	34.3	36.1	
14			Average Temperature Deviation (°C)	

Figure 19: Table with short-term temperature data

In order to determine the likelihood of conditions being more than or less than the average, the number of times the projected conditions are above or below the long-term monthly average should be counted. However, the user has to determine the number of times the observed monthly average is above the long-term monthly average/mean. In order to do this the “temperature deviation” should be calculated.

The “temperature deviation” will be calculated for each month. This will indicate to the user if the observed average monthly temperature was more than, less than or equal to the long-term monthly average/mean (the average monthly long-term temperature in this case is considered “normal temperature”). The average of the 12 months will be determined to get an overall idea of what the rainfall was like during that period.

- In order to calculate the “Deviation °C” insert the following equation into excel:

$$= (S2 - T2)$$

- where S2 is the average for the month, and T2 is the long-term monthly average.

- Calculate the overall average temperature deviation for the last 12 months using the equation below:

$$= \text{Average} (U2: U13)$$

Where U2:U13 is the range of temperature deviations calculated for the January to December.

- The final table should look as indicated in (Figure 20).

	R	S	T	U
1	Month and year	Average Temperature for the month (°C)	Average monthly temperature (°C)	Deviation (°C)
2	Jun 17	32	32.3	-0.3
3	Jul 17	31	30.9	0.1
4	Aug 17	29.9	30	-0.1
5	Sep 17	30.5	30.7	-0.2
6	Oct 17	33.4	33.5	-0.1
7	Nov 17	35.9	35.5	0.4
8	Dec 17	33.3	35.2	-1.9
9	Jan 18	33.3	34.8	-1.5
10	Feb 18	38.6	37.8	0.8
11	Mar 18	37.9	38.9	-1
12	Apr 18	37.3	38.7	-1.4
13	May 18	34.3	36.1	-1.8
14			Average Temperature Deviation (°C)	-0.58

Figure 20: Final table with all calculations for temperature

The temperature deviation (°C) is the difference between the observed average temperature for the month and the monthly long-term average temperature. Negative values indicate that temperature was less than the average/mean, while positive values indicate temperatures were more than the average/mean. In the above example, the observed temperature during the analysis period decreased (i.e. -0.58°C). Using table 7 below, the physical conditions experienced by the water utility can be determined.

Table 7: Range of deviations in temperature (°C)

Temperature deviation (°C)	Physical conditions
3 to 5	Major increase
2 to 3	Moderate Increase
1 to 2	Minor increase
0 to 1	Near normal
0	Normal
0 to -1	Near normal
-1 to -2	Minor decrease
-2 to -3	Moderate decrease
-3 to -5	Major decrease



Near Normal

Considering the above table 7, we can see that the utility in the example experienced temperature deviations between 0 to -1 °C, indicating “near normal” physical conditions.

Note: In the Portal within the Temperature (MOD11A1) dataset, there is a sub-dataset called “Temperature deviation”. The dataset is used as a drought index and describes the deviation of the temperature from the long-term mean. The data is available in time series, column chart and raster formats. This dataset is particularly useful to see how temperature has deviated from the long-term mean (can be viewed at different spatial scales), and which parts of the basin experienced temperature conditions either above or below the mean. An example is the below map for the Volta basin (Figure 21). Based on the below image, most of the Volta basin experienced conditions that equalled the mean (empty cells), whereas large areas of the basin experienced conditions that were below the mean (Blue cells). Very small parts of the basin experienced conditions that were above the mean (red cells). **The categories used in table 7 differ from the categories used in the Portal (Figure 21). This is because the Portal has a category that indicates increases in temperatures greater than 5°C (>5 °C) above the mean, and decreases in temperature of 5°C (<5°C) below the mean (Figure 21).**

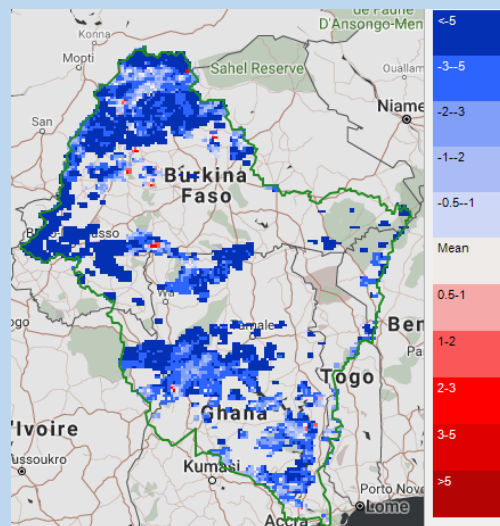


Figure 21: An example of a temperature deviation in raster format

8.1.3 Determining short-term climate change related risks

Considering the previously presented examples, an analysis of the Rainfall (TRMM) and Temperature (MOD11A1) datasets indicates that conditions within the water utility are expected to be wetter than normal as follows:

- **Rainfall**
 - Likelihood: 5 out of 12 months had rainfall that exceeded the average/mean.
 - Severity: mildly wet

- **Temperature**

- Likelihood: 3 out of 12 month experienced conditions that exceeded the average/mean.
- Severity: near normal

Note: The below methodology can be applied to both hazards and hazardous events associated wetter or drier conditions. The example of the specific hazard in the below scenario, was used as conditions based on the above analysis that determined conditions were wetter than normal. Further examples of hazards and hazardous events, associated with wetter and drier conditions are listed in appendix A.

8.1.4 Scenario 1

The water utility has completed the analysis, and has determined that the physical conditions are mildly wet. The mildly wet conditions are an issue of concern to the water utility, because in the past increased rainfall and increased flows (flooding) has caused damage to their infrastructure. The damage to the infrastructure affected their ability to provide water of an adequate quantity and quality (Figure 22). The water utility would like to determine if there is an increased risk of damage to infrastructure and reduced water quality as a result of mildly wet conditions, so that they may implement the necessary actions to avoid damage to their infrastructure occurring again.



Figure 22: The effects increased flows had on drinking water quality (Photo courtesy: MWAUWASA water utility).

In order to determine if there will be a change in the risk rating, the water utility should use the following steps

- The user should determine their water utility's current risk rating for the hazard and hazardous event in question (this should be in the water utility's current WSP), and in particular know both the likelihood and severity for a climate change related hazard/hazardous event (see Table 8).
- By way of example and considering a typical 5 x 5 matrix used for water safety planning risk assessments, if the water utility's current risk rating for the hazard and hazardous event is "medium" with likelihood categorised as "unlikely", and the severity categorised as "moderate", then the risk rating is calculated as 6 (see the circled values in the table 8 below).

Table 8: Current Risk Matrix

Likelihood	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
		Insignificant or no impact 1	Mild or minor 2	Moderate 3	Major 4	Catastrophic 5
Severity						
Risk Score	<6		6-9		10-15	
Risk rating	Low		Medium		High	
					Very High	

Considering the previous example: In the above example

- For rainfall,
 - Likelihood: 5 months were above the average/mean, and 7 were below the average/mean
 - Severity: mildly wet

- For temperature,
 - Likelihood: 3 months were above the average/mean, and 9 months with below the average/mean temperature (°C)
 - Severity: near normal

The tables that follow can be used to determine the possible changes to likelihood and severity (Table 9, Table 10, Table 11 and Table 12).

What if my utility uses a risk matrix different from the one described in the example?

The user should note that in the examples below change factors are presented for both likelihood and severity. These change factors are the suggested approach developed for this guidance document and is designed to be used with the 5x5 risk matrix found in the WHO/IWA WSP manual. However, not all water utilities use the 5x5 risk matrix as described in the Water Safety Planning manual. Water utilities may be using a simpler risk matrix such as a 3x3 risk matrix, or another risk matrix that is required by the law within their country. Should the user's water utility be using a different risk matrix, the user may amend the change factors to suit their own needs. In the case of the 3x3 risk matrix the maximum change factor should not exceed +2. **Furthermore, the applicability of the approach should be tested on a case-by-case basis, and amended as required (e.g. Is the suggested approach too sensitive for our utility? Should we adjust the change factors and make them more conservative?).**

When determining the likelihood of wetter or drier conditions the water utility should count the number of months' rainfall was higher than "normal" and how many times it was lower than "normal". The water utility may get a combination of for e.g. 8 months wetter than "normal" and 4 months drier than "normal" or, the water utility may get a combination of 8 months drier than "normal" and 4 months wetter than "normal". In the case of the example presented above, the combination is 7 months below average/mean and 5 months above average/mean for rainfall (Table 9). The same should be done for temperature, the water utility should count the number of months whereby temperature deviations were above or below the mean. The water utility may get a combination of 10 months above the mean and 2 months below the mean or, the utility may get a combination of 10 months below the mean and 2 months above the mean. In the case of the example presented above, the combination is 9 months below average/mean and 3 months above average/mean for rainfall (Table 9). Considering these combinations of likelihood for rainfall and temperature, table 10 can be used to determine the likelihood change factor. The water utility should

look for each combination in table 10, and find the point where they intersect. In the case of the example presented above, the likelihood change factor is +1 (Table 10).

Table 9: Likelihood for rainfall and temperature

Number of observations above or below mean	
12 months and 0 months	
11 months and 1 month	
10 months and 2 months	
9 months and 3 months	
8 months and 4 months	
7 months and 5 months	
6 months and 6 months	

Table 10: Determining the overall change factor for likelihood

Rain	12 months and 0 months	+1	+1	+2	+2	+2	+2	+2
	11 months and 1 month	+1	+1	+1	+1	+2	+2	+2
	10 months and 2 months	1	+1	+1	+1	+1	+2	+2
	9 months and 3 months	0	0	+1	+1	+1	+1	+2
	8 months and 4 months	0	0	+1	+1	+1	+1	+1
	7 months and 5 months	0	0	0	+1	+1	+1	+1
	6 months and 6 months	0	0	0	0	0	+1	+1
		6 months and 6 months	7 months and 5 months	8 months and 4 months	9 months and 3 months	10 months and 2 months	11 months and 1 month	12 months and 0 months
		Temperature						

The change factor for severity is determined using the physical conditions determined when doing the short-term analysis for rainfall and temperature. In this case rainfall was “mildly wet” and temperature was “Near normal” (Table 11). Considering these physical conditions for rainfall and temperature, table 12 can be used to determine the severity change factor. The water utility should look for the severity for both

rainfall and temperature, and find the point where they intersect. In the case of the example presented above, the severity change factor is 0 (Table 12).

Table 11: Severity for rainfall and temperature

Severity as per the physical conditions	
Rainfall	Temperature
Extremely wet/dry	Major increase/decrease
Very wet/dry	Moderate Increase/ decrease
Moderately wet/dry	Minor increase/ decrease
Mildly wet/dry	Near normal
Normal	Normal

Table 12: Determining the overall change factor for severity

Rain	Extremely Wet	>175	+2	+2	+2	+1	+1	+1	+2	+2	+2
	Very Wet	150 – 175	+2	+2	+1	+1	+1	+1	+1	+2	+2
	Moderately Wet	125 – 150	+1	+1	+1	0	0	0	+1	+1	+1
	Mildly Wet	100 – 125	+1	+1	0	0	0	0	0	+1	+1
	Normal	100	+1	+1	0	0	0	0	0	+1	+1
	Mildly Dry	75 – 100	+1	+1	0	0	0	0	0	+1	+1
	Moderately Dry	50 – 75	+1	+1	+1	0	0	0	+1	+1	+1
	Very Dry	25 – 50	+2	+2	+1	+1	+1	+1	+1	+2	+2
	Extremely Dry	<25	+2	+2	+2	+1	+1	+1	+2	+2	+2
			-3 to -5	-2 to -3	-1 to -2	0 to -1	0	0 to 1	1 to 2	2 to 3	3 to 5
			Major decrease	Moderate decrease	Minor decrease	Near normal	Normal	Near normal	Minor increase	Moderate Increase	Major increase
Temperature											

The change factors should be added to the current value for likelihood and severity (Table 13). As conditions are mildly wet, the water utility should focus on the hazards and hazardous events associated with wet conditions. These aspects will be discussed in further detail in **Section 9** of this guideline. If the water utility has a current Likelihood of 2 for the hazard and the change factor for likelihood was determined to be +1, then the new likelihood changes to 3 (moderate). If the water utility has a current severity of 3 and a change factor of 0, then severity rating remains the same (Table 13).

Table 13: Adding change factors to current likelihood and severity

Likelihood		Severity	
Current	Change Factor	Current	Change Factor
2	+1	3	0
Amended Likelihood: 2 + 1 = 3 (Moderate)		Amended Severity: 3 + 0 = 3 (Moderate)	

The amended risk rating will be as below (Table 14).

Table 14: New risk rating

Likelihood	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
		Insignificant or no impact 1	Mild or minor 2	Moderate 3	Major 4	Catastrophic 5
Severity						

Risk Score	<6	6-9	10-15	>15
Risk rating	Low	Medium	High	Very High

After the change factors were added to the likelihood and severity, the risk score increased from 6 to 9 (i.e. Medium). This is indicating that the risk is medium, and the water utility should consider taking action in order to mitigate the risk. These actions should be recorded in the water safety plan and, mitigating measures must be implemented in the current year to reduce the risk of failure should a hazard and hazardous event occur (i.e. in the short-term).

Note: The water utility should note in some instances, after applying the change factors to likelihood and severity, the “new” likelihood or severity may exceed the maximum category as presented in the risk matrix. By way of example:

Likelihood:

- if the initial condition for likelihood was 4, and
- the change factor for likelihood is for +2
- the new likelihood will be 6

OR

Severity:

- if the initial condition for severity was 5, and
- the change factor for severity is for +2
- the new severity will be 7

In these instances, the water utility should use the maximum category for likelihood and severity used in the risk matrix. In the case of the above example, the maximum category is 5 for both likelihood and severity.

8.2 Long-term Climate Analysis

Long-term analysis of climatic variables is necessary for utilities in order to facilitate planning for disasters associated with climate change and to anticipate future changes in likelihood and severity of hazardous events. This is because climate change may have an impact on a water utility’s “normal operations”, and their ability to respond during emergency situations. Water utilities may experience wetter or drier conditions as a result of increases or decreases in precipitation, temperature and evapotranspiration. Long-term planning and implementation of control measures may reduce the impacts of climate related disasters on the water utility. The Flood and Drought Portal provides climate change datasets as well datasets of relevant climatic variables. The climate change and climatic variables datasets include (Table 15):

Table 15: List of datasets for long-term climate analysis

List of long-term climate analysis datasets	
1	Rainfall (CRU) – Rainfall (mm/month) (CRU)
2	Precip. RCP45 2016-2035
3	Temperature – CRU Temperature C
4	TEMP RCP45 2016-2035

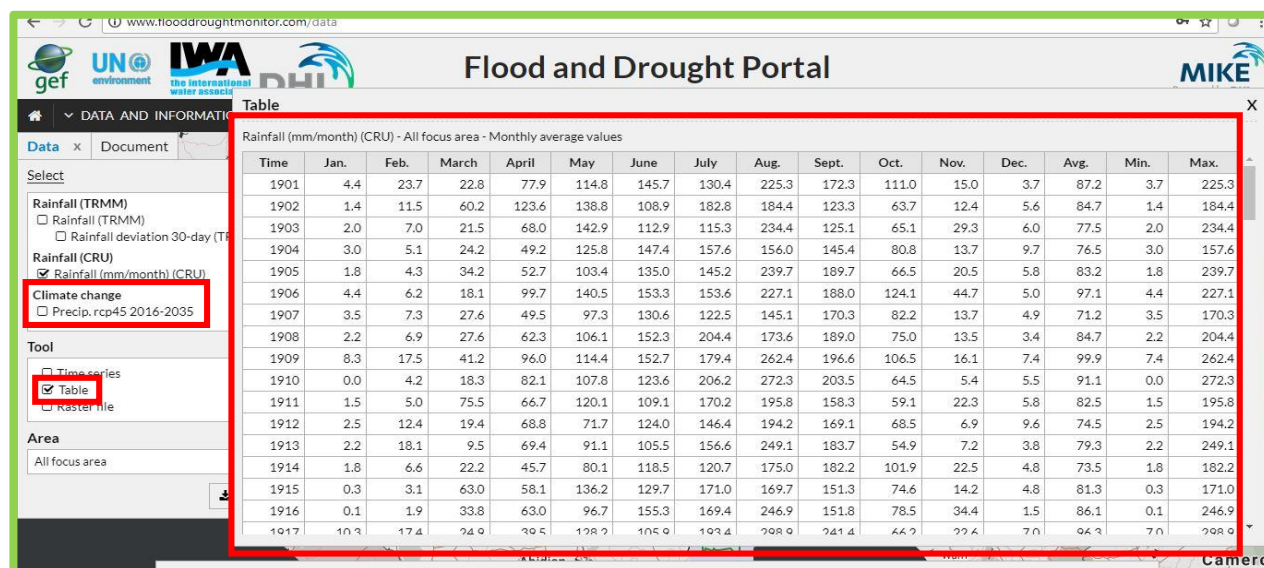
According to Kwak et. Al. (2014) the RCP45 climate scenario “will most effectively reflect future climate in accordance with the present condition”, therefore RCP45 is the preferred climate change dataset.

There are four Representative Concentration Pathways (RCP), each consisting of a set of numbers in table format. Each RCP presents a concentration trajectory for greenhouse gases. The RCP45 climate scenario presents “a stabilization scenario in which the total radiative forcing is stabilized shortly after 2100, without overshooting the long-run radiative forcing target level” (Wayne, 2013).

These datasets listed in Table 15 should be added if not done thus far, as explained under Section 2: Data overview. The user may view the graphs, maps and tables for each dataset, to get a general idea of what the basin data looks like.

8.2.1 Steps for analysing long-term rainfall data

- In the dataset dialog select the Rainfall (CRU).
- In the “Tool” dialog select the “Table” option and download the table data for the dataset (Figure 23), the downloaded data will be in “.csv” format and can be accessed using Microsoft excel.



Time	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg.	Min.	Max.
1901	4.4	23.7	22.8	77.9	114.8	145.7	130.4	225.3	172.3	111.0	15.0	3.7	87.2	3.7	225.3
1902	1.4	11.5	60.2	123.6	138.8	108.9	182.8	184.4	123.3	63.7	12.4	5.6	84.7	1.4	184.4
1903	2.0	7.0	21.5	68.0	142.9	112.9	115.3	234.4	125.1	65.1	29.3	6.0	77.5	2.0	234.4
1904	3.0	5.1	24.2	49.2	125.8	147.4	157.6	156.0	145.4	80.8	13.7	9.7	76.5	3.0	157.6
1905	1.8	4.3	34.2	52.7	103.4	135.0	145.2	239.7	189.7	66.5	20.5	5.8	83.2	1.8	239.7
1906	4.4	6.2	18.1	99.7	140.5	153.3	153.6	227.1	188.0	124.1	44.7	5.0	97.1	4.4	227.1
1907	3.5	7.3	27.6	49.5	97.3	130.6	122.5	145.1	170.3	82.2	13.7	4.9	71.2	3.5	170.3
1908	2.2	6.9	27.6	62.3	106.1	152.3	204.4	173.6	189.0	75.0	13.5	3.4	84.7	2.2	204.4
1909	8.3	17.5	41.2	96.0	114.4	152.7	179.4	262.4	196.6	106.5	16.1	7.4	99.9	7.4	262.4
1910	0.0	4.2	18.3	82.1	107.8	123.6	206.2	272.3	203.5	64.5	5.4	5.5	91.1	0.0	272.3
1911	1.5	5.0	75.5	66.7	120.1	109.1	170.2	195.8	158.3	59.1	22.3	5.8	82.5	1.5	195.8
1912	2.5	12.4	19.4	68.8	71.7	124.0	146.4	194.2	169.1	68.5	6.9	9.6	74.5	2.5	194.2
1913	2.2	18.1	9.5	69.4	91.1	105.5	156.6	249.1	183.7	54.9	7.2	3.8	79.3	2.2	249.1
1914	1.8	6.6	22.2	45.7	80.1	118.5	120.7	175.0	182.2	101.9	22.5	4.8	73.5	1.8	182.2
1915	0.3	3.1	63.0	58.1	136.2	129.7	171.0	169.7	151.3	74.6	14.2	4.8	81.3	0.3	171.0
1916	0.1	1.9	33.8	63.0	96.7	155.3	169.4	246.9	151.8	78.5	34.4	1.5	86.1	0.1	246.9
1917	10.3	17.4	24.9	30.5	128.2	105.9	109.4	208.9	241.4	64.2	22.4	7.0	96.3	7.0	208.9

Figure 23: Rainfall (CRU) dataset in table format

Note: When opening the downloaded files, the data may appear in one single column. It is very important that the data be separated, before the analysis starts (Figure 24). This may not always occur and it is largely dependent on the Version of the Microsoft Office software on your computer.

	A	B	C	D	E	F	G	H
1	description==Monthly average values							
2	Time,Jan.,Feb.,March,April,May,June,July,Aug.,Sept.,Oct.,Nov.,Dec.,Avg.,Min.,Max							
3	1901,4.4,23.7,22.8,77.9,114.8,145.7,130.4,225.3,172.3,111.0,15.0,3.7,87.2,3.7,225.3							
4	1902,1.4,11.5,60.2,123.6,138.8,108.9,182.8,184.4,123.3,63.7,12.4,5.6,84.7,1.4,184.4							
5	1903,2.0,7.0,21.5,68.0,142.9,112.9,115.3,234.4,125.1,65.1,29.3,6.0,77.5,2.0,234.4							
6	1904,3.0,5.1,24.2,49.2,125.8,147.4,157.6,156.0,145.4,80.8,13.7,9.7,76.5,3.0,157.6							
7	1905,1.8,4.3,34.2,52.7,103.4,135.0,145.2,239.7,189.7,66.5,20.5,5.8,83.2,1.8,239.7							
8	1906,4.4,6.2,18.1,99.7,140.5,153.3,153.6,227.1,188.0,124.1,44.7,5.0,97.1,4.4,227.1							
9	1907,3.5,7.3,27.6,49.5,97.3,130.6,122.5,145.1,170.3,82.2,13.7,4.9,71.2,3.5,170.3							
10	1908,2.2,6.9,27.6,62.3,106.1,152.3,204.4,173.6,189.0,75.0,13.5,3.4,84.7,2.2,204.4							
11	1909,8.3,17.5,41.2,96.0,114.4,152.7,179.4,262.4,196.6,106.5,16.1,7.4,99.9,7.4,262.4							
12	1910,0.0,4.2,18.3,82.1,107.8,123.6,206.2,272.3,203.5,64.5,5.4,5.5,91.1,0.0,272.3							
13	1911,1.5,5.0,75.5,66.7,120.1,109.1,170.2,195.8,158.3,59.1,22.3,5.8,82.5,1.5,195.8							
14	1912,2.5,12.4,19.4,68.8,71.7,124.0,146.4,194.2,169.1,68.5,6.9,9.6,74.5,2.5,194.2							
15	1913,2.2,18.1,9.5,69.4,91.1,105.5,156.6,249.1,183.7,54.9,7.2,3.8,79.3,2.2,249.1							
16	1914,1.8,6.6,22.2,45.7,80.1,118.5,120.7,175.0,182.2,101.9,22.5,4.8,73.5,1.8,182.2							
17	1915,0.3,3.1,63.0,58.1,136.2,129.7,171.0,169.7,151.3,74.6,14.2,4.8,81.3,0.3,171.0							
18	1916,0.1,1.9,33.8,63.0,96.7,155.3,169.4,246.9,151.8,78.5,34.4,1.5,86.1,0.1,246.9							
19	1917,10.3,17.4,24.9,39.5,128.2,105.9,193.4,298.9,241.4,66.2,22.6,7.0,96.3,7.0,298.9							
20	1918,0.3,2.4,46.7,59.8,120.1,163.6,193.5,184.9,156.1,85.1,35.4,19.2,88.9,0.3,193.5							
21	1919,2.2,6.6,49.5,50.6,123.3,124.4,132.6,131.5,178.5,81.8,13.3,0.8,74.6,0.8,178.5							
22	1920,0.2,11.2,15.2,64.7,96.7,121.2,160.9,186.7,175.5,53.3,26.5,2.0,76.2,0.2,186.7							
23	1921,0.5,11.9,29.2,49.3,82.1,119.0,170.6,223.7,206.9,62.8,26.0,2.2,82.0,0.5,223.7							
24	1922,0.9,10.4,15.4,92.9,98.4,104.3,138.6,178.1,236.8,102.1,33.2,5.7,84.7,0.9,236.8							
25	1923,6.3,9.4,45.0,87.5,79.5,120.5,152.7,155.6,186.3,76.8,20.6,5.9,78.8,5.9,186.3							

Figure 24: Rainfall CRU data appearing in one column

If your data appears in one column, the data can be separated into multiple columns using the following steps:

- Select column A in the spreadsheet then click the “Data” tab in excel.
- In the data tools Select “Text to Columns”.
- In the Window that opens choose “Delimited”, then click next.
- In delimiters check the box marked “Comma” and uncheck the “Tab” box.
- Then click “Finished”.

The data should be separated into individual columns (Figure 25).

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	description==Monthly average values															
2	Time	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg.	Min.	Max.
3	1901	4.4	23.7	22.8	77.9	114.8	145.7	130.4	225.3	172.3	111.0	15.0	3.7	87.2	3.7	225.3
4	1902	1.4	11.5	60.2	123.6	138.8	108.9	182.8	184.4	123.3	63.7	12.4	5.6	84.7	1.4	184.4
5	1903	2.0	7.0	21.5	68.0	142.9	112.9	115.3	234.4	125.1	65.1	29.3	6.0	77.5	2.0	234.4
6	1904	3.4	5.1	24.2	49.2	125.8	147.4	157.6	156.0	145.4	80.8	13.7	9.7	76.5	3.0	157.6
7	1905	1.8	4.3	34.2	52.7	103.4	135.0	145.2	239.7	189.7	66.5	20.5	5.8	83.2	1.8	239.7
8	1906	4.4	6.2	18.1	99.7	140.5	153.3	153.6	227.1	188.0	124.1	44.7	5.0	97.1	4.4	227.1
9	1907	3.5	7.3	27.6	49.5	97.3	130.6	122.5	145.1	170.3	82.2	13.7	4.9	71.2	3.5	170.3
10	1908	2.2	6.9	27.6	62.3	106.1	152.3	204.4	173.6	189.0	75.0	13.5	3.4	84.7	2.2	204.4
11	1909	8.3	17.5	41.2	96.0	114.4	152.7	179.4	262.4	196.6	106.5	16.1	7.4	99.9	7.4	262.4
12	1910	0.0	4.2	18.3	82.1	107.8	123.6	206.2	272.3	203.5	64.5	5.4	5.5	91.1	0.0	272.3
13	1911	1.5	5.0	75.5	66.7	120.1	109.1	170.2	195.8	158.3	59.1	22.3	5.8	82.5	1.5	195.8
14	1912	2.5	12.4	19.4	68.8	71.7	124.0	146.4	194.2	169.1	68.5	6.9	9.6	74.5	2.5	194.2
15	1913	2.2	18.1	9.5	69.4	91.1	105.5	156.6	249.1	183.7	54.9	7.2	3.8	79.3	2.2	249.1
16	1914	1.8	6.6	22.2	45.7	80.1	118.5	120.7	175.0	182.2	101.9	22.5	4.8	73.5	1.8	182.2
17	1915	0.3	3.1	63.0	58.1	136.2	129.7	171.0	169.7	151.3	74.6	14.2	4.8	81.3	0.3	171.0
18	1916	0.1	1.9	33.8	63.0	96.7	155.3	169.4	246.9	151.8	78.5	34.4	1.5	86.1	0.1	246.9
19	1917	10.3	17.4	24.9	39.5	128.2	105.9	193.4	298.9	241.4	66.2	22.6	7.0	96.3	7.0	298.9
20	1918	0.3	2.4	46.7	59.8	120.1	163.6	193.5	184.9	156.1	85.1	35.4	19.2	88.9	0.3	193.5
21	1919	2.2	6.6	49.5	50.6	123.3	124.4	132.6	131.5	178.5	81.8	13.3	0.8	74.6	0.8	178.5
22	1920	0.2	11.2	15.2	64.7	96.7	121.2	160.9	186.7	175.5	53.3	26.5	2.0	76.2	0.2	186.7
23	1921	0.5	11.9	29.2	49.3	82.1	119.0	170.6	223.7	206.9	62.8	26.0	2.2	82.0	0.5	223.7
24	1922	0.9	10.4	15.4	92.9	98.4	104.3	138.6	178.1	236.8	102.1	33.2	5.7	84.7	0.9	236.8
25	1923	6.3	9.4	45.0	87.5	79.5	120.5	152.7	155.6	186.3	76.8	20.6	5.9	78.8	5.9	186.3
26	1924	4.0	13.1	47.5	71.4	84.8	165.6	182.7	158.6	210.3	84.0	13.7	5.9	86.8	4.0	210.3
27	1925	0.0	8.2	42.5	64.3	114.8	137.5	163.6	212.5	220.1	132.5	36.4	1.7	94.5	0.0	220.1

Figure 25: Rainfall CRU data separated into individual columns

- Next select the “Precip. RCP45 2016-2035” dataset and in the “Tool” dialog select and download “Time series” option. The downloaded datasets will download in “.csv” format which can be accessed using Microsoft Excel (Figure 26).

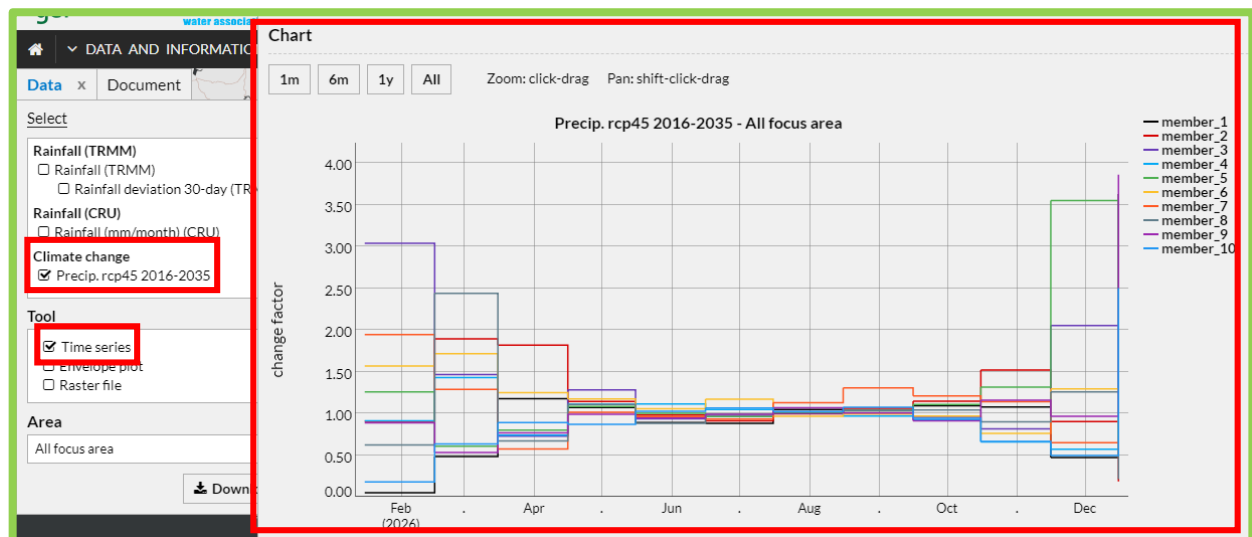


Figure 26: Precip. RCP45 time series data

The dataset “Precip. RCP45 2016-2035” is delta change factors. The delta change factor is the ratio between General Circulation Models (GCM) simulations of future and current climate. It is used to obtain future regional conditions by multiplying the delta change factor by the corresponding average

precipitation for each month. For example, if delta change is 3 in February for “Precip. RCP45 2016-2035”, this means that there is a possibility that current average rainfall will be 3 times the volume in February.

- The data should be separated into columns (if not automatically done).
- In order to separate the data, follow the same steps as described above. It should be noted that the RCP45 should be transposed so that the months appear at the top of the data and the “member” on the left of the data. To transpose the data:
 - Select all the data in the RCP45 dataset
 - Right click and copy the data
 - Select the place in the spreadsheet where you want the transposed data placed and right click, under the paste options choose transpose. The data should be transposed (Figure 27).

Time	member_1	member_2	member_3	member_4	member_5	member_6	member_7	member_8	member_9	member_10
2026-01-16 00:00	0.049	0.904	3.038	0.911	1.258	1.567	1.945	0.621	0.886	0.178
2026-02-16 00:00	0.483	1.894	1.465	1.429	0.605	1.714	1.287	2.439	0.529	0.633
2026-03-16 00:00	1.174	1.817	0.725	0.737	0.798	1.249	0.572	0.668	0.765	0.889
2026-04-16 00:00	1.071	1.141	1.280	1.110	1.083	1.171	1.014	1.106	0.990	0.869
2026-05-16 00:00	0.890	0.979	0.933	1.112	1.002	1.056	0.962	0.880	0.944	1.026
2026-06-16 00:00	0.880	0.910	0.965	1.046	0.960	1.168	0.930	0.930	0.987	1.065
2026-07-16 00:00	1.047	0.995	1.001	1.009	1.009	0.965	1.126	1.013	1.067	1.021
2026-08-16 00:00	1.032	1.063	1.036	0.966	1.036	0.992	1.305	1.035	1.005	1.074
2026-09-16 00:00	1.091	1.146	0.951	0.922	1.105	0.968	1.208	1.041	0.911	0.939
2026-10-16 00:00	1.077	1.519	0.813	0.658	1.314	0.758	1.139	0.899	1.157	0.662
2026-11-16 00:00	0.470	0.901	2.051	0.569	3.549	1.293	0.647	1.257	0.964	0.495
2026-12-16 00:00	3.628	0.184	1.111	2.481	0.722	0.476	0.515	0.212	3.862	2.502

Time	2026-01-1	2026-02-1	2026-03-1	2026-04-1	2026-05-1	2026-06-1	2026-07-1	2026-08-1	2026-09-1	2026-10-1	2026-11-1	2026-12-1
member_1	0.049	0.483	1.174	1.071	0.890	0.880	1.047	1.032	1.091	1.077	0.470	3.628
member_2	0.904	1.894	1.817	1.141	0.979	0.910	0.995	1.060	1.146	1.519	0.901	0.184
member_3	3.038	1.465	0.725	1.280	0.933	0.965	1.001	1.036	0.951	0.813	2.051	1.111
member_4	0.911	1.429	0.737	1.110	1.112	1.046	1.009	0.966	0.922	0.658	0.569	2.481
member_5	1.258	0.605	0.798	1.083	1.002	0.960	1.009	1.036	1.105	1.314	3.549	0.722
member_6	1.567	1.714	1.249	1.171	1.056	1.168	0.965	0.992	0.968	0.758	1.293	0.476
member_7	1.945	1.287	0.572	1.014	0.962	0.930	1.126	1.305	1.208	1.139	0.647	0.515
member_8	0.621	2.439	0.668	1.106	0.880	0.990	1.013	1.035	1.041	0.899	1.257	0.212
member_9	0.886	0.529	0.765	0.990	0.944	0.987	1.067	1.005	0.911	1.157	0.964	3.862
member_10	0.178	0.633	0.889	0.869	1.026	1.065	1.021	1.074	0.939	0.662	0.495	2.502

Figure 27: Transposed RCP45 data. Note that dates and members have switched positions after applying the transpose function

- The transposed RCP45 data should be copied and moved to the spreadsheet containing the sorted Rainfall (CRU) data. Paste the transposed data in columns “R” to “AD”. This step should be done as predicted changes in precipitation are calculated using both the datasets.

What are members, and why is the data described to me as members?

The RCP45 2016-2035 datasets form part of an ensemble of delta change factors. Instead of doing a single forecast, the forecast is done 10 times for each month. Each forecast has slightly different starting conditions, because the delta change factors vary. The complete set of forecasts is referred to as the ensemble, and the individual forecasts within it are referred to as ensemble members.

- Expand the table using the same steps as described earlier (see short-term rainfall analysis). The labels for each column should be as follows:

A121 – Time

A122 to A131 – add the labels “member_1” to “member_10”

B121 to M121- Add the months from January to December

A132 – Monthly projected average rainfall (mm/month)

A133 – 25th percentile

A134 – 75th percentile

A135 – Median

A136 – Percent of normal (%)

The processed data will be done in this table (Figure 28).

	A	B	C	D	E	F	G	H	I	J	K	L	M
120	Delta Change Factors												
121	Time	January	February	March	April	May	June	July	August	September	October	November	December
122	member_1												
123	member_2												
124	member_3												
125	member_4												
126	member_5												
127	member_6												
128	member_7												
129	member_8												
130	member_9												
131	member_10												
132	Monthly projected average rainfall (mm/month)												
133	25th percentile												
134	75th percentile												
135	Median												
136	Percent of normal (%)												

Figure 28: Expanded table wherein long-term data will be processed

The downloaded Rainfall (CRU) data contains the annual averages, maximums and minimums and the long-term monthly averages, maximums and minimum. The statistic of interest in this instance is the long-term monthly averages. The steps and equations are as follows:

- Select the cell B122 (under the label January) in the spreadsheet

- Enter the following formula:

$$= S2 * \$B\$114$$

Where $\$B\114 is the long-term average for January and S2 is the RCP45 value for “member_1” for January.

Note: that the “\$” symbol is required as it ensures that the equation always uses the value in cell B114 as the long-term average value when calculating projected changes for January (Figure 29).

Time	January
member_1	=S2*\$B\$114

Figure 29: The Equation as it should be entered when performing calculations to determine projected changes

- Perform this calculation from member_1 to member_10 in the month of January to determine the projected changes for the month of January
- Next apply this method for the rest of the months using the corresponding long-term monthly average and members for each month.

The table with the calculated climate projections should look as below (Figure 30).

	A	B	C	D	E	F	G	H	I	J	K	L	M
120	Delta Change Factors												
121	Time	January	February	March	April	May	June	July	August	September	October	November	December
122	member_1	0.13	4.69	38.74	71.22	94.43	115.46	175.06	211.04	198.34	89.39	7.57	19.59
123	member_2	2.35	18.37	59.96	75.88	103.87	119.39	166.36	216.77	208.34	126.08	14.51	0.99
124	member_3	7.90	14.21	23.93	85.12	98.99	126.61	167.37	211.86	172.89	67.48	33.02	6.00
125	member_4	2.37	13.86	24.32	73.82	117.98	137.24	168.70	197.55	167.62	54.61	9.16	13.40
126	member_5	3.27	5.87	26.33	72.02	106.31	125.95	168.70	211.86	200.89	109.06	57.14	3.90
127	member_6	4.07	16.63	41.22	77.87	112.04	153.24	161.35	202.86	175.98	62.91	20.82	2.57
128	member_7	5.06	12.48	18.88	67.43	102.07	122.02	188.27	266.87	219.61	94.54	10.42	2.78
129	member_8	1.61	23.66	22.04	73.55	93.37	129.89	169.37	211.66	189.25	74.62	20.24	1.14
130	member_9	2.30	5.13	25.25	65.84	100.16	129.49	178.40	205.52	165.62	96.03	15.52	20.85
131	member_10	0.46	6.14	29.34	57.79	108.86	139.73	170.71	219.63	170.71	54.95	7.97	13.51
132	Monthly projected average rainfall (mm/month)												
133	25th percentile												
134	75th percentile												
135	Median												
136	Percent of normal (%)												

Figure 30: Table with climate projections

- Finally determine the projected average for each month using the average function in excel. In cell B132 insert the following formula:

$$= \text{Average} (B122: B131)$$

Where the range B122:B131 is the projected values for January for all the members for the month of January (Figure 31).

	A	B	C	D	E	F	G	H	I	J	K	L	M
120	Delta Change Factors												
121	Time	January	February	March	April	May	June	July	August	September	October	November	December
122	member_1	0.13	4.69	38.74	71.22	94.43	115.46	175.06	211.04	198.34	89.39	7.57	19.59
123	member_2	2.35	18.37	59.96	75.88	103.87	119.39	166.36	216.77	208.34	126.08	14.51	0.99
124	member_3	7.90	14.21	23.93	85.12	98.99	126.61	167.37	211.86	172.89	67.48	33.02	6.00
125	member_4	2.37	13.86	24.32	73.82	117.98	137.24	168.70	197.55	167.62	54.61	9.16	13.40
126	member_5	3.27	5.87	26.33	72.02	106.31	125.95	168.70	211.86	200.89	109.06	57.14	3.90
127	member_6	4.07	16.63	41.22	77.87	112.04	153.24	161.35	202.86	175.98	62.91	20.82	2.57
128	member_7	5.06	12.48	18.88	67.43	102.07	122.02	188.27	266.87	219.61	94.54	10.42	2.78
129	member_8	1.61	23.66	22.04	73.55	93.37	129.89	169.37	211.66	189.25	74.62	20.24	1.14
130	member_9	2.30	5.13	25.25	65.84	100.16	129.49	178.40	205.52	165.62	96.03	15.52	20.85
131	member_10	0.46	6.14	29.34	57.79	108.86	139.73	170.71	219.63	170.71	54.95	7.97	13.51
132	Monthly projected average rainfall (mm/month)	2.95	12.10	31.00	72.05	103.81	129.90	171.43	215.56	186.93	82.97	19.64	8.47
133	25th percentile												
134	75th percentile												
135	Median												
136	Percent of normal (%)												

Figure 31: Projected data with monthly projected averages

The data in the above table shows the range of possibilities of rainfall volume in the future under the RCP45 climate scenario, and each projection is equally likely to occur.

8.2.2 Plotting graphs for projected rainfall

The data has to be plotted into two graphs. The first graph will indicate the 25th and 75th percentiles and the median. This graph is important as it will give the user an idea of the uncertainty around the median. It is important to know that there is some uncertainty as these are climate projections and **not** actual estimates. The second graph will indicate the monthly average of the observed data over the long-term, and the monthly average of the projected data. This will be a graphical indication as to what projected conditions may look like on a monthly basis.

Before the graph can be plotted the 25th and 75th percentiles and the median of the projected data have to be determined

- Determine the 25th percentile for each month using the below formula

$$= \text{PERCENTILE}(B122:B131; 0.25)$$

Where the range B122:B131 is the projections for the month, and 0.25 is the 25th percentile

- Determine 75th percentile for each month using the below formula

$$= \text{PERCENTILE}(B122:B131; 0.75)$$

Where the range B122:B131 is the projections for the month, and 0.75 is the 75th percentile

- Determine the Median for each month using the below formula

$$= \text{MEDIAN}(B122:B131)$$

Where the range B122:B131 is the projected median for the month

The table should look as below (Figure 32).

	A	B	C	D	E	F	G	H	I	J	K	L	M
120	Delta Change Factors												
121	Time	January	February	March	April	May	June	July	August	September	October	November	December
122	member_1	0.13	4.69	38.74	71.22	94.43	115.46	175.06	211.04	198.34	89.39	7.57	19.59
123	member_2	2.35	18.37	59.96	75.88	103.87	119.39	166.36	216.77	208.34	126.08	14.51	0.99
124	member_3	7.90	14.21	23.93	85.12	98.99	126.61	167.37	211.86	172.89	67.48	33.02	6.00
125	member_4	2.37	13.86	24.32	73.82	117.98	137.24	168.70	197.55	167.62	54.61	9.16	13.40
126	member_5	3.27	5.87	26.33	72.02	106.31	125.95	168.70	211.86	200.89	109.06	57.14	3.90
127	member_6	4.07	16.63	41.22	77.87	112.04	153.24	161.35	202.86	175.98	62.91	20.82	2.57
128	member_7	5.06	12.48	18.88	67.43	102.07	122.02	188.27	266.87	219.61	94.54	10.42	2.78
129	member_8	1.61	23.66	22.04	73.55	93.37	129.89	169.37	211.66	189.25	74.62	20.24	1.14
130	member_9	2.30	5.13	25.25	65.84	100.16	129.49	178.40	205.52	165.62	96.03	15.52	20.85
131	member_10	0.46	6.14	29.34	57.79	108.86	139.73	170.71	219.63	170.71	54.95	7.97	13.51
132	Monthly projected average rainfall (mm/month)	2.95	12.10	31.00	72.05	103.81	129.90	171.43	215.56	186.93	82.97	19.64	8.47
133	25th percentile	1.96	6.00	24.12	69.33	99.57	123.98	168.04	208.28	171.80	65.20	9.79	2.68
134	75th percentile	3.67	15.42	34.87	74.85	107.59	133.57	173.24	216.17	199.62	95.28	20.53	13.45
135	Median	2.37	12.48	26.33	72.05	103.81	129.49	169.37	211.86	186.93	82.97	15.52	6.00
136	Percent of normal (%)												
137													

Figure 32: Table with percentiles and median

The percentiles and median have to put into a graph.

- Select the data and labels for the 25th percentile, 75th percentile and the median
- Go to insert, and under “Charts” select “Line”
- This should generate the graph. However, the graph will not have the months added
- To add the months, right click on the graph, and choose select data
- In the “Horizontal (Category) Axis Labels” click edit
- Select the months as the “Axis label range”
- The final graph should be as below (Figure 33)

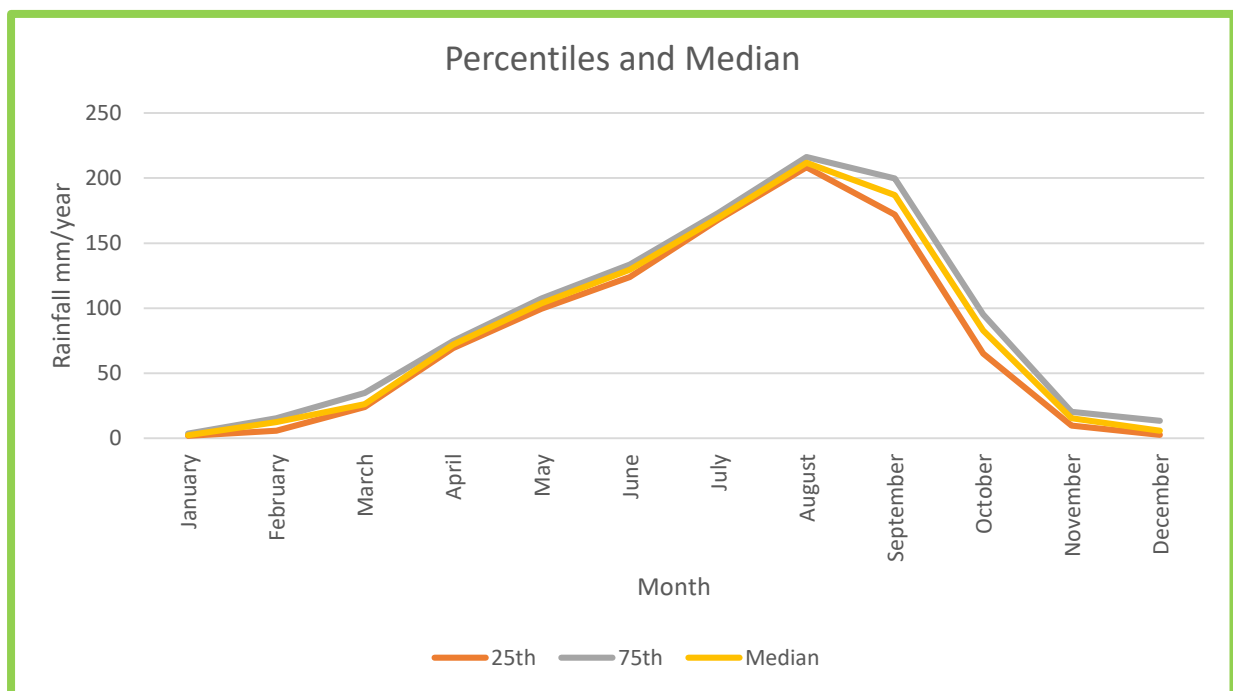


Figure 33: Graph indicating the percentiles and the median.

The above graph indicates that there is very little uncertainty in the months from March to July. Whereas, the months from August to November have the most uncertainty.

In order to plot graph long-term averages with the projected averages follow the below steps:

- Select the long-term averages for the Rainfall (CRU) dataset
- Go to insert, and under “Charts” select “Line”
- This should generate the graph. However, the graph will not have the monthly projected averages added nor the months
- To add the monthly projected averages, right click on the graph and click select data
- In the Legend Entries (Series) click add
- Select the monthly projected averages as the data range
- To add the months, right click on the graph, and choose select data
- In the “Horizontal (Category) Axis Labels click edit
- Select the months as the “Axis label range”
- The final graph should be as below (Figure 34)

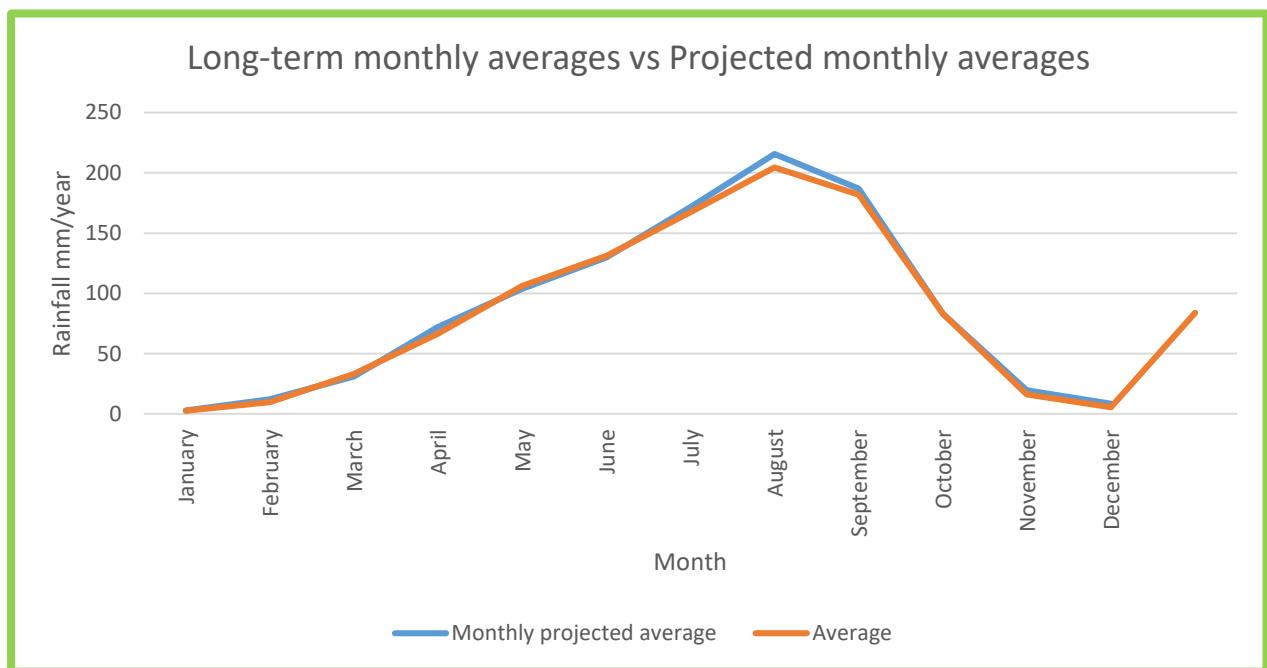


Figure 34: Graph indicating the long-term averages versus the monthly projected averages

Based on a visual analysis the above graph indicates the projected monthly rainfall is expected to be variable, with the months from July to September December indicated projected monthly rainfall to be above the long-term mean. However, the visual analysis should only be used to get a general idea as to the expected future conditions. The user should note that the data presented in Figure 34 only provides

information on monthly projections and possible extremes that could be experienced during each month. The data presented in Figure 34 does not provide information for days or periods with extremes.

In order to determine the likelihood of conditions increasing or decreasing, the number of times the projected conditions are above or below the long-term average should be counted. However, the user has to determine the number of times the monthly projected average is above the long-term mean. In order to do this the “percent of normal” should be calculated.

The “percent of normal” will be calculated for each month. This will indicate to the user if the projected rainfall is expected to be more than, less than or equal to the long-term average/mean (the average monthly long-term rainfall in this case is considered “normal rainfall”).

- In order to calculate the “percent of normal” insert the following equation into excel:

$$= (B132/B114) * 100$$

where B132 is the monthly projected rainfall for the month, and B114 is the monthly long-term average. Multiplying by 100 will give the answer as a percentage. In order to determine the overall percent of normal for the projected monthly rainfall, the average of the percent of normal should be calculated.

The “Percent of normal (%)” calculates the percentage increase or decrease observed in rainfall relative to the average/mean.

- If the percent of normal is greater than 100 then projected rainfall for that month is expected to exceed the mean, if the percent of normal is less than 100 then projected rainfall for that month is expected to be less than the mean
- Count the number of times the percent of normal exceeds 100, and count the number of times the percent of normal is less than 100 (Figure 35)

	A	B	C	D	E	F	G	H	I	J	K	L	M
120	Delta Change Factors												
121	Time	January	February	March	April	May	June	July	August	September	October	November	December
122	member_1	0.13	4.69	38.74	71.22	94.43	115.46	175.06	211.04	198.34	89.39	7.57	19.59
123	member_2	2.35	18.37	59.96	75.88	103.87	119.39	166.36	216.77	208.34	126.08	14.51	0.99
124	member_3	7.90	14.21	23.93	85.12	98.99	126.61	167.37	211.86	172.89	67.48	33.02	6.00
125	member_4	2.37	13.86	24.32	73.82	117.98	137.24	168.70	197.55	167.62	54.61	9.16	13.40
126	member_5	3.27	5.87	26.33	72.02	106.31	125.95	168.70	211.86	200.89	109.06	57.14	3.90
127	member_6	4.07	16.63	41.22	77.87	112.04	153.24	161.35	202.86	175.98	62.91	20.82	2.57
128	member_7	5.06	12.48	18.88	67.43	102.07	122.02	188.27	266.87	219.61	94.54	10.42	2.78
129	member_8	1.61	23.66	22.04	73.55	93.37	129.89	169.37	211.66	189.25	74.62	20.24	1.14
130	member_9	2.30	5.13	25.25	65.84	100.16	129.49	178.40	205.52	165.62	96.03	15.52	20.85
131	member_10	0.46	6.14	29.34	57.79	108.86	139.73	170.71	219.63	170.71	54.95	7.97	13.51
132	Monthly projected average rainfall (mm/month)	2.95	12.10	31.00	72.05	103.81	129.90	171.43	215.56	186.93	82.97	19.64	8.47
133	25th percentile	1.96	6.00	24.12	69.33	99.57	123.98	168.04	208.28	171.80	65.20	9.79	2.68
134	75th percentile	3.67	15.42	34.87	74.85	107.59	133.57	173.24	216.17	199.62	95.28	20.53	13.45
135	Median	2.37	12.48	26.33	72.05	103.81	129.49	169.37	211.86	186.93	82.97	15.52	6.00
136	Percent of normal (%)	113.57	124.78	93.94	108.35	97.84	99.01	102.53	105.41	102.82	99.96	121.96	156.93

Figure 35: Delta change table with percent of normal calculated

$$= Average(B136:M136)$$

Where the range B136:M136 is the percent of normal for projected monthly values for January to December

- This will indicate to the user if the overall projected rainfall is expected to be above or below the mean (Figure 36)

	A	B	C	D	E	F	G	H	I	J	K	L	M
120	Delta Change Factors												
121	Time	January	February	March	April	May	June	July	August	September	October	November	December
122	member_1	0.13	4.69	38.74	71.22	94.43	115.46	175.06	211.04	198.34	89.39	7.57	19.59
123	member_2	2.35	18.37	59.96	75.88	103.87	119.39	166.36	216.77	208.34	126.08	14.51	0.99
124	member_3	7.90	14.21	23.93	85.12	98.99	126.61	167.37	211.86	172.89	67.48	33.02	6.00
125	member_4	2.37	13.86	24.32	73.82	117.98	137.24	168.70	197.55	167.62	54.61	9.16	13.40
126	member_5	3.27	5.87	26.33	72.02	106.31	125.95	168.70	211.86	200.89	109.06	57.14	3.90
127	member_6	4.07	16.63	41.22	77.87	112.04	153.24	161.35	202.86	175.98	62.91	20.82	2.57
128	member_7	5.06	12.48	18.88	67.43	102.07	122.02	188.27	266.87	219.61	94.54	10.42	2.78
129	member_8	1.61	23.66	22.04	73.55	93.37	129.89	169.37	211.66	189.25	74.62	20.24	1.14
130	member_9	2.30	5.13	25.25	65.84	100.16	129.49	178.40	205.52	165.62	96.03	15.52	20.85
131	member_10	0.46	6.14	29.34	57.79	108.86	139.73	170.71	219.63	170.71	54.95	7.97	13.51
132	Monthly projected average rainfall (mm/month)	2.95	12.10	31.00	72.05	103.81	129.90	171.43	215.56	186.93	82.97	19.64	8.47
133	25th percentile	1.96	6.00	24.12	69.33	99.57	123.98	168.04	208.28	171.80	65.20	9.79	2.68
134	75th percentile	3.67	15.42	34.87	74.85	107.59	133.57	173.24	216.17	199.62	95.28	20.53	13.45
135	Median	2.37	12.48	26.33	72.05	103.81	129.49	169.37	211.86	186.93	82.97	15.52	6.00
136	Percent of normal (%)	113.57	124.78	93.94	108.35	97.84	99.01	102.53	105.41	102.82	99.96	121.96	156.93
137										Average of percent of normal %			110.59

Figure 36: Final table for long-term rainfall analysis

In the case of the above example the projected likelihood indicates that 8 of the projected points are above the average/mean. The rainfall amount has increased to 110.59% of average/mean, using table 6 the severity was determined to be mildly wet.

8.2.3 Steps for analysing long-term temperature data

- In the dataset dialog select the Temperature (CRU).
- In the “Tool” dialog select the “Table” option and download the table data for the dataset (Figure 37), the downloaded data will be in “.csv” format and can be accessed using Microsoft excel.

The screenshot shows the 'Data x Document' interface. On the left, the 'Select' panel is active, showing 'Rainfall (TRMM)' and 'Temperature' options. 'CRU Temperature C' is selected under 'Temperature'. Below it, 'Climate change' and 'TEMP rcp45 2016-2035' are also visible. The 'Tool' panel shows 'Time series' and 'Raster file' options. The 'Area' panel shows 'All focus area'. A 'Download' button is at the bottom left. The main area displays a table titled 'CRU Temperature C - All focus area - Monthly average values'.

Time	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg.	Min.	Max.
1901	23.4	28.3	28.8	30.0	28.0	28.0	26.5	25.9	26.5	27.9	27.6	23.9	27.1	23.4	30.0
1902	24.3	27.9	29.8	31.9	30.3	26.1	26.6	26.2	26.1	25.9	28.0	25.9	27.4	24.3	31.9
1903	26.1	28.7	30.2	30.8	29.7	27.8	25.9	25.5	25.9	28.3	27.2	25.9	27.7	25.5	30.8
1904	25.7	27.4	30.4	30.6	30.1	28.3	26.3	25.9	26.8	28.3	27.7	26.4	27.8	25.7	30.6
1905	25.0	25.6	28.9	31.0	29.7	27.1	26.5	25.1	26.1	27.8	28.3	26.7	27.3	25.0	31.0
1906	25.3	27.4	30.6	32.8	29.9	28.1	25.8	24.8	27.1	28.0	27.6	26.5	27.8	24.8	32.8
1907	25.6	26.1	28.8	29.8	30.3	27.5	27.2	25.4	26.7	29.5	27.7	24.9	27.5	24.9	30.3
1908	25.8	27.5	29.6	31.2	30.8	28.8	27.1	25.2	26.6	27.5	26.7	25.3	27.7	25.2	31.2
1909	26.0	29.7	32.7	30.8	29.4	26.1	25.1	24.0	26.4	26.5	27.8	26.0	27.6	24.0	32.7
1910	24.3	28.5	30.1	30.1	29.9	29.3	27.0	26.0	26.8	27.4	27.7	26.4	27.8	24.3	30.1
1911	25.5	27.8	29.6	30.6	29.0	26.3	26.5	25.3	26.0	27.0	27.1	24.5	27.1	24.5	30.6
1912	25.9	28.6	30.0	31.6	29.8	27.9	27.3	26.2	27.0	27.4	26.1	25.9	27.8	25.9	31.6
1913	26.4	28.3	28.0	30.3	30.2	29.4	28.5	27.8	28.2	27.1	24.4	24.2	27.7	24.2	30.3
1914	28.6	27.9	29.5	30.4	31.2	29.4	27.6	25.5	26.6	28.0	28.7	25.5	28.2	25.5	31.2
1915	23.2	26.4	31.4	29.1	29.6	26.0	26.6	25.7	25.5	26.2	26.2	24.4	26.7	23.2	31.4
1916	23.0	25.1	29.7	28.6	28.1	26.3	26.6	24.1	24.0	25.3	24.0	26.2	25.9	23.0	29.7
1917	26.4	28.7	27.5	28.8	27.4	26.1	26.5	25.9	24.3	25.5	23.0	25.2	26.3	23.0	28.7

Figure 37: Temperature (CRU) dataset in tabular format

1	description==Monthly average values																		
2	Time,Jan.,Feb.,March,April,May,June,July,Aug.,Sept.,Oct.,Nov.,Dec.,Avg.,Min.,Ma																		
3	1901,23.4,28.3,28.8,30.0,28.0,28.0,26.5,25.9,26.5,27.9,27.6,23.9,27.1,23.4,30.0																		
4	1902,24.3,27.9,29.8,31.9,30.3,26.1,26.6,26.2,26.1,25.9,28.0,25.9,27.4,24.3,31.9																		
5	1903,26.1,28.7,30.2,30.8,29.7,27.8,25.9,25.5,25.9,28.3,27.2,25.9,27.7,25.5,30.8																		
6	1904,25.7,27.4,30.4,30.6,30.1,28.3,26.3,25.9,26.8,28.3,27.7,26.4,27.8,25.7,30.6																		
7	1905,25.0,25.6,28.9,31.0,29.7,27.1,26.5,25.1,26.1,27.8,28.3,26.7,27.3,25.0,31.0																		
8	1906,25.3,27.4,30.6,32.8,29.9,28.1,25.8,24.8,27.1,28.0,27.6,26.5,27.8,24.8,32.8																		
9	1907,25.6,26.1,28.8,29.8,30.3,27.5,27.2,25.4,26.7,29.5,27.7,24.9,27.5,24.9,30.3																		
10	1908,25.8,27.5,29.6,31.2,30.8,28.8,27.1,25.2,26.6,27.5,26.7,25.3,27.7,25.2,31.2																		
11	1909,26.0,29.7,32.7,30.8,29.4,26.1,25.1,24.0,26.4,26.5,27.8,26.0,27.6,24.0,32.7																		
12	1910,24.3,28.5,30.1,30.1,29.9,29.3,27.0,26.0,26.8,27.4,27.7,26.4,27.8,24.3,30.1																		
13	1911,25.5,27.8,29.6,30.6,29.0,26.3,26.5,25.3,26.0,27.0,27.1,24.5,27.1,24.5,30.6																		
14	1912,25.9,28.6,30.0,31.6,29.8,27.9,27.3,26.2,27.0,27.4,26.1,25.9,27.8,25.9,31.6																		
15	1913,26.4,28.3,28.0,30.3,30.2,29.4,28.5,27.8,28.2,27.1,24.4,24.2,27.7,24.2,30.3																		
16	1914,28.6,27.9,29.5,30.4,31.2,29.4,27.6,25.5,26.6,28.0,28.7,25.5,28.2,25.5,31.2																		
17	1915,23.2,26.4,31.4,29.1,29.6,26.0,26.6,25.7,25.5,26.2,26.2,24.4,26.7,23.2,31.4																		
18	1916,23.0,25.1,29.7,28.6,28.1,26.3,26.6,24.1,24.0,25.3,24.0,26.2,25.9,23.0,29.7																		
19	1917,26.4,28.7,27.5,28.8,27.4,26.1,26.5,25.9,24.3,25.5,23.0,25.2,26.3,23.0,28.8																		
20	1918,24.5,23.9,26.0,29.1,27.9,27.8,26.2,23.3,24.0,26.7,25.9,26.0,26.0,23.3,29.1																		
21	1919,26.3,28.9,30.3,30.5,29.6,27.8,26.2,25.8,26.2,27.8,27.6,26.3,27.8,25.8,30.5																		
22	1920,26.3,28.9,30.4,30.7,29.8,27.9,26.3,25.8,26.3,27.8,27.4,26.2,27.8,25.8,30.7																		
23	1921,26.2,28.8,30.5,30.6,29.5,27.6,26.4,25.9,26.4,28.0,27.5,26.2,27.8,25.9,30.6																		
24	1922,26.4,28.9,30.6,30.6,29.8,28.0,26.4,23.5,23.5,26.0,25.9,24.8,27.0,23.5,30.6																		

Figure 38: Temperature (CRU) data appearing in one column

If your data appears in one column, the data can be separated into multiple columns using the following steps:

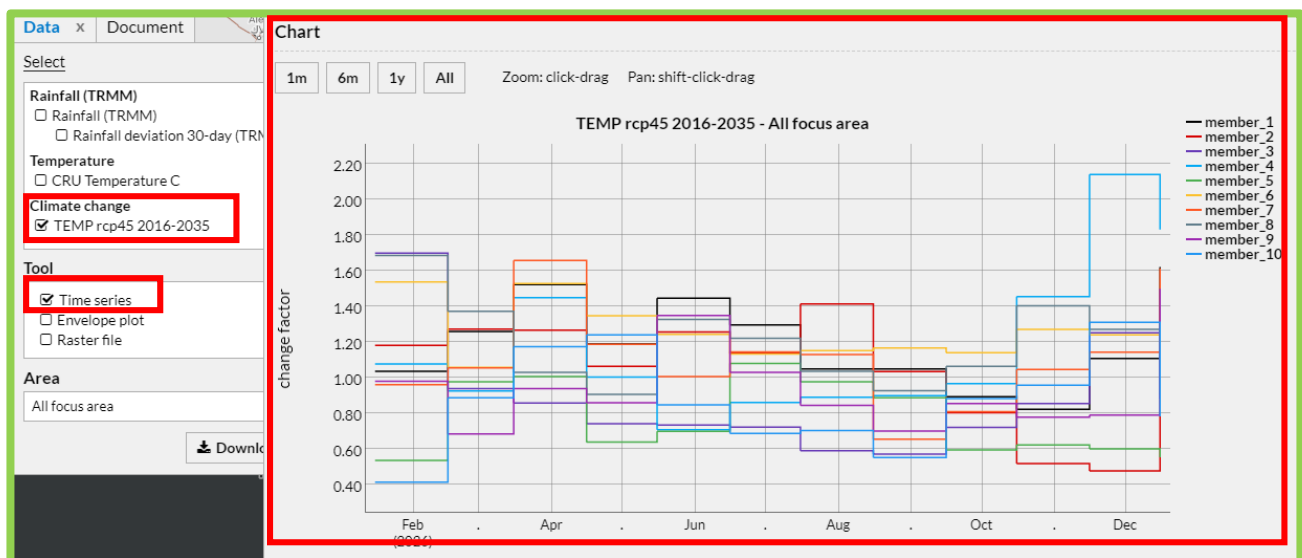
- Select column A in the spreadsheet then click the “Data” tab in excel.
- Under the data tools Select “Text to Columns”.
- In the Window that opens choose “Delimited”, then click next.
- Under delimiters check the box marked “Comma” and uncheck the “Tab” box.
- Then click “Finished”.

The data should be separated into individual columns (Figure 39)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	description==Monthly average values															
2	Time	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Avg.	Min.	Max.
3	1901	23.4	28.3	28.8	30.0	28.0	28.0	26.5	25.9	26.5	27.9	27.6	23.9	27.1	23.4	30.0
4	1902	24.3	27.9	29.8	31.9	30.3	26.1	26.6	26.2	26.1	25.9	28.0	25.9	27.4	24.3	31.9
5	1903	26.1	28.7	30.2	30.8	29.7	27.8	25.9	25.5	25.9	28.3	27.2	25.9	27.7	25.5	30.8
6	1904	25.7	27.4	30.4	30.6	30.1	28.3	26.3	25.9	26.8	28.3	27.7	26.4	27.8	25.7	30.6
7	1905	25.0	25.6	28.9	31.0	29.7	27.1	26.5	25.1	26.1	27.8	28.3	26.7	27.3	25.0	31.0
8	1906	25.3	27.4	30.6	32.8	29.9	28.1	25.8	24.8	27.1	28.0	27.6	26.5	27.8	24.8	32.8
9	1907	25.6	26.1	28.8	29.8	30.3	27.5	27.2	25.4	26.7	29.5	27.7	24.9	27.5	24.9	30.3
10	1908	25.8	27.5	29.6	31.2	30.8	28.8	27.1	25.2	26.6	27.5	26.7	25.3	27.7	25.2	31.2
11	1909	26.0	29.7	32.7	30.8	29.4	26.1	25.1	24.0	26.4	26.5	27.8	26.0	27.6	24.0	32.7
12	1910	24.3	28.5	30.1	30.1	29.9	29.3	27.0	26.0	26.8	27.4	27.7	26.4	27.8	24.3	30.1
13	1911	25.5	27.8	29.6	30.6	29.0	26.3	26.5	25.3	26.0	27.0	27.1	24.5	27.1	24.5	30.6
14	1912	25.9	28.6	30.0	31.6	29.8	27.9	27.3	26.2	27.0	27.4	26.1	25.9	27.8	25.9	31.6
15	1913	26.4	28.3	28.0	30.3	30.2	29.4	28.5	27.8	28.2	27.1	24.4	24.2	27.7	24.2	30.3
16	1914	28.6	27.9	29.5	30.4	31.2	29.4	27.6	25.5	26.6	28.0	28.7	25.5	28.2	25.5	31.2
17	1915	23.2	26.4	31.4	29.1	29.6	26.0	26.6	25.7	25.5	26.2	26.2	24.4	26.7	23.2	31.4
18	1916	23.0	25.1	29.7	28.6	28.1	26.3	26.6	24.1	24.0	25.3	24.0	26.2	25.9	23.0	29.7
19	1917	26.4	28.7	27.5	28.8	27.4	26.1	26.5	25.9	24.3	25.5	23.0	25.2	26.3	23.0	28.8
20	1918	24.5	23.9	26.0	29.1	27.9	27.8	26.2	23.3	24.0	26.7	25.9	26.0	26.0	23.3	29.1
21	1919	26.3	28.9	30.3	30.5	29.6	27.8	26.2	25.8	26.2	27.8	27.6	26.3	27.8	25.8	30.5
22	1920	26.3	28.9	30.4	30.7	29.8	27.9	26.3	25.8	26.3	27.8	27.4	26.2	27.8	25.8	30.7
23	1921	26.2	28.8	30.5	30.6	29.5	27.6	26.4	25.9	26.4	28.0	27.5	26.2	27.8	25.9	30.6
24	1922	26.4	28.9	30.6	30.6	29.8	28.0	26.4	23.5	23.5	26.0	25.9	24.8	27.0	23.5	30.6
25	1923	25.8	27.6	29.7	28.7	28.8	27.6	26.0	25.0	25.8	27.5	27.2	26.6	27.2	25.0	29.7
26	1924	25.7	30.0	31.1	30.2	29.4	27.4	25.7	25.3	25.9	27.7	27.3	25.5	27.6	25.3	31.1
27	1925	23.2	27.9	30.7	31.2	29.8	27.0	26.3	25.7	26.1	26.9	27.2	25.4	27.3	23.2	31.2
28	1926	25.8	28.3	30.0	30.2	29.1	26.8	25.6	26.2	26.8	28.2	27.2	26.3	27.6	25.6	30.2
29	1927	24.1	27.7	28.7	30.4	28.8	26.6	25.9	24.4	25.8	26.9	26.7	25.2	26.8	24.1	30.4

Figure 39: Temperature (CRU) data separated into individual columns

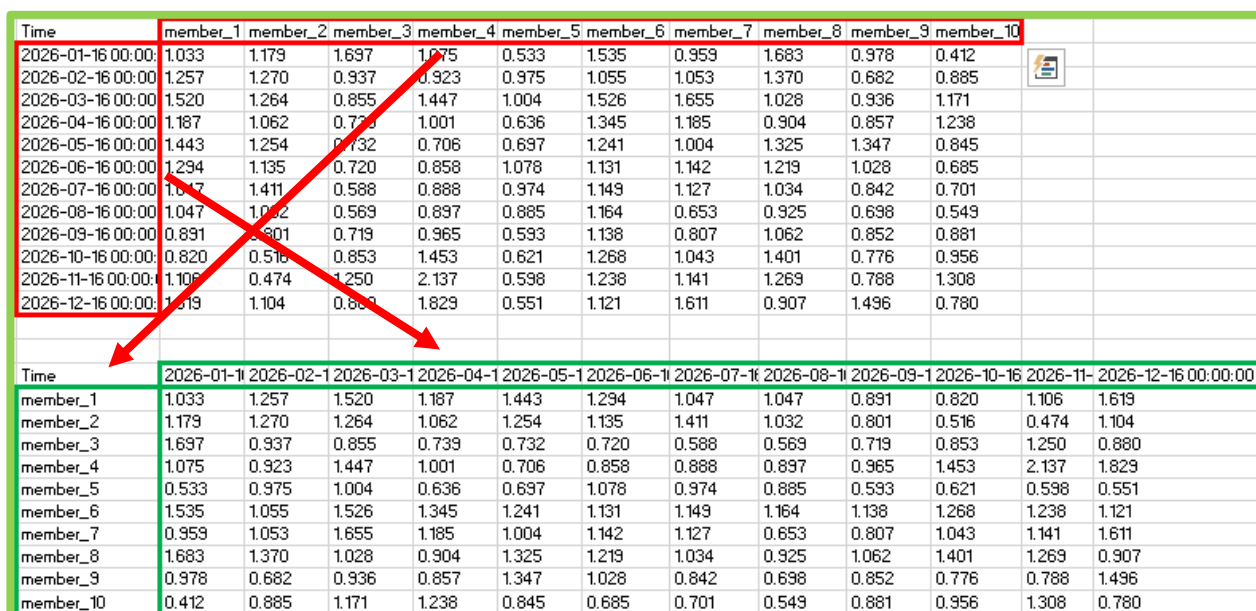
- Next select the “TEMP. RCP45 2016-2035” dataset and in the “Tool” dialog select and download “Time series” option. The downloaded datasets will download in “.csv” format which can be accessed using Microsoft Excel.



The dataset “Temp. RCP45 2016-2035” is delta change factors. The delta change factor is the ratio between GCM simulations of future and current climate. It is used to obtain future regional conditions by multiplying the delta change factor by the corresponding average temperature for each month. For

example, if delta change is 2 in March for “Temp. RCP45 2016-2035”, this means that there is a possibility that current average temperature will be 2 times higher in March.

- The data should be separated into columns (if not automatically done).
- In order to separate the data, follow the same steps as above. It should be noted that the RCP45 should be transposed so that the months appear at the top of the data and the “member” on the left of the data. To transpose the data:
 - Select all the data in the RCP45 dataset
 - Right click and copy the data
 - Select the place in the spreadsheet where you want the data placed and right click, under the paste options choose transpose. The data should be transposed (Figure 40).



Time	member_1	member_2	member_3	member_4	member_5	member_6	member_7	member_8	member_9	member_10
2026-01-16 00:00	1.033	1.179	1.697	1.075	0.533	1.535	0.959	1.683	0.978	0.412
2026-02-16 00:00	1.257	1.270	0.937	0.923	0.975	1.055	1.053	1.370	0.682	0.885
2026-03-16 00:00	1.520	1.264	0.855	1.447	1.004	1.526	1.655	1.028	0.936	1.171
2026-04-16 00:00	1.187	1.062	0.739	1.001	0.636	1.345	1.185	0.904	0.857	1.238
2026-05-16 00:00	1.443	1.254	0.732	0.706	0.697	1.241	1.004	1.325	1.347	0.845
2026-06-16 00:00	1.294	1.135	0.720	0.858	1.078	1.131	1.142	1.219	1.028	0.685
2026-07-16 00:00	1.047	1.411	0.588	0.888	0.974	1.149	1.127	1.034	0.842	0.701
2026-08-16 00:00	1.047	1.032	0.569	0.897	0.885	1.164	0.653	0.925	0.698	0.549
2026-09-16 00:00	0.891	0.801	0.719	0.965	0.593	1.138	0.807	1.062	0.852	0.881
2026-10-16 00:00	0.820	0.516	0.853	1.453	0.621	1.268	1.043	1.401	0.776	0.956
2026-11-16 00:00	1.106	0.474	1.250	2.137	0.598	1.238	1.141	1.269	0.788	1.308
2026-12-16 00:00	1.619	1.104	0.880	1.829	0.551	1.121	1.611	0.907	1.496	0.780

Time	2026-01-16 00:00	2026-02-16 00:00	2026-03-16 00:00	2026-04-16 00:00	2026-05-16 00:00	2026-06-16 00:00	2026-07-16 00:00	2026-08-16 00:00	2026-09-16 00:00	2026-10-16 00:00	2026-11-16 00:00	2026-12-16 00:00
member_1	1.033	1.257	1.520	1.187	1.443	1.294	1.047	1.047	0.891	0.820	1.106	1.619
member_2	1.179	1.270	1.264	1.062	1.254	1.135	1.411	1.032	0.801	0.516	0.474	1.104
member_3	1.697	0.937	0.855	0.739	0.732	0.720	0.588	0.569	0.719	0.853	1.250	0.880
member_4	1.075	0.923	1.447	1.001	0.706	0.858	0.888	0.897	0.965	1.453	2.137	1.829
member_5	0.533	0.975	1.004	0.636	0.697	1.078	0.974	0.885	0.593	0.621	0.598	0.551
member_6	1.535	1.055	1.526	1.345	1.241	1.131	1.149	1.164	1.138	1.268	1.238	1.121
member_7	0.959	1.053	1.655	1.185	1.004	1.142	1.127	0.653	0.807	1.043	1.141	1.611
member_8	1.683	1.370	1.028	0.904	1.325	1.219	1.034	0.925	1.062	1.401	1.269	0.907
member_9	0.978	0.682	0.936	0.857	1.347	1.028	0.842	0.698	0.852	0.776	0.788	1.496
member_10	0.412	0.885	1.171	1.238	0.845	0.685	0.701	0.549	0.881	0.956	1.308	0.780

Figure 40: Transposed RCP45 data. Note that dates and members have switched positions after applying the transpose function

- The transposed RCP45 data should be copied and moved to the spreadsheet containing the sorted Temperature (CRU) data. Paste the transposed data in columns “R” to “AD”. This step should be done as predicted changes in temperature are calculated using both the datasets.

What are members, and why is the data described as members?

The RCP45 2016-2035 datasets form part of an ensemble of delta change factors. Instead of doing a single forecast, the forecast is done 10 times for each month. Each forecast has slightly different starting conditions, because the delta change factors vary. The complete set of forecasts is referred to as the ensemble, and the individual forecasts within it are referred to as ensemble members.

- Expand the table using the same steps as described earlier (see short-term rainfall analysis). The labels for each column should be as follows:

A122 – Time

A123 to A132 – add the labels “member_1” to “member_10”

B122 to M122 - Add the months from January to December

A133 – Monthly projected average temperature (°C)

A134 – 25th percentile

A135 – 75th percentile

A136 – Median

A137 –Deviation (°C)

The processed data will be done in this table (Figure 41).

	A	B	C	D	E	F	G	H	I	J	K	L	M
121	Delta change factors												
122	Time	January	February	March	April	May	June	July	August	September	October	November	December
123	member_1												
124	member_2												
125	member_3												
126	member_4												
127	member_5												
128	member_6												
129	member_7												
130	member_8												
131	member_9												
132	member_10												
133	Monthly projected average temperature (°C)												
134	25th percentile												
135	75th percentile												
136	Median												
137	Deviation (°C)												

Figure 41: Expanded table wherein long-term data will be processed

The downloaded Temperature (CRU) data contains the annual averages, maximums and minimums and the long-term monthly averages, maximums and minimum. The statistic of interest in this instance is the long-term monthly averages. The steps and equations are as follows:

- Select the cell B123 (under the label January) in the
- Enter the following formula:

$$= S2 * \$B\$117$$

Where \$B\$117 is the long-term average for January and S2 is the RCP45 value for “member_1” for January.

Note: that the “\$” symbol is required as it ensures that the equation always uses the value in cell B116 as the long-term average value when calculating projected changes for January (Figure 42).

Time	January
member_1	=S2*\$B\$117

Figure 42: The Equation as it should be entered when performing calculations to determine projected changes

- Perform this calculation from member_1 to member_10 in the month of January to determine the projected changes for the month of January
- Next apply this method for the rest of the months using the corresponding long-term monthly average and members for each month.

The table with the calculated climate projections should look as below (Figure 43).

	A	B	C	D	E	F	G	H	I	J	K	L	M
121	Delta change factors												
122	Time	January	February	March	April	May	June	July	August	September	October	November	December
123	member_1	26.90	35.83	39.57	30.90	37.57	33.69	27.26	27.26	23.20	21.35	28.80	42.15
124	member_2	30.70	36.20	38.42	32.73	37.42	31.63	37.37	26.58	21.11	14.31	13.04	28.81
125	member_3	44.18	26.71	25.99	22.78	21.84	20.07	15.57	14.65	18.95	23.65	34.40	22.96
126	member_4	27.99	26.31	43.98	30.85	21.07	23.91	23.52	23.10	25.44	40.29	58.81	47.73
127	member_5	13.88	27.79	30.52	19.60	20.80	30.05	25.80	22.79	15.63	17.22	16.46	14.38
128	member_6	39.96	30.07	46.38	41.46	37.03	31.52	30.43	29.97	30.00	35.16	34.07	29.25
129	member_7	24.97	30.01	50.30	36.52	29.96	31.83	29.85	16.82	21.27	28.92	31.40	42.04
130	member_8	43.82	39.05	31.25	27.86	39.53	33.98	27.39	23.82	27.99	38.84	34.92	23.67
131	member_9	25.46	19.44	28.45	26.42	40.19	28.65	22.30	17.97	22.46	21.52	21.69	39.04
132	member_10	10.73	25.22	35.59	38.16	25.21	19.09	18.57	14.14	23.22	26.51	36.00	20.35
133	Monthly projected average temperature (°C)												
134	25th percentile												
135	75th percentile												
136	Median												
137	Deviation (°C)												

Figure 43: Table with climate projections

- Finally determine the monthly projected average for each month using the average function in excel:

$$= \text{Average} (B123: B132)$$

Where the range B123:B132 is the projected values for January for all the members for the month of January (Figure 44).

	A	B	C	D	E	F	G	H	I	J	K	L	M
121	Delta change factors												
122	Time	January	February	March	April	May	June	July	August	September	October	November	December
123	member_1	26.90	35.83	39.57	30.90	37.57	33.69	27.26	27.26	23.20	21.35	28.80	42.15
124	member_2	30.70	36.20	38.42	32.73	37.42	31.63	37.37	26.58	21.11	14.31	13.04	28.81
125	member_3	44.18	26.71	25.99	22.78	21.84	20.07	15.57	14.65	18.95	23.65	34.40	22.96
126	member_4	27.99	26.31	43.98	30.85	21.07	23.91	23.52	23.10	25.44	40.29	58.81	47.73
127	member_5	13.88	27.79	30.52	19.60	20.80	30.05	25.80	22.79	15.63	17.22	16.46	14.38
128	member_6	39.96	30.07	46.38	41.46	37.03	31.52	30.43	29.97	30.00	35.16	34.07	29.25
129	member_7	24.97	30.01	50.30	36.52	29.96	31.83	29.85	16.82	21.27	28.92	31.40	42.04
130	member_8	43.82	39.05	31.25	27.86	39.53	33.98	27.39	23.82	27.99	38.84	34.92	23.67
131	member_9	25.46	19.44	28.45	26.42	40.19	28.65	22.30	17.97	22.46	21.52	21.69	39.04
132	member_10	10.73	25.22	35.59	38.16	25.21	19.09	18.57	14.14	23.22	26.51	36.00	20.35
133	Monthly projected average temperature (°C)	28.86	29.66	37.05	30.73	31.06	28.44	25.81	21.71	22.93	26.78	30.96	31.04
134	25th percentile												
135	75th percentile												
136	Median												
137	Deviation (°C)												

Figure 44: Projected data with monthly projected averages

The data in the above table shows the range of possibilities of temperature (°C) in the future under the RCP45 climate scenario, and each projection is equally likely to occur.

8.2.4 Plotting graphs for projected temperature

The data has to be plotted into two graphs. The first graph will indicate the 25th and 75th percentiles and the median. This graph is important as it will give the user an idea of the uncertainty around the median. It is important to know that there is some uncertainty as these are climate projections and **not** actual estimates. The second graph will indicate the monthly average of the observed data over the long-term, and the monthly average of the projected data. This will be a graphical indication as to what projected conditions may look like on a monthly basis.

Before the graph can be plotted the 25th and 75th percentiles and the median of the projected data have to be determined

- Determine the 25th percentile for each month using the below formula

$$= \text{PERCENTILE}(B123:B132; 0.25)$$

Where the range B123:B132 is the projections for the month, and 0.25 is the 25th percentile

- Determine 75th percentile for each month using the below formula

$$= \text{PERCENTILE}(B123:B132; 0.75)$$

Where the range B123:B132 is the projections for the month, and 0.75 is the 75th percentile

- Determine the Median for each month using the below formula

$$= \text{MEDIAN}(B123:B132)$$

Where the range B123:B132 is the projected median for the month, the above steps to determine the percentiles and median should be repeated for each month.

The table should look as below (Figure 45).

	A	B	C	D	E	F	G	H	I	J	K	L	M
121	Delta change factors												
122	Time	January	February	March	April	May	June	July	August	September	October	November	December
123	member_1	26.90	35.83	39.57	30.90	37.57	33.69	27.26	27.26	23.20	21.35	28.80	42.15
124	member_2	30.70	36.20	38.42	32.73	37.42	31.63	37.37	26.58	21.11	14.31	13.04	28.81
125	member_3	44.18	26.71	25.99	22.78	21.84	20.07	15.57	14.65	18.95	23.65	34.40	22.96
126	member_4	27.99	26.31	43.98	30.85	21.07	23.91	23.52	23.10	25.44	40.29	58.81	47.73
127	member_5	13.88	27.79	30.52	19.60	20.80	30.05	25.80	22.79	15.63	17.22	16.46	14.38
128	member_6	39.96	30.07	46.38	41.46	37.03	31.52	30.43	29.97	30.00	35.16	34.07	29.25
129	member_7	24.97	30.01	50.30	36.52	29.96	31.83	29.85	16.82	21.27	28.92	31.40	42.04
130	member_8	43.82	39.05	31.25	27.86	39.53	33.98	27.39	23.82	27.99	38.84	34.92	23.67
131	member_9	25.46	19.44	28.45	26.42	40.19	28.65	22.30	17.97	22.46	21.52	21.69	39.04
132	member_10	10.73	25.22	35.59	38.16	25.21	19.09	18.57	14.14	23.22	26.51	36.00	20.35
133	Monthly projected average temperature (°C)	28.86	29.66	37.05	30.73	31.06	28.44	25.81	21.71	22.93	26.78	30.96	31.04
134	25th percentile	25.09	26.41	30.70	26.78	22.68	25.10	22.61	17.11	21.15	21.39	23.46	23.14
135	75th percentile	37.65	30.06	42.59	35.58	37.32	31.61	29.24	23.64	24.88	33.60	34.79	37.04
136	Median	27.44	28.90	37.01	30.88	33.49	30.78	26.53	22.94	22.83	25.08	32.74	29.03
137	Deviation (°C)												

Figure 45: Table with percentiles and median

The percentiles and median have to put into a graph.

- Select the data and labels for the 25th percentile, 75th percentile and the median
- Go to insert, and under “Charts” select “Line”
- This should generate the graph. However, the graph will not have the months added
- To add the months, right click on the graph, and choose select data
- In the “Horizontal (Category) Axis Labels click edit
- Select the months as the “Axis label range”
- The final graph should be as below (Figure 46)

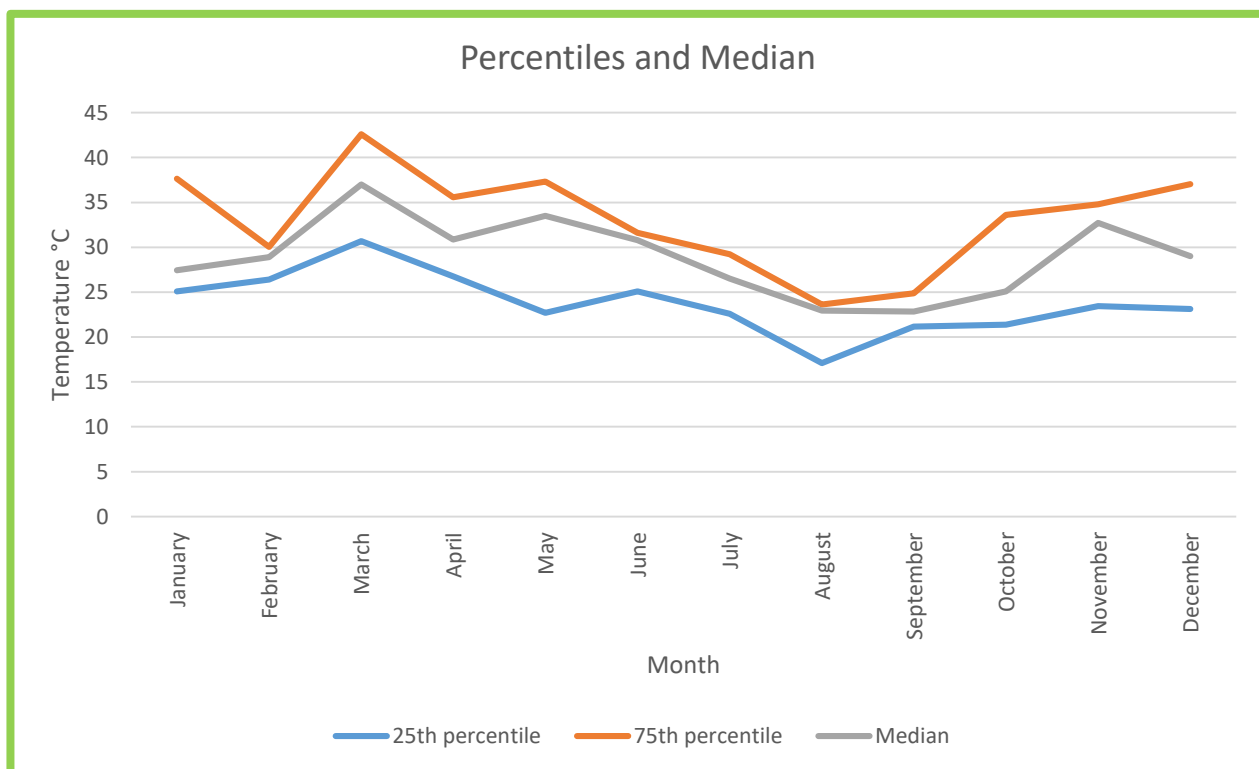


Figure 46: Graph indicating the percentiles and median

The above graph indicates that there is a lot of uncertainty in temperature projections. The months of February, June, August and November indicate that median temperatures are closer to the 75th percentile. Whereas, the other points all fall closer to the middle of both the 25th percentile and 75th percentile.

In order to plot graph long-term averages with the projected averages follow the below steps:

- Select the long-term averages for the Temperature (CRU) dataset
- Go to insert, and under “Charts” select “Line”
- This should generate the graph. However, the graph will not have the monthly projected averages added nor the months
- To add the monthly projected averages, right click on the graph and click select data
- In the Legend Entries (Series) click add
- Select the monthly projected averages as the data range
- To add the months, right click on the graph, and choose select data
- In the “Horizontal (Category) Axis Labels click edit
- Select the months as the “Axis label range”

The final graph should be as below (Figure 47).

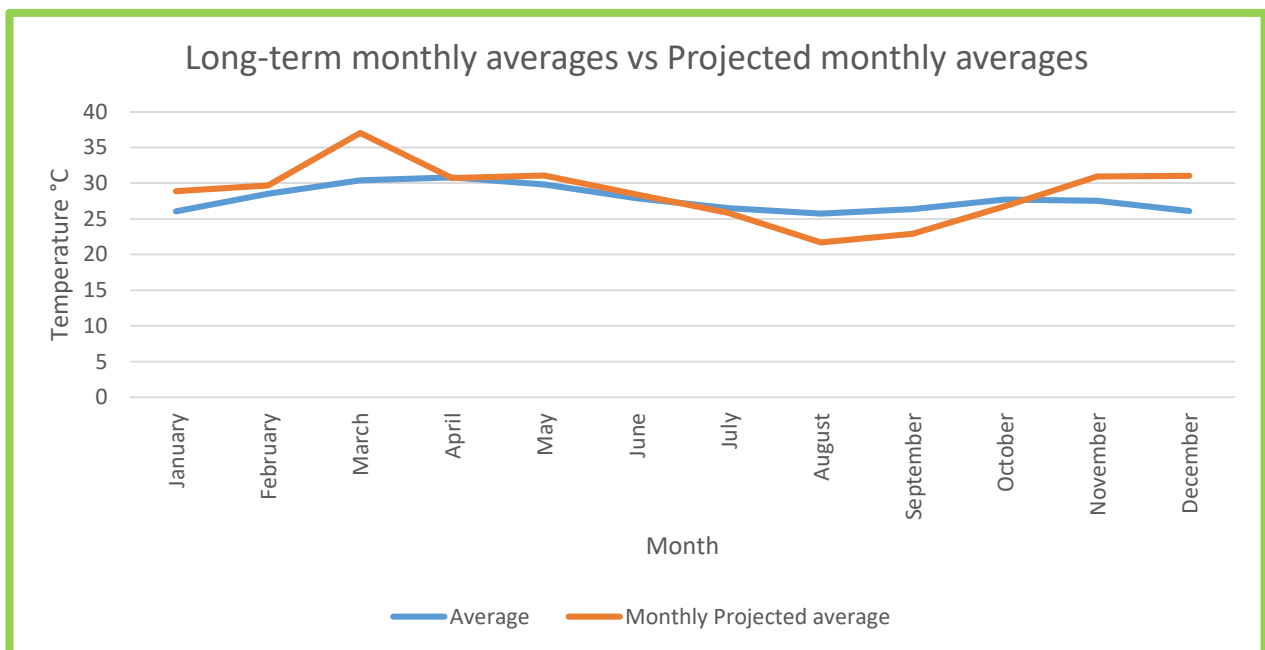


Figure 47: Long-term monthly averages vs Projected monthly averages

Based on a visual analysis the above graph indicates the projected monthly temperature is expected to be variable, with the months January, February, March, May, November and December indicated projected

monthly temperature to be above the long-term mean. However, the visual analysis should only be used to get a general idea as to the expected future conditions. The user should note that the data presented in Figure 47 only provides information on monthly projections and possible extremes that could be experienced during each month. The data presented in Figure 47 does not provide information for days or periods with extremes.

In order to determine the likelihood of conditions increasing or decreasing, the number of times the projected conditions are above or below the long-term average should be counted. However, the user has to determine the number of times the monthly projected average is above the long-term mean. In order to do this the “temperature deviation” should be calculated.

The “temperature deviation” will be calculated for each month. This will indicate to the user if the projected temperature is expected to be more than, less than or equal to the long-term average/mean.

- In order to calculate the “temperature deviation” insert the following equation into excel:

$$= B133 - B117$$

where B133 is the monthly projected temperature for the month, and B117 is the monthly long-term average. In order to determine the overall deviation for the projected monthly temperature, the average of the of the “temperature deviation” should be calculated.

- If the temperature deviation is positive then projected temperature for that month is expected to exceeded the mean, if the temperature deviation is negative then projected temperature for that month is expected to be less than the mean
- Count the number of times the temperature deviation is positive, and count the number of times the temperature deviation is negative (Figure 48)

	A	B	C	D	E	F	G	H	I	J	K	L	M
121	Delta change factors												
122	Time	January	February	March	April	May	June	July	August	September	October	November	December
123	member_1	26.90	35.83	39.57	30.90	37.57	33.69	27.26	27.26	23.20	21.35	28.80	42.15
124	member_2	30.70	36.20	38.42	32.73	37.42	31.63	37.37	26.58	21.11	14.31	13.04	28.81
125	member_3	44.18	26.71	25.99	22.78	21.84	20.07	15.57	14.65	18.95	23.65	34.40	22.96
126	member_4	27.99	26.31	43.98	30.85	21.07	23.91	23.52	23.10	25.44	40.29	58.81	47.73
127	member_5	13.88	27.79	30.52	19.60	20.80	30.05	25.80	22.79	15.63	17.22	16.46	14.38
128	member_6	39.96	30.07	46.38	41.46	37.03	31.52	30.43	29.97	30.00	35.16	34.07	29.25
129	member_7	24.97	30.01	50.30	36.52	29.96	31.83	29.85	16.82	21.27	28.92	31.40	42.04
130	member_8	43.82	39.05	31.25	27.86	39.53	33.98	27.39	23.82	27.99	38.84	34.92	23.67
131	member_9	25.46	19.44	28.45	26.42	40.19	28.65	22.30	17.97	22.46	21.52	21.69	39.04
132	member_10	10.73	25.22	35.59	38.16	25.21	19.09	18.57	14.14	23.22	26.51	36.00	20.35
133	Monthly projected average temperature (°C)	28.86	29.66	37.05	30.73	31.06	28.44	25.81	21.71	22.93	26.78	30.96	31.04
134	25th percentile	25.09	26.41	30.70	26.78	22.68	25.10	22.61	17.11	21.15	21.39	23.46	23.14
135	75th percentile	37.65	30.06	42.59	35.58	37.32	31.61	29.24	23.64	24.88	33.60	34.79	37.04
136	Median	27.44	28.90	37.01	30.88	33.49	30.78	26.53	22.94	22.83	25.08	32.74	29.03
137	Deviation (°C)	2.82	1.16	6.65	-0.09	1.22	0.57	-0.68	-4.04	-3.43	-0.95	3.44	4.94

Figure 48: Delta change table with temperature deviations calculated

- To get the severity calculate the average “temperature deviation”

$$= \text{Average}(B137:M137)$$

Where the range B137:M137 is the temperature deviation for projected monthly values for January to December

- This will indicate to the user if the overall projected temperature is expected to be above or below the mean (Figure 49)

	A	B	C	D	E	F	G	H	I	J	K	L	M
121	Delta change factors												
122	Time	January	February	March	April	May	June	July	August	September	October	November	December
123	member_1	26.90	35.83	39.57	30.90	37.57	33.69	27.26	27.26	23.20	21.35	28.80	42.15
124	member_2	30.70	36.20	38.42	32.73	37.42	31.63	37.37	26.58	21.11	14.31	13.04	28.81
125	member_3	44.18	26.71	25.99	22.78	21.84	20.07	15.57	14.65	18.95	23.65	34.40	22.96
126	member_4	27.99	26.31	43.98	30.85	21.07	23.91	23.52	23.10	25.44	40.29	58.81	47.73
127	member_5	13.88	27.79	30.52	19.60	20.80	30.05	25.80	22.79	15.63	17.22	16.46	14.38
128	member_6	39.96	30.07	46.38	41.46	37.03	31.52	30.43	29.97	30.00	35.16	34.07	29.25
129	member_7	24.97	30.01	50.30	36.52	29.96	31.83	29.85	16.82	21.27	28.92	31.40	42.04
130	member_8	43.82	39.05	31.25	27.86	39.53	33.98	27.39	23.82	27.99	38.84	34.92	23.67
131	member_9	25.46	19.44	28.45	26.42	40.19	28.65	22.30	17.97	22.46	21.52	21.69	39.04
132	member_10	10.73	25.22	35.59	38.16	25.21	19.09	18.57	14.14	23.22	26.51	36.00	20.35
133	Monthly projected average temperature (°C)	28.86	29.66	37.05	30.73	31.06	28.44	25.81	21.71	22.93	26.78	30.96	31.04
134	25th percentile	25.09	26.41	30.70	26.78	22.68	25.10	22.61	17.11	21.15	21.39	23.46	23.14
135	75th percentile	37.65	30.06	42.59	35.58	37.32	31.61	29.24	23.64	24.88	33.60	34.79	37.04
136	Median	27.44	28.90	37.01	30.88	33.49	30.78	26.53	22.94	22.83	25.08	32.74	29.03
137	Deviation (°C)	2.82	1.16	6.65	-0.09	1.22	0.57	-0.68	-4.04	-3.43	-0.95	3.44	4.94
138										Average of temperature deviations (°C)			0.97

Figure 49: Final table for long-term temperature analysis

In the case of the above example the projected likelihood indicates that 7 of the projected points are above the average/mean, and 5 of the projected points are below the average/mean. The temperature has deviated by 0.97 °C of average/mean, using table 7 the severity was determined to be near normal.

8.2.5 Determining long-term climate change related risks

Considering the previously presented examples, an analysis of the Rainfall (CRU) – Rainfall (mm/month) (CRU) and Temperature – CRU Temperature C datasets indicates that conditions within the water utility are expected to be wetter than normal as follows:

- Rainfall**
 - Likelihood: 8 out of 12 projected points (members of the climate model ensemble) had rainfall that exceeded the average/mean.
 - Severity: mildly wet
- Temperature**
 - Likelihood: 7 out of 12 projected points (members of the climate model ensemble) experienced conditions that exceeded the average/mean.
 - Severity: near normal

Note: The below methodology can be applied to both hazards and hazardous events associated wetter or drier conditions. The example of the specific hazard in the below scenario, was used as conditions based on the above analysis that determined conditions were wetter than normal. Further examples of hazards and hazardous events, associated with wetter and drier conditions are listed in appendix A.

8.2.6 Scenario 2

The water utility has completed the analysis, and has determined that the physical conditions are expected to be mildly wet, under climate change conditions. The mildly wet conditions are an issue of concern to the water utility, as they are not prepared for the effects these types of hazards and hazardous events could have on their water utility's infrastructure and operations. Based on the water utility's past experience, periods with increased rainfall conditions may lead to increased erosion, which could result in damage to their infrastructure. The Water utility has noted that intense precipitation events may occur more frequently under the effects of climate change, concentrating the annual total rainfall into episodes that challenge current infrastructure for water management and flood control. When the protections fail, inundation may disrupt service and damage infrastructure such as treatment plants, intake facilities and water conveyance and distribution systems. The damage to the infrastructure may affect their operations by reducing their ability to provide water of an adequate quantity and quality. The water utility would like to determine if there is an increased risk of damage to infrastructure and reduced water quality as a result of mildly wet conditions (Figure 50), so that they may implement the necessary actions to avoid damage to their infrastructure occurring in future.



Figure 50: The effects increased flows had on the water quality and infrastructure. Large material such as boulders may cause damage to the infrastructure as seen in the above image (circled in red).

In order to determine if there will be a change in the risk rating, the utility should use the following steps

- The user should determine their water utility's current risk rating (this should be in the water utility's current WSP), and in particular know both the likelihood and severity for a climate change related hazard/hazardous event (see Table 16).
- By way of example and considering a typical 5 x 5 matrix used for water safety planning risk assessments, if the water utility's current risk rating is "Low" with likelihood categorised as "unlikely", and the severity categorised as "mild or minor", then the risk rating is calculated as 4 (see the circled value in table 16 below).

Table 16: Current Risk Matrix

Likelihood	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
		Insignificant or no impact 1	Mild or minor 2	Moderate 3	Major 4	Catastrophic 5
Severity						

Risk Score	<6	6-9	10-15	>15
Risk rating	Low	Medium	High	Very High

Considering the previous example: In the above example

- For rainfall,
 - Likelihood: 8 months were above the average/mean, and 4 were below the average/mean
 - Severity: mildly wet
- For temperature,
 - Likelihood: 7 months were above the average/mean, and 5 months with below the average/mean temperature (°C)

- Severity: near normal

The tables that follow can be used to determine the possible changes to likelihood and severity (Table 17, Table 18, Table 19 and Table 20).

Note: The user should note that in the below examples change factors are presented for both likelihood and severity. These change factors are the suggested approach developed for this guidance document and is designed to be used with the 5x5 risk matrix found in the WHO/IWA WSP manual. If the user's water utility is using a different risk matrix, the user may amend the change factors to suit their own needs. Furthermore, the applicability of the approach should be tested on a case-by-case basis, and amended as required (e.g. Is the suggested approach to sensitive for our utility? Should we adjust the change factors and make them more conservative?)

When determining the likelihood of wetter or drier conditions the water utility should count the number of months' rainfall was higher than "normal" and how many times it was lower than "normal". The water utility may get a combination of for e.g. 7 months wetter than "normal" and 5 months drier than "normal" or, the water utility may get a combination of 7 months drier than "normal" and 5 months wetter than "normal". In the case of the example presented above the combination is 4 months below average/mean and 8 months above average/mean for rainfall (Table 17). The same should be done for temperature, the water utility should count the number of months where temperature deviations were above or below the mean. The water utility may get a combination of 10 months above the mean and 2 months below the mean or, the utility may get a combination of 10 months below the mean and 2 months above the mean. In the case of the example presented above the combination is 5 months below average/mean and 7 months above average/mean for rainfall (Table 17). Considering these combinations of likelihood for rainfall and temperature, table 18 can be used to determine the likelihood change factor. The water utility should look for each combination in table 18, and see where they meet up in the table. In the case of the example presented above, the likelihood change factor is 0 (Table 18).

Table 17: Likelihood change factor

Number of ensemble members above or below mean	
12 months and 0 months	
11 months and 1 month	
10 months and 2 months	
9 months and 3 months	
8 months and 4 months	
7 months and 5 months	
6 months and 6 months	

Table 18: Determining the overall change factor for likelihood

Rain	12 months and 0 months	+1	+1	+2	+2	+2	+2	+2
	11 months and 1 month	+1	+1	+1	+1	+2	+2	+2
	10 months and 2 months	1	+1	+1	+1	+1	+2	+2
	9 months and 3 months	0	0	+1	+1	+1	+1	+2
	8 months and 4 months	0	0	+1	+1	+1	+1	+1
	7 months and 5 months	0	0	0	+1	+1	+1	+1
	6 months and 6 months	0	0	0	0	0	+1	+1
		6 months and 6 months	7 months and 5 months	8 months and 4 months	9 months and 3 months	10 months and 2 months	11 months and 1 month	12 months and 0 months
		Temperature						

The change factor for severity is determined using the physical conditions determined when doing the long-term analysis for rainfall and temperature. In this case rainfall was “mildly wet” and temperature was “Near normal” (Table 19). Considering these physical conditions for rainfall and temperature, table 20 can be used to determine the severity change factor. The water utility should look for the severity for both rainfall and temperature, and see where they meet up in the table. In the case of the example presented above, the severity change factor is 0 (Table 20).

Table 19: Severity change factor

Severity as per the physical conditions	
Rainfall	Temperature
Extremely wet/dry	Major increase/decrease
Very wet/dry	Moderate Increase/decrease
Moderately wet/dry	Minor increase/decrease
Mildly wet/dry	Near normal
Normal	Normal

Table 20: Determining the overall change factor for severity

Rain	Extremely Wet	>175	+2	+2	+2	+1	+1	+1	+2	+2	+2
	Very Wet	150 – 175	+2	+2	+1	+1	+1	+1	+1	+2	+2
	Moderately Wet	125 – 150	+1	+1	+1	0	0	0	+1	+1	+1
	Mildly Wet	100 – 125	+1	+1	0	0	0	0	0	+1	+1
	Normal	100	+1	+1	0	0	0	0	0	+1	+1
	Mildly Dry	75 – 100	+1	+1	0	0	0	0	0	+1	+1
	Moderately Dry	50 – 75	+1	+1	+1	0	0	0	+1	+1	+1
	Very Dry	25 – 50	+2	+2	+1	+1	+1	+1	+1	+2	+2
	Extremely Dry	<25	+2	+2	+2	+1	+1	+1	+2	+2	+2
			-3 to -5	-2 to -3	-1 to -2	0 to -1	0	0 to 1	1 to 2	2 to 3	3 to 5
			Major decrease	Moderate decrease	Minor decrease	Near normal	Normal	Near normal	Minor increase	Moderate Increase	Major increase
Temperature											

The change factors should be added to the current value for likelihood and severity (Table 21). As conditions are mildly wet, the water utility should focus on the hazards and hazardous events associated with wet conditions. These aspects will be discussed in further detail in **Section 9** of this guideline. If the water utility has a current Likelihood of 2 for the hazard and the change factor for likelihood was determined to be 0, then the likelihood remains the same. If the water utility has a current severity of 2 and a change factor of 0, then severity rating remains the same (Table 21).

Table 21: adding change factors to current likelihood and severity.

Likelihood		Severity	
Current	Change Factor	Current	Change Factor
2	0	2	0
Amended Likelihood: 2 + 0 = 2 (Unlikely)		Amended Severity: 2 + 0 = 2 (Moderate)	

The amended risk rating will be as below (Table 22).

Table 22: Risk Matrix considering climate change

Likelihood	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
		Insignificant or no impact 1	Mild or minor 2	Moderate 3	Major 4	Catastrophic 5
Severity						

Risk Score	<6	6-9	10-15	>15
Risk rating	Low	Medium	High	Very High

After the change factors were added to the likelihood and severity, risk rating and risk score remained at 4 (i.e. Low). Low risks may not require immediate action and the water utility should focus on those risks with higher risk ratings. The long-term analysis should be done annually to determine if, the long-term conditions are expected to change and if there are changes in likelihood and severity of the hazards and hazardous events.

Note: The water utility should note in some instances, after applying the change factors to likelihood and severity, the “new” likelihood or severity may exceed the maximum category as presented in the risk matrix. By way of example:

Likelihood:

- if the initial condition for likelihood was 4, and
- the change factor for likelihood is for +2
- the new likelihood will be 6

OR

Severity:

- if the initial condition for severity was 5, and
- the change factor for severity is for +2
- the new severity will be 7

In these instances, the water utility should use the maximum category for likelihood and severity used in the risk matrix. In the case of the above risk matrix used above, the maximum category is 5 for both likelihood and severity

What if the Short-Term and Long-Term Risk Assessment findings differ?

When the analyses for short-term climate change risks and long-term climate change risks have been completed, the situation may arise whereby calculated risks differ. By way of example:

- Short-term risk may have gone from 6 (Low) → 12 (High) and;
- Long-term risk may have gone from 6 (Low) → 16 (Very high)

In this situation the user should consider the implications of both short and long-term calculated risks in deciding the appropriateness of both existing control measures and potential corrective actions. By way of example:

The utility might decide that in the next 12 months they might implement a) actions to address the short-term identified impacts, and b) first step actions to address long-term identified impacts.

It is important for water utilities to cross reference the data in the Portal with in-situ data and should not only rely on satellite data. In terms of climate projections, the methodology can provide some information on expected conditions. The methodology only provides the water utility with a starting point, and the water utility is encouraged to get further input and analysis from climate scientists.

9. Water Safety Planning

This section provides guidance on (1) how to develop a Water Safety Plan for your utility in the Flood and Drought Portal, and (2) how to incorporate climate change data into your WSP, with a particular focus on amending your risk assessment and associated control measures/mitigation.

A Water Safety Plan (WSP) consists of 11 modules. The Water Safety Planning tool on the Portal considers all 11 modules and provides step-by-step guidance to developing a WSP. Full details of each module can be found in the WHO/IWA Water Safety Plan Manual, which can be accessed by following the link: [Water Safety Plan Manual](#). To start developing a WSP via the Portal, go to the home page and select the Water Safety Planning tool (Figure 51).

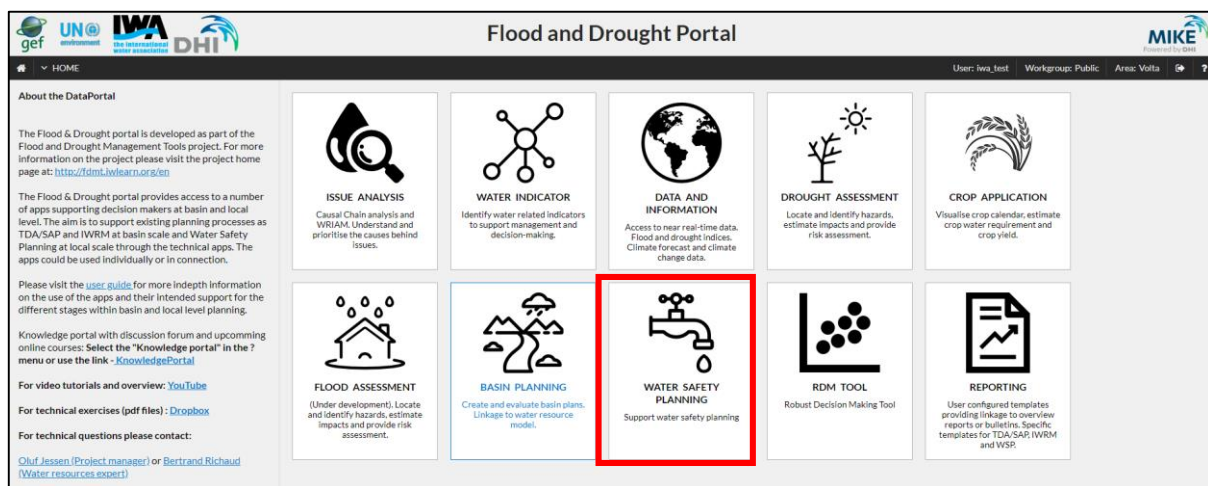


Figure 51: Flood and Drought Portal home page

The following step-by-step process for developing WSP will be described:

- Module 1: Assembling the WSP team
- Module 2: Describe the water supply system
- Module 3: Identify hazards and hazardous events
- Module 4: Determine and validate control measures, reassess and prioritize the risks
- Module 5: Develop, implement and maintain an improvement/upgrade plan
- Module 6: Define monitoring and control measures
- Module 7: Verify the effectiveness of the WSP
- Module 8: Prepare management procedures
- Module 9: Develop supporting programmes
- Module 10: Plan and carry out periodic review of the WSP
- Module 11: Revise the WSP following an incident

9.1 Module 1: Assembling the WSP team

Establishment of a qualified, dedicated team is a prerequisite to securing the technical expertise needed to develop a WSP. Establish a qualified team with the expertise to understand the water supply systems, identify hazards, determine control measures and ensure relevance of the WSP. Appoint a strong team leader and define the responsibilities for each team member. Be sure to engage the senior management to secure financial and resource support (WHO & IWA, 2018).

The WSP team may include the following persons:

- Water systems operator
- Engineers
- Water quality operators
- Managers and technical specialists
- Representatives of the health and environmental sectors
- Additional support to help obtain and interpret climate related information
- Public health or water quality specialist provide inset on health impacts
- Emergency planning or civil protection expert to advise on disaster risk reduction
- Water planner
- Consultants/Extra-ordinary members of the team may include climatologists or hydrologists, specialising in impacts and adaptation planning.

9.1.1 Assembling the WSP team in the Portal

- In the WSP application select module 1. At the far right end there is an option to “Add”. Click on this option (Figure 52).

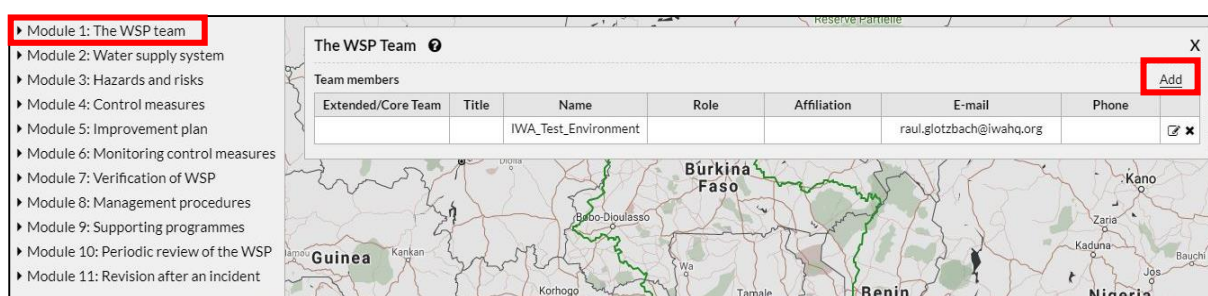
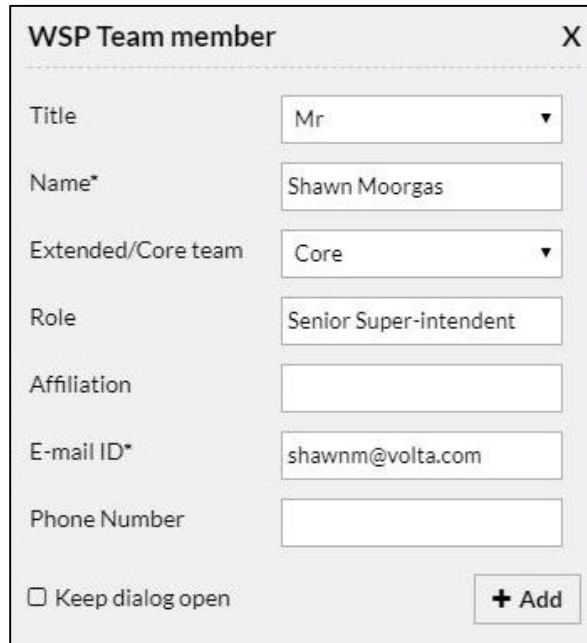


Figure 52: Water Safety Planning application assembling the team

Figure 52 shows a list of the WSP modules in the Portal. When selecting Module 1 a pop-up labelled “The WSP Team” appears. The pop-up indicates a list of all the WSP team members. New WSP team members can be added here, or the information of current WSP team members can be edited.

- After clicking on “Add” another pop-up will open, add the information of The WSP team members (Figure 53).



The form is titled "WSP Team member" and has a close button (X) in the top right corner. It contains the following fields:

- Title: A dropdown menu with "Mr" selected.
- Name*: A text input field containing "Shawn Moorgas".
- Extended/Core team: A dropdown menu with "Core" selected.
- Role: A text input field containing "Senior Super-intendent".
- Affiliation: An empty text input field.
- E-mail ID*: A text input field containing "shawnm@volta.com".
- Phone Number: An empty text input field.

At the bottom left, there is a checkbox labeled "Keep dialog open". At the bottom right, there is a button labeled "+ Add".

Figure 53: pop-up to be completed when adding WSP team members

- Repeat the above steps by clicking on “Add” and insert the information in the pop-up for each WSP team member.

Exercise: Module 1 – Assemble the WSP Team

Consider:

- Who is on your WSP team?
- Who will you include (internal or external) as a climate expert?
- What other team members (internal or external) do you need? This could be the engineer who designed the reservoir or a hydrologist.

Add this information into Module 1.

9.2 Module 2 – Water Supply System

Module 2 provides a thorough and accurate system description of the complete water supply chain, from catchment to consumer, with sufficient detail to facilitate identification of hazards and hazardous events. System descriptions should be validated through on-site field checking and cross referencing should be made with other documentation.

The description includes:

- written description of all major process steps
- system flow diagrams / schematics
- description of intended users and uses of the water supply
- comparison of water quality standards or targets with water quality achieved in practice.

9.2.1 Water Supply System in the Portal

- In the WSP application select Module 2. Next to “Level 1-Process Steps” click “Add” this opens another pop-up (Figure 54).

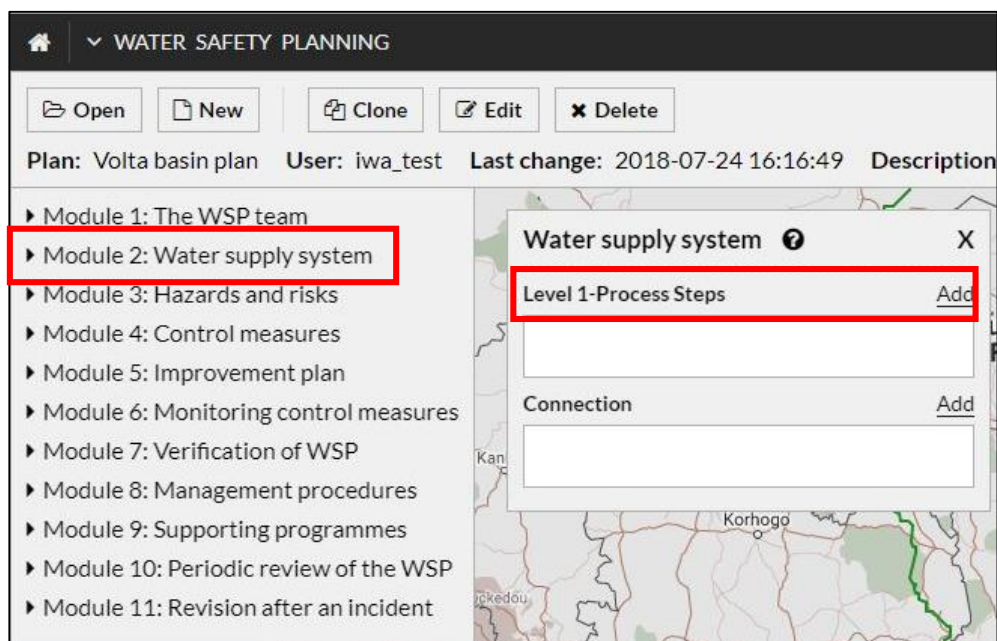


Figure 54: Water Safety Planning application Water supply system, adding different process steps

- The following relevant information should be inserted:
 - The name of the component (names should be easily understood by all WSP team members).
 - There are three different options for “Area” (namely “Catchment”, “Treatment” and “Distribution”). Select the most relevant option.
 - After choosing the specific Area, the “Component type” options change to reflect the “Area” you have chosen (Figure 55).

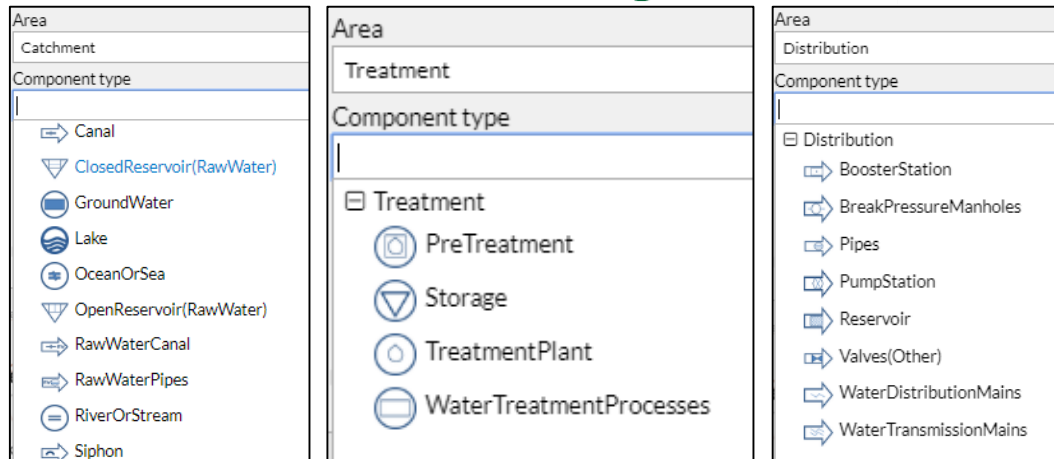


Figure 55: The different component types available for each "Area" in the water system

- "Direct Control" means that the utility has control of what happens to the component, (or possible impacts on the component are outside of your control – e.g. can be due to upstream users).
- The coordinates for the location is added by clicking directly on the map. First click in the empty location pop-up, then click the area on the map where the specific component is located (Figure 56).

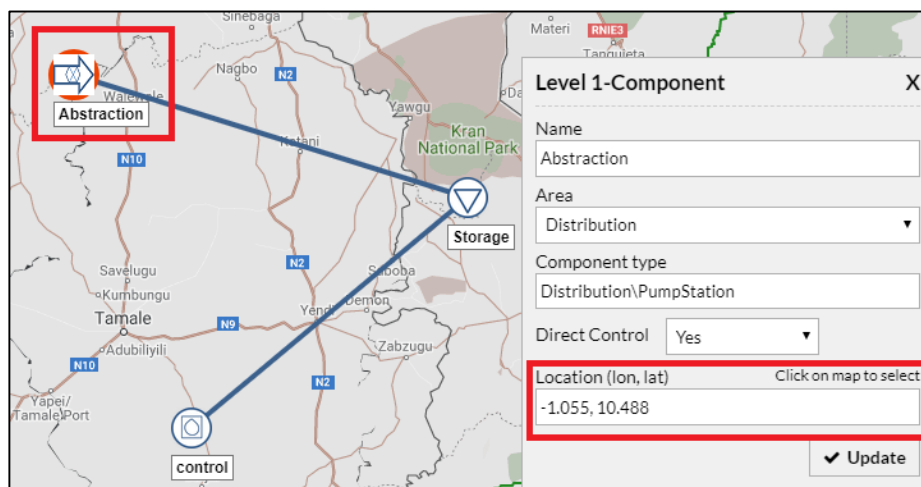


Figure 56: Adding different components to the water supply system. The coordinates are added by finding the component location on the map and clicking on it.

Figure 56 shows one of the components filled in for the Abstraction in the Volta basin, as well as the connection between the abstraction and catchment. As seen there is more than one component type added to the abstraction.

- After adding all the different processes within the water utility, the connections between these processes should be added.
- To make the connections click on "Add" next to Connection, under the "Process Steps" (Figure 57).

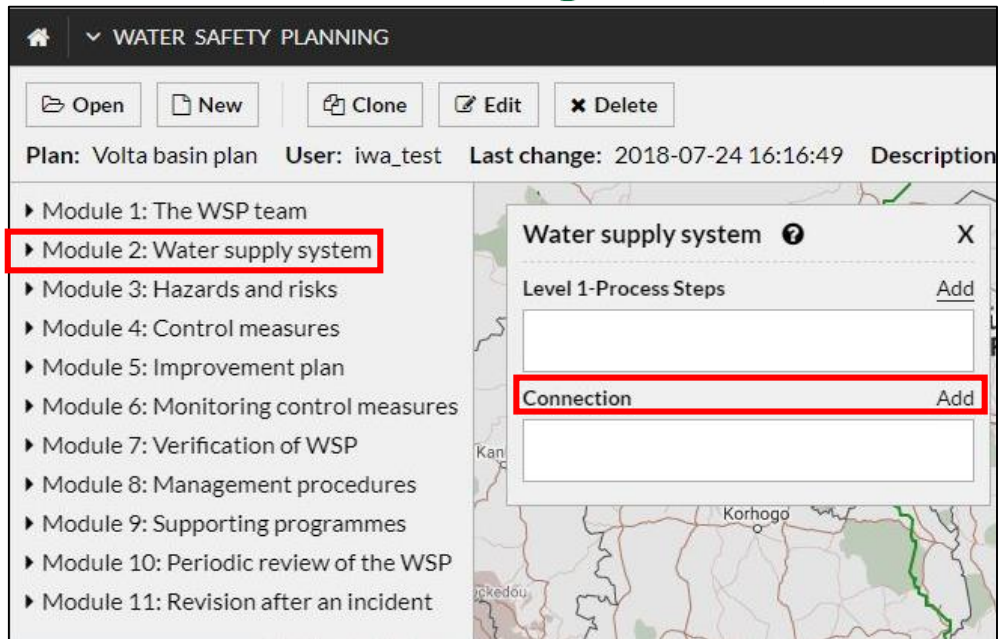


Figure 57: Water Safety Planning application Water supply system, adding different connections

- Connect the different process steps by providing the start and end points between each component (Figure 58).

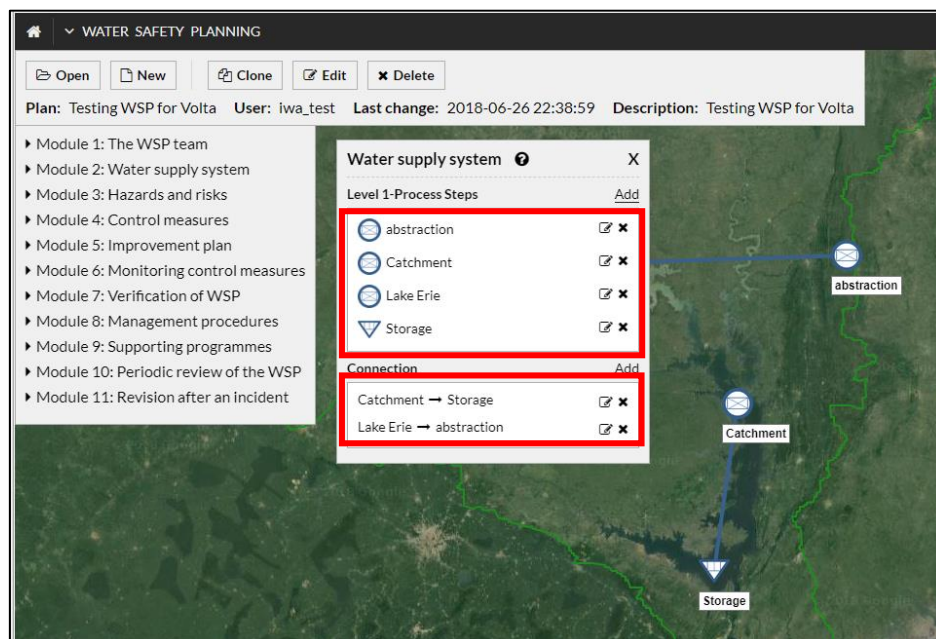


Figure 58: Different process steps and the connections between each process step

Exercise: Module 2 – Describe the Water Supply System

With your WSP team members first discuss:

- What are the key parts of your system?
- What parts of your system are likely to be affected by climate impacts (flooding, droughts)?

Based on the discussion of the parts of your system

- Enter 1 process step for each Level 1 Component (Catchment, water treatment plant, distribution).
- Click on the Level 1 Component and add a Level 2 Component (Sub-process).

9.3 Module 3 – Hazards and Risks

For each step in the water supply chain, identify hazards and hazardous events that threaten the safety of the water supply, and assess the associated risks. The WSP team is required to assess the level of risk presented by each hazard and hazardous event.

9.3.1 Hazards and Risks in the Portal

- Select Module 3 in the Portal. The “Hazards and Risks Overview” pop-up will open. At the top right corner of the pop-up click on “Add new Hazard & Risk” (Figure 59).

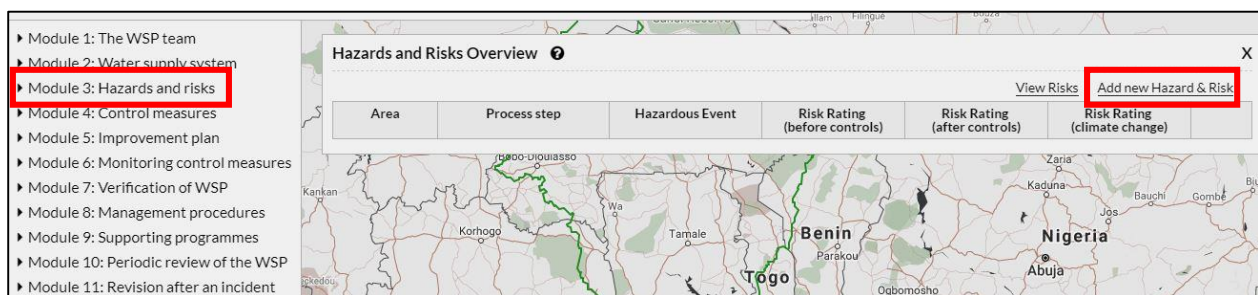


Figure 59: Water safety Planning application Hazards and Risks

- The “Add Hazards and Risks” dialog will open, type in the hazards and hazardous events your WSP team has identified for your water utility (Figure 60). (Each hazard and hazardous events should be evaluated separately.)
- “Process Step” refers to the different processes identified under section 2, such as the reservoir or treatment works. When the first hazard and hazardous event has been identified, link it to the specific process step that will be affected by the hazard and hazardous event.

- The “Area” and “Direct Control” would be filled in automatically during follow up steps, therefore, the user need not fill them in.
- In the hazardous event line, insert the hazardous event identified by the WSP team.
- The hazard type can be “**Microbial**”, “**Chemical**” or “**Physical**”.
- First the utility should provide the current risk rating of the specific hazardous event being evaluated – giving their own prediction of the likelihood and severity of such a risk as listed in the drop-down boxes.

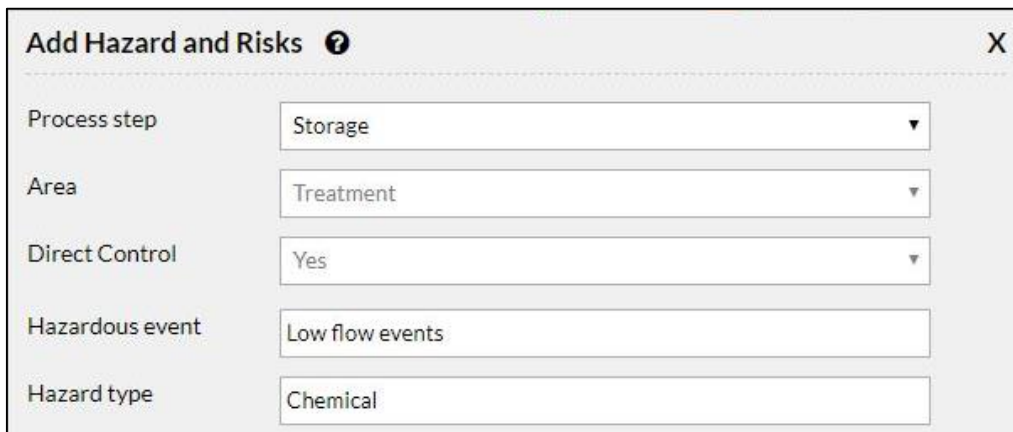


Figure 60: Adding hazards and risks in the Portal

In Section 8 the risk of wetter or drier conditions was determined, and this information was used to complete the following section. In the “Process Step”, “Hazardous Event” and “Hazard Type” sections the following information was added.

- “Process Step”: Storage
- “Hazardous Event”: Low flow events
- “Hazard type”: Chemical

The current analysis is determined by the utilities water safety plan already in place. Figure 61 shows the current likelihood and severity at the utility, showing that there is an unlikely chance of low flow events, and if this should occur the severity will be moderate impact on the utility, this gave a medium risk.

	Current	Future (Climate change)
Likelihood	Unlikely	
Severity	Moderate	
Risk rating	Medium risk	High risk

Figure 61: Current risk rating

In the short-term analysis rainfall showed that 5 months had rainfall amounts above the mean, and 7 months had rainfall amounts below the mean. Whereas, temperature showed that 3 months had temperatures above the average/mean, and 9 months had temperatures below the average/mean This corresponds to a likelihood change factor of +1.

The short-term rainfall analysis showed that rainfall was 107.2 % of normal. Based on Table 6, the area experienced mildly wet physical conditions in the short-term. Whereas, temperature showed a -0.58 °C deviation from the average for the previous 12 months. Based on Table 7, the area experienced near normal physical conditions in the short-term. This corresponds with a Severity change factor of 0.

These values are added to the current conditions to predict the “Future (Climate change)”, by increasing the likelihood of the current risk assessment by +1, the likelihood of “Unlikely” changes to “Possible”, and the Severity would increase by 0, and remain “Moderate/Medium”. See Figure 62 showing the “Future (Climate change)” risk increasing.

	Current	Future (Climate change)
Likelihood	Unlikely	Possible
Severity	Moderate	Moderate
Risk rating	Medium risk	Medium risk

Figure 62: Future climate change risk rating

The same change factors for likelihood and severity should be used for the risk assessment and applied to every hazardous event identified in your area that **may be influenced by climate change, for the associated condition (wetter or drier).**

Exercise: Module 3 – Identify Hazards

With your team members first discuss:

- What are the top 3 hazards and hazardous events to the system?
- Which of these hazards and hazardous events effect the key process steps (e.g. reservoir, treatment plant, etc.) you identified in Module 2?
- How are the hazards and hazardous events identified impacted by increased rainfall or decreased of rainfall and high / low temperatures?

Based on the discussion with your team enter information into the WSP application:

- Select one of the process steps you have entered in Module 2 (e.g. reservoir, treatment plant, etc.).
- Enter the hazard and hazardous event which could affect this process step (refer to **section 5** on how to describe hazards and hazardous events)
- Enter information on this hazard and hazardous event and assess the risk (without a control measure in place).
- Reassess the risk with climate change impacts (*hint consider climate change in the future*).

9.4 Module 4 – Control Measures

This module consists of 2 main actions:

Part 1 – Identify the existing control measures for all hazardous events identified in Module 3 and validate their effectiveness.

Part 2 – Reassess and prioritize the risks, taking into account the effectiveness of the existing control measures. This second (or ‘residual’) risk assessment considers the effectiveness of the existing control measures and allows the WSP team to determine clearly where additional control measures are required.

9.4.1 Control Measures in the Portal

- Select module 4 in the Portal, this opens up the “Hazards and Risks Overview” pop-up, click “Add new Hazard and Risk” (Figure 63).

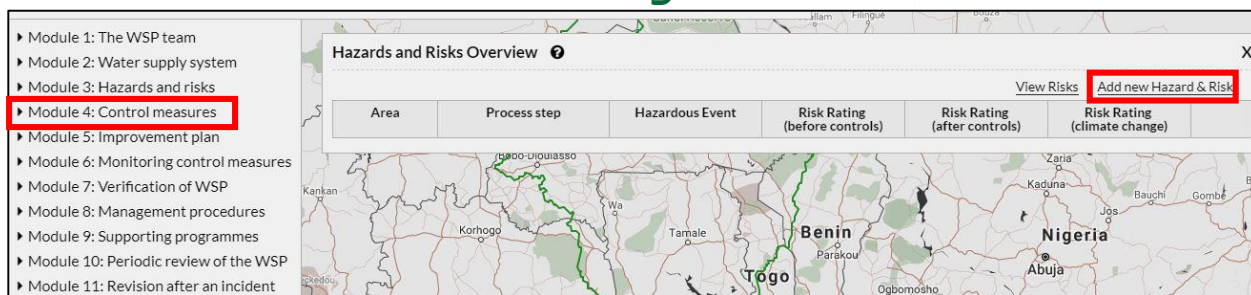


Figure 63: Water safety planning application Control measures

- In the “Control measures” tab add the existing control measure for the identified hazards (Figure 64).

Hazard and risks	Control measures	Improvement plan
Existing control measures		
Existing Control measure	Catchment\Covering and protecting springs	
Effectiveness	Yes	
Note		
Re-assessment of risk (with existing Control measure)		
	Current	Future (Climate change)
Likelihood	Possible	Most unlikely
Severity	Minor	Moderate
Risk rating	Medium risk	Low risk

Figure 64: Control measure already in place

- The control measures are filled in by the WSP team using their own knowledge of the WSP and the effectiveness of the control measure

Note: Only one control measure can be added per hazard and hazardous event. If the water utility has more than one control measure for a particular hazard and hazardous event, the water utility will have to add the hazard again using a unique name e.g. **Vandals break into the treatment grounds 01**, **Vandals break into the treatment ground 02**, etc. Then different control measures can be added for the same hazard.

- State the effectiveness of the control measures.
- Now you should re-assess the risk with the existing control measures in place.
- The likelihood and severity should be changed in accordance to WSP team’s own assessment.

9.4.2 Hazards and hazardous events and their control measures in the risk matrix

Examples of hazardous events for the Volta basin under wetter conditions, and examples of hazardous events for Lake Victoria under drier conditions, can be found in table 23. The Likelihood and severity were

increased using the change factors determined in tables 10 and 12. This also shows possible control measures that can be implemented with the corresponding hazardous events.

Table 23: Hazards and hazardous events before climate change consideration

Hazardous events due to wetter conditions		Likelihood	Severity	Risk	Possible control measures
1.	Changes in seasonal runoff and loss of snowpack	Unlikely 2	Moderate 3	Medium 6	Monitor flood events and drivers that may result in the increase in floods
2.	Altered surface water quality				Manage reservoir water quality by investing in practices such as lake aeration to minimise algal blooms due to higher temperature
3.	High flow events and flooding				Monitor surface water conditions, including river discharge, snowmelt, and streamflow
Hazardous events due to drier conditions		Likelihood	Severity	Risk	Possible control measures
1.	Low flow conditions and altered water quality	Unlikely 2	Minor 2	Low 4	Enforce or support regulations, ordinances or terms of device that prohibit water waste and address irrigation and other design inefficiency and misuses of water
2.	Lower lake and reservoir levels				Practice conjunctive use of water. Example, storing groundwater in the wet months and using the water in the dry months
3.	Increase fire risks				Practice fire management plans in the watershed, such as mechanical thinning, weed control, selective harvesting, controlled burns, and creating more fire breaks

More examples for hazardous events and control measures can be found in **Appendix A and B**.

The below table 24 considers the same hazardous events; however, the risk has changed (due to the assessment described in Section 8).

Table 24: Hazards and hazardous events after climate change consideration

Hazardous events due to wetter conditions		Likelihood	Severity	Risk	Possible control measures
1.	Changes in seasonal runoff and loss of snowpack	Moderate 3	Moderate 3	Medium 9	Monitor flood events and drivers that may result in the increase in floods Is this control measure still applicable? WSP team to review and amend as required.
2.	Altered surface water quality				Manage reservoir water quality by investing in practices such as lake aeration to minimise algal blooms due to higher temperature Is this control measure still applicable? WSP team to review and amend as required.
3.	High flow events and flooding				Monitor surface water conditions, including river discharge, snowmelt, and streamflow Is this control measure still applicable? WSP team to review and amend as required.
Hazardous events due to drier conditions		Likelihood	Severity	Risk	Possible control measures
1.	Low flow conditions and altered water quality	Moderate 3	Mild 2	Medium 6	Enforce or support regulations, ordinances or terms of device that prohibit water waste and address irrigation and other design inefficiency and misuses of water. Is this control measure still applicable? WSP team to review and amend as required.
2.	Lower lake and reservoir levels				Practice conjunctive use of water. Example, storing groundwater in the wet months and using the water in the dry months Is this control measure still applicable? WSP team to review and amend as required.
3.	Increased fire risks				Practice fire management plans in the watersheds, such as mechanical thinning, weed control, selective harvesting, controlled burns, and creating more fire breaks Is this control measure still applicable? WSP team to review and amend as required.

More examples for hazardous events and control measures can be found in **Appendix A** and **B**.

Exercise: Module 4 – Determine and Validate Control Measures

With your team members first discuss:

- What existing control measures do you have for each hazard and hazardous event?
- Will the control measures be sufficient?
- Based on the assessment, will the control measures be sufficient with increased flooding?
- What about drought and water scarcity?

Based on the discussion with your team enter information into the WSP application:

- Select one of the hazards and hazardous events you have entered.
- Click on the **Control measures** tab.
- Type or select a control measure that is being implemented to address the hazard and hazardous event and indicate the effectiveness.
- Re-assess the **likelihood** and **severity** of the hazard and hazardous event with the control measure.
- Re-assess the **likelihood** and **severity** of the hazard and hazardous event within the context of **climate change** impacts (keep in mind that the control measure is still in place).

The validation process of the WSP is important as this provides an opportunity for water utilities to assess their control measures, and determine if new control measures should be implemented. Validation is the process of obtaining evidence about how well a control measure works, and to show that the control measure can effectively control the hazard/hazardous event. This is mandatory when introducing a control measure. The validation of the control measure is relative to the control measure. This means that the control measure may be simple or quite advanced depending on the level at which the water utilities systems are operating. A simple validation may take the form of a question like: Is the control measure capable of being effective? To which one may have to choose between 3 answers: Yes, No, or Not sure/somewhat effective. Data/information obtained in 'monitoring of control measures' may be used for validation. It is important for water utilities to be properly trained on WSP to be able to effectively implement the control measures.

9.5 Module 5 – Improvement Plan

Develop, implement and maintain a detailed improvement/upgrade plan to address all significant risks that require additional control. Generally, some improvements can be implemented immediately at little or no cost, while other improvements may require significant resources and more time to implement. Improvement/upgrade plans should allow for “incremental improvement” i.e. step-by-step improvements in risk management, to allow time for planning and for the necessary funding to become available.

9.5.1 Improvement Plan in the Portal

- Select module 5 in the Portal, this opens up the “Hazards and Risks Overview” pop-up, click “Add new Hazard & Risk” (Figure 65).

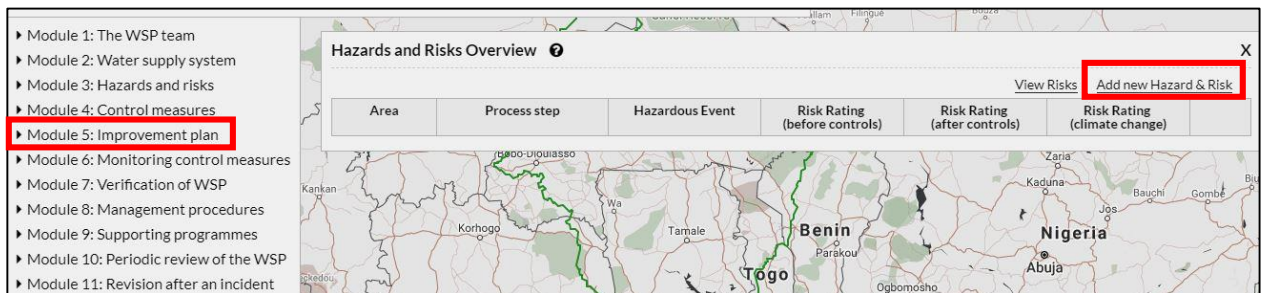


Figure 65: Water safety planning application Improvement plan

- Select the “improvement Plan” tab
- A dialog labelled “Improvements” will appear, fill in the relevant information and click on “Add” (Figure 66)

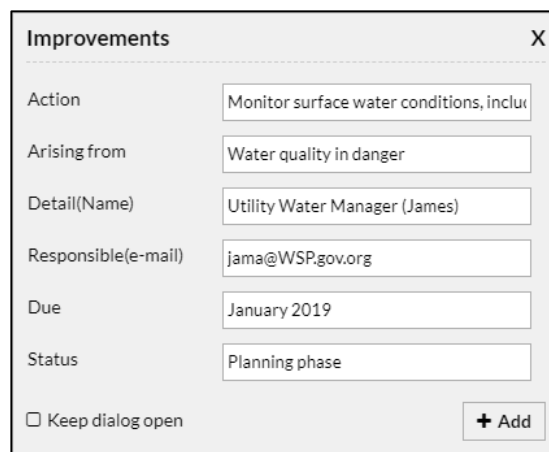


Figure 66: Improvement plan dialog

Note: After the first hazardous event analysis the water utility should repeat steps 4 and 5 until all hazardous events and provided control measures for each event have been covered.

Exercise: Module 5 – Improvement Plan

With your team members first discuss:

- What are the long-term impacts of climate hazards on a water utility?
- Which control measures are not working well and need to be improved?
- What improvements can be put in place?
- What new control measures can be put in place to deal with future climate hazards (e.g. water scarcity and flooding)?
- What can be addressed by a water utility?
- What can be addressed by other stakeholders? (list these stakeholders)

Based on the discussion with your team enter information into the WSP application:

- Click on the improvement plan tab and click on Add new improvement plan.
- Enter information in the required fields to complete the improvement plan.

9.6 Module 6 – Monitoring of control measures


Monitoring of control measures is essential for supporting risk management by demonstrating that the control measure is effective and that if a deviation is detected, actions can be taken in a timely manner to prevent water quality targets from being compromised.

9.6.1 Monitoring control measures in the portal

- Select module 6 in the Portal, this opens up the “Hazards and Risks Overview” pop-up, click “Add new Hazard and Risk” (Figure 67).



Figure 67: Monitoring control measures application

- A pop-up will open, showing the different control measure/s in place, linked to the hazardous event/s. Click on the editing tool .
- Complete the open fields (Figure 68)

Edit Control Measure
X

Hazardous Event	Introduction of chemicals to source wat
Control Measure	Catchment\Covering and protecting spr
Critical limit	Potable water standards undrinkable
What	e-coli count
Where	Reservoir
When	Daily
How	Sampling and testing
Who	Water utility testing facility
Corrective action	Fines
Data provider	
Data type	

✓ Update

Figure 68: Editing control measures

Definitions of different aspects of control measure monitoring:

- **Hazardous event:** An event or situation that introduces hazards to, or fails to remove them from, the water supply. The source of a hazard
- **Control Measure:** Any action and activity that can be used to prevent or eliminate a water safety hazard or reduce it to an acceptable level.
- **Critical limit:** A criterion which separates acceptability from unacceptability.
- **What:** What will be monitored
- **When:** The timing or frequency of monitoring
- **Where:** Where will it be monitored
- **How:** How will it be monitored
- **Who:** Who will do the monitoring (and analysis)
- **Corrective action:** Any action to be taken when the results of monitoring at the control measure indicate a loss of control.
- **Data provider:** Source of data for monitoring of control measures
- **Data type:** Format of data (text, ...)

Exercise: Module 6 – Monitoring of Control Measures

With your team members first discuss:

- How can you monitor the control measures in place? What indicator is used?

Based on the discussion with your team enter information into the WSP application:

- Open Module 6
- For a control measure you have entered, enter the required information that will allow you to monitor the control measure.

9.7 Module 7 – Verification of the WSP

Having a formal process for verification and auditing of the WSP ensures that it is working properly.

Verification involves four activities which are undertaken together to provide evidence that the WSP is working effectively. These activities and the definitions are provided below:

1. **Compliance monitoring:** Monitoring of water quality (usually at the delivery points) to demonstrate (or verify) compliance with the agreed water quality standards or set limits – usually as set out by the regulatory authority. This monitoring is usually specifically collected and obtained to check compliance with regulations. Compliance monitoring can be used as evidence for some aspects of verification.
2. **Internal Auditing:** An internal examination and verification of WSP records, to demonstrate that the WSP has been properly designed, is being implemented correctly, and is effective. The Water Safety Plan Quality Assurance Tool was developed to enable a water supplier to objectively assess WSP implementation and identify areas of progress and areas for improvement. The tool is available at: [WSP Quality Assurance Tool](#)
3. **External auditing:** An external examination and verification of WSP records, to demonstrate that the WSP has been properly designed, is being implemented correctly, and is effective. WHO and IWA developed the ‘A practical guide to auditing water safety plans’ that provides guidance on developing and implementing a WSP auditing scheme, covering such topics as the aim and role of auditing, auditor training and certification, audit criteria, audit timing and frequency and audit reporting. Further information including the guide can be obtained here: [Auditing WSP's](#)
4. **Consumer satisfaction monitoring:** Customer satisfaction surveys examine the quality of the service and the acceptance of the product by customers/clients. The surveys may help to discourage use of unsafe alternative sources.

9.7.1 Verification of the WSP in the Portal

- Select module 7 in the Portal, this opens up the “Verify the effectiveness” pop-up (Figure 69)

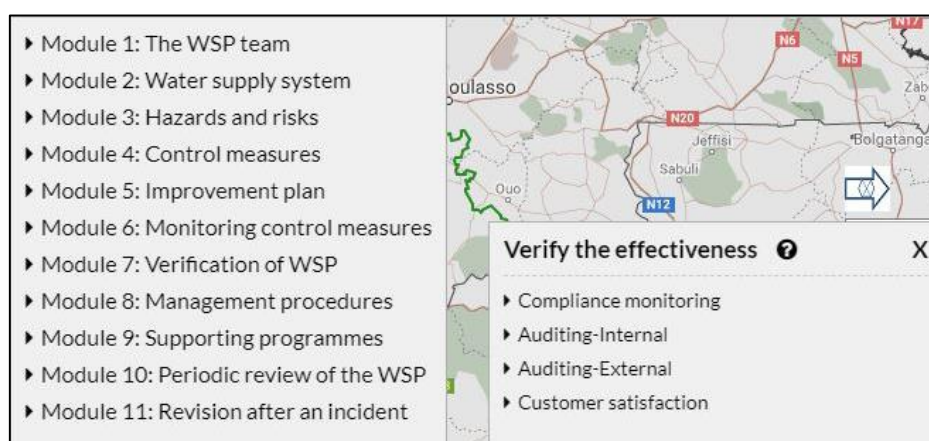


Figure 69: Four activities for verifying the effectiveness of the WSP

- There are 4 different options available in the pop-up. When selecting “Compliance monitoring” and “Customer satisfaction” options another pop-up will open, this allows you to upload you own documents under each option (Figure 70).

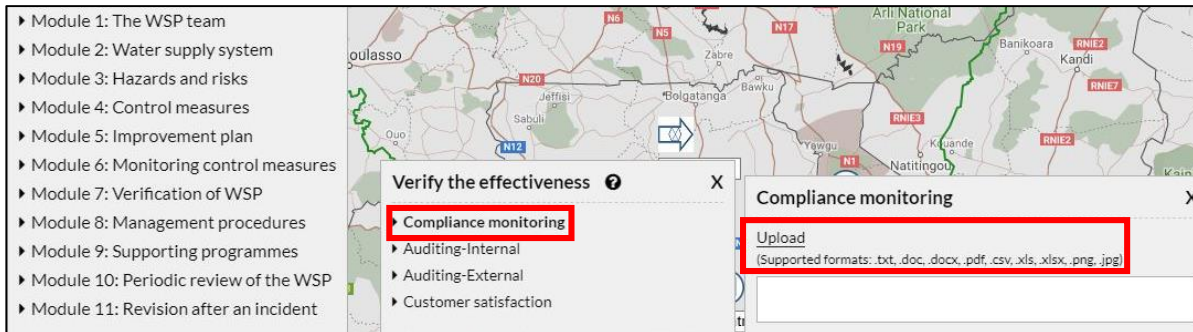


Figure 70: Upload documents for compliance monitoring.

- When selecting the two auditing options, “Auditing-Internal” and “Auditing-External”, the audits should be uploaded. The auditing options also allow the user to download a template, which can be edited as needed (Figure 71).

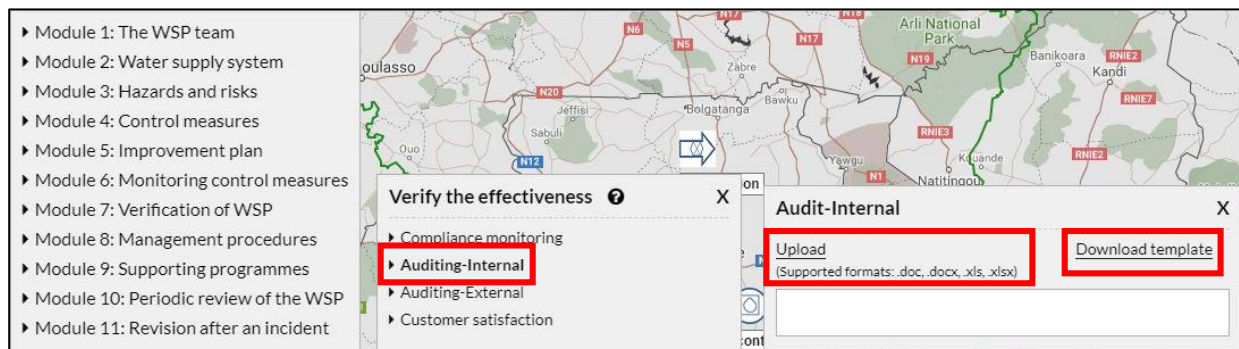


Figure 71: Auditing allows the user to upload their internal or external audits. A template is also available for download.

Exercise: Module 7 – Verification of the WSP Effectiveness

With your team members first discuss:

- Do you have internal and/or external auditing?

Based on the discussion with your team enter information into the WSP application:

- Open Module 7 in the WSP application
- Click on one of the options and discuss what documentation you have that you would upload
- Upload an example document
- In the WSP Resources folder, Module 7 Folder open the file for the Water Safety Plan Quality Assurance Tool (WQA) and explore the user manual and excel file, or by following the link below:

[WSP Quality Assurance Tool](#)



WQA

WSP_Quality Assurance Tool_User Manual

9.8 Module 8 – Management Procedures

Document clear management procedures indicating actions to be taken when the system is operating under normal conditions (Standard Operating Procedures or SOPs) or when the system is operating in 'incident' situations (corrective actions). Documentation should be written by experienced staff to ensure that it captures all required activities and should be updated as necessary, particularly in light of implementation of the improvement/upgrade plan and reviews of incidents, emergencies and near misses. Having detailed documents is especially important to capture institutional knowledge of the system, and will assist new operators in understanding the system. The link below provides more information on management procedures: [Management procedures](#)

Effective management should define:

- Corrective actions i.e. actions to be taken in response to variations that occur during normal operating conditions (Standard Operating Procedures);
- Actions to be taken in 'incident' situations where a loss of control of the system may occur; and
- Procedures to be followed in unforeseen and emergency situations.

The procedures should have:

- Clear description of the actions required in the event of a deviation
- Clear accountabilities and contact details for key personnel
- Location of backup equipment
- Relevant logistical and technical information

9.8.1 Management Procedures in the Portal

The management procedures should be documented as per the requirements of your utility and uploaded on the WSP application. To upload the management procedures documents:

- Select module 8 in the Portal, this opens up the “Management procedures” pop-up (Figure 72)
- Click “upload” in the pop-up, and select the water utilities management procedures document to be uploaded to the Portal

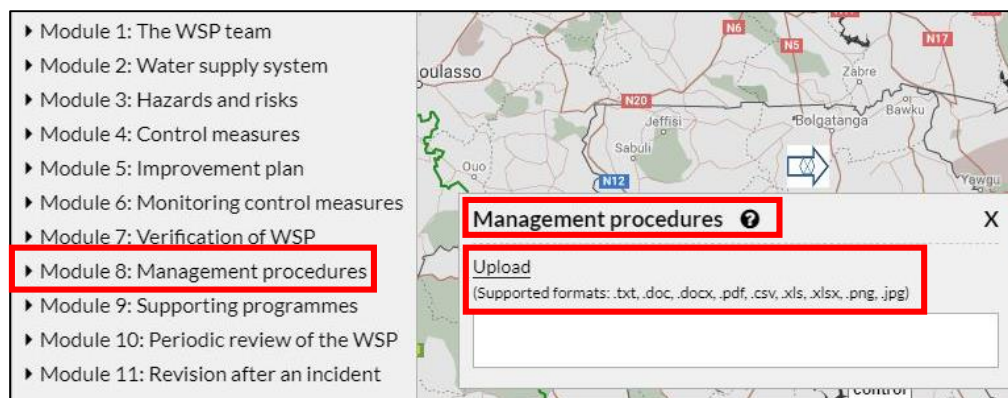


Figure 72: Management procedures in the Portal

Exercise: Module 8 – Management Procedures

With your team members first discuss:

- What management procedures do you have for normal and incident/emergency situations (e.g. Incident management protocol)?
- What management procedures do you have that consider weather emergencies (flooding and droughts)? (See Appendix A)

Based on the discussion with your team enter information into the WSP application:

- Open Module 8 in the WSP application.
- Upload an example document from WSP Resources folder, Module 8 Folder.

9.9 Module 9 – Supporting Programmes

Supporting programmes are activities that support the development of people's skills and knowledge, commitment to the WSP approach, and capacity to manage systems to deliver safe water. They are as important as control measures in controlling water quality risks but are used where application tends to cover long time frames and/or broader organizational or geographic areas. Supporting activities can be operator trainings and development, consumer education and research and development.

There are three steps to develop supporting programmes:

- Review what is needed;
- Revise any existing programmes; and
- Develop new ones as needed

The link provides more information on supporting programmes: [Develop supporting programmes](#)

9.9.1 Supporting Programmes in the Portal

- Select module 9 in the Portal, this opens up the “Supporting programmes” pop-up (Figure 73)
- Click “upload” in the pop-up, and select the water utilities supporting programmes document to be uploaded to the Portal

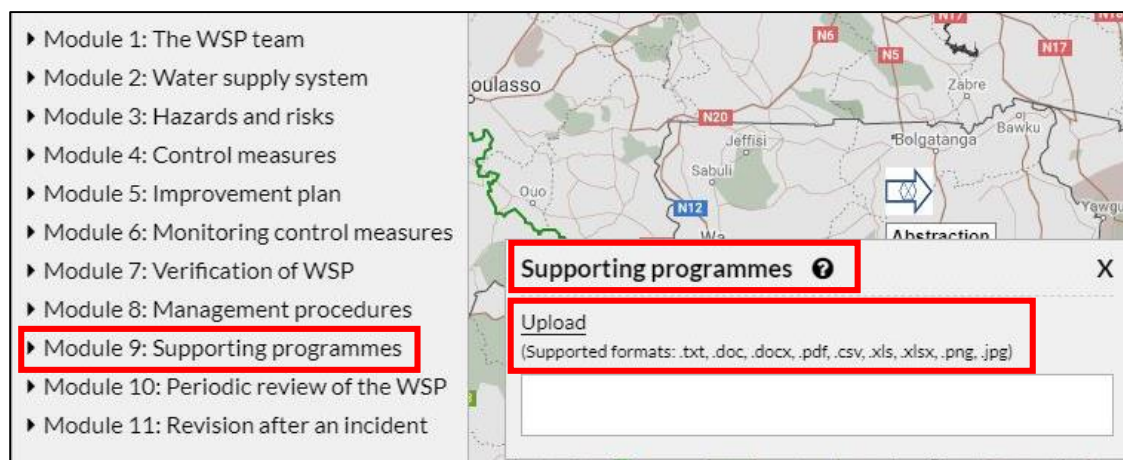


Figure 73: Supporting programmes in the Portal

Exercise: Module 9 – Supporting Programmes

With your team members first discuss:

- What supporting programmes does the water utility have to develop people's skills in implementing WSP?
- What supporting programmes include climate risk?
- Identify the climate aspects that may require more research

Based on the discussion with your team enter information into the WSP application:

- Open Module 9 in the WSP application.
- Upload an example document from WSP Resources folder, Module 9 Folder.

9.10 Module 10 – Periodic Review of the WSP in the Portal

Ensure that the WSP is up-to-date and effective through regular review and, if necessary, revision. This will ensure that new risks threatening the production and supply of safe drinking-water are regularly assessed and addressed and that the WSP is continuously improved.

A WSP can quickly be out of date through:

- catchment, treatment and distribution changes and improvement programmes which can impact on process diagrams and risk assessments;
- revised procedures;
- staff changes;
- stakeholder contact changes

The WSP team should therefore agree to meet regularly to review all aspects of the WSP to ensure that they are still accurate. The WSP review may include site visits or the input of local operators and water service providers. Operational monitoring results and trends should be assessed. **Furthermore, the review of the WSP should include the re-analysis of the flood and drought datasets for both short and long-term, to identify any changes that may occur as conditions change.**

9.10.1 Periodic Review of the WSP in the Portal

- Select module 10 in the Portal, this opens up the “Periodic review of the WSP” dialog (Figure 74)

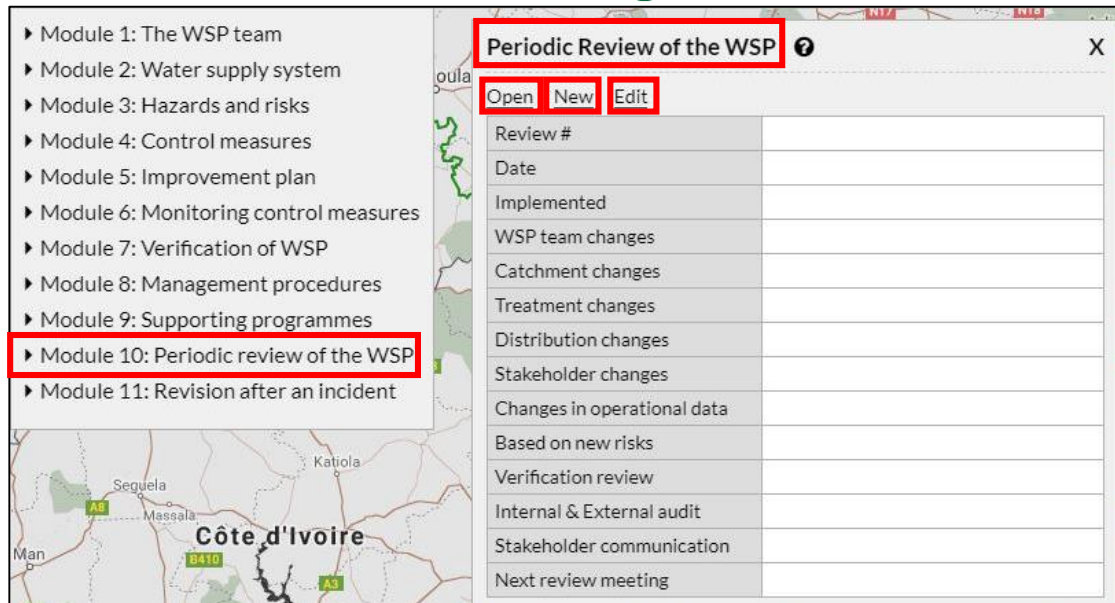


Figure 74: Periodic review of the WSP in the Portal

- Clicking on “Open” allows you to view information on previous reviews that were recorded in the Portal
- Clicking on “New”, this allows you to start adding information in the dialog
- Clicking on “Edit” allows you to edit the information

Exercise: Module 10 – Periodic Review

With your team members first discuss:

- How often do you review the WSP or plan to review the WSP?
- What is the process of reviewing your WSP?
- What changes might there need to be in your existing WSP?

Based on the discussion with your team enter information into the WSP application:

- Open Module 10 in the WSP application
- Enter information in the checklist as follows:

Review: Specify the review number

Date: Current date

Implemented: Date review was implemented

WSP team changes: Indicate if there were any changes in the WSP team

Catchment changes: Indicate if there were any changes in the catchment

Treatment changes: Indicate if there were any changes in the treatment system

Distribution changes: Indicate if there were any changes in the distribution

Stakeholder changes: Indicate if there were any stakeholder changes

Changes in operational data: Indicate if there were any changes in the operational data

Based on new risks: *Please explain here*

Verification review: *Please explain here*

Internal & External audit: Indicate if there were any internal and/or external audits

Stakeholder communication: Indicate if there was any communication with stakeholders

Next review meeting: Indicate when the next review meeting will take place

Note: After every review the WSP team will need to make changes to **all the affected modules in the WSP**. It is Advised that you “Clone” the WSP and make the changes on the latest version. This allows the WSP team to keep previous versions in the system for future reference.

Exercise: Module 11 – Review the WSP After an Incident

With your team members first discuss:

- Have you reviewed the WSP after an incident? What kind of incident occurred?
- What climate hazards might result in an incident at your water utility?
- What would be the impact on the water supply system (e.g. flood damages to infrastructure)?
- What other climate related incidents could occur within the water utility

Based on the discussion with your team enter information into the WSP application:

- Open Module 11 in the WSP application.
- Assume that one of the incidents has occurred at the utility, review the incident and input the results of the discussion into the WSP application under Module 11.

10. Concluding Remarks

The Flood and Drought Portal provides a useful set of applications that assists utilities with assessing how components of their system may be affected by climate change. The data and information application is particularly useful as it provides a variety of climate change related datasets in one location. This prevents the need of having to access and register with different websites/Portal. The data is updated in near real-time, thus allowing water utilities to monitor the current status and how these conditions change over time.

It is strongly suggested that the proposed methodology of incorporating climate change impacts into WSPs presented within this guidance document should be tested at a number of sites, and further refined (as required) based on local conditions and circumstance.

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Appendix A: List of Possible Hazards and Hazardous Events

Hazardous event	Hazard	Physical Conditions
Decrease in mean annual precipitation, reduction in runoff and higher loss of water from vegetation and evaporation due to higher temperatures.	Physical	Drier
Increase temperature and shifting of precipitation patterns will alter seasonal runoff and storage of water in snowpack's. These disruptions in water supply could strain the capacity of reservoirs to hold large and earlier peak runoff flows, cause shortages in the summer due to the longer hot and dry season and compromise biodiversity goals	Physical	Wetter
Less annual total precipitation concentration in fewer, more extreme rainfall events. Lower precipitation will lead to lower streamflow in many locations, which may lead to diminished water quality. Turbidity from sediment washing downstream following storm events also impacts water quality, particularly in areas where fires have diminished the ability of landscapes to hold soil. Diminished water quality in receiving water may lead to more stringent requirements for wastewater discharges and impacts to ecosystems that area sensitive to temperature	Microbial	Drier
Projected sea-level-rise, combined with higher water demand from coastal communities, can lead to saltwater intrusion in both coastal groundwater aquifers and estuaries. This may reduce water quality and increase treatment costs for water treatment facilities drawing from coastal aquifers or surface water intakes in tidal estuaries near the saltwater line. Desalination plants may have to treat water with higher salt content, which would also increase costs.	Physical and Chemical	Wetter and Drier
Higher temperatures can lead to algal blooms, which compromise source water quality and may require more advanced treatment.	Microbial	Drier
Intense precipitation events may occur more frequently, concentrating the annual total rainfall into episodes that challenge current infrastructure for water management and flood control. When the protection fail, inundation may disrupt service and damage infrastructure such as treatment plants, intake facilities and water conveyance and distribution systems. Episodic peak flows into reservoirs will strain the capacity of these systems. Furthermore, inflow will be of lesser quality due to soil erosion and contaminants form overland flows, leading to treatment challenges and degraded conditions in reservoirs.	Physical	Wetter
In locations where sea-level rise is combined with projected increases in storm frequency or intensity, coastal storm surge may increase in frequency and extent. This combination results in inundation of coastal areas and damage to infrastructure such as treatment plants, intake	Physical	Wetter

facilities, water conveyance and distribution systems, and may result in disruption of service. Drinking water treatment plants are typically not as vulnerable as wastewater plants to coastal flooding, as they are often located at higher elevations. However, desalination plants would be vulnerable to sea-level rise and storm surges. Moreover, cities built on coastal estuaries may not have much high ground and could be strongly affected by changes in sea level or storm surge magnitude		
Sea-level rise and increasing frequency of damaging tropical storms can lead to losses of coastal and stream ecosystems. Loss of coastal wetlands can reduce the buffer against coastal storms, leading to damage to coastal treatment plants and infrastructure, such as intake facilities and water conveyance and distribution systems, and may cause disruption of services.	Physical	Wetter
Changes in climate coupled with potential droughts or changes in evaporation and soil-water retention, may lead to increased risks of wildfire. Fires present a direct risk to property and infrastructure, in addition to potential degradation of water supply. Runoff and flash floods from burned areas can increase sedimentation in reservoirs, reducing their capacity and effective service lifespan. In reservoirs, increased pollutant loads, such as heavy metals and nutrients, could result in higher turbidity, algal blooms and subsequent higher treatment costs.	Physical, Chemical, Microbial	Drier
Drought may increase in frequency and severity in some areas due to projected declining precipitation and increased loss of water from vegetation and evaporation. High temperatures will reduce snowpack, thereby decreasing water storage. This results in decreased streamflow, reservoir safe yield and groundwater recharge. These impacts will reduce the available supplies for water systems dependent on surface water as well as groundwater, and potentially lead to service disruption.	Physical	Drier
Water usage in energy generation depends on many factors and is significant in scale. Where the energy required by the water sector to provide services is also significant.	Physical, Chemical, Microbial	Wetter and Drier
Population growth as well as climate change impacts, such as increasing temperatures and the increased risk of prolonged periods of droughts, can contribute to unsustainable demands on water services and thus increase the risk of water shortages	Physical	Drier

Appendix B: List of Possible Control Measures

- a) Use the Portal to monitor the weather conditions for rainfall and temperature.
- b) Finance systems to recycle water this can include greywater for homes and businesses
- c) Reduce agricultural and irrigation water demand by working with irrigators to install advanced equipment (e.g. drip or other micro-irrigation systems with weather-linked controls)
- d) Practice demand management through communication to public on water conservation actions and implementation features such as: water metering, leak detection, water loss monitoring. Award those who has installed water conserving appliances/toilets/rainwater harvesting
- e) Monitor surface water conditions, including river discharge, snowmelt, and streamflow
- f) Practice fire management plans in the watershed, such as mechanical thinning, weed control, selective harvesting, controlled burns, and creating more fire breaks.
- g) Manage reservoir water quality by investing in practices such as lake aeration to minimise algal blooms due to higher temperature
- h) Monitor vegetation changes in watersheds
- i) Monitor and inspect the integrity of existing infrastructure
- j) Monitor flood events and drivers that may impact flood and water quality models (e.g. storm intensity and sea level)
- k) Practice conjunctive use of water. Example, storing groundwater in the wet months and using the water in the dry months.
- l) Improve energy efficiency of operations (e.g. installing more energy efficient pumps)
- m) Optimise operations by restricting some energy-intensive activities during the summer to times of reduced electricity demand (i.e. night time) and work with energy utility on off-peak pricing
- n) Practice water conservation and demand management to reduce energy demand and associated costs
- o) Minimise the water used in space cooling equipment in accordance with manufacturer recommendations. Shut off cooling units when not needed.
- p) Ensure that fire hydrants are tamper proof to eliminate unauthorised consumption of water
- q) Promote water efficient landscape practices for homeowners and businesses, especially those with large irrigated properties. Practices can include the use of native plants, landscape renovation to reduce water use, use of greywater for irrigation.
- r) Enforce or support regulations, ordinances or terms of device that prohibit water waste and address irrigation and other design inefficiency and misuses of water.

- s) If permitted by local ordinances, encourage industrial and commercial customers to harvest rainwater and use condensate from large cooling systems to be used on-site for irrigation and other non-portable uses.