Strategic Recommendations for Climate Smart Water Utilities

Using the Flood and Drought Portal in Planning

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1 Introduction

"The top three risks for cities are extreme events such as floods and droughts, declining water quality, and challenges to water availability due to increasing water stress and scarcity"

IWA Action Agenda for Basin-Connected Cities

The effect of climate change on the hydrological cycle is becoming a growing phenomenon and resulting in impacts including flood and drought events, disappearance of glaciers, decrease in groundwater recharge, and water quality degradation (e.g. oxygen depletion in water reservoirs during extreme heat events) (WHO, 2017).

Such events are becoming increasingly common, more severe and less predictable with increasing climate variability and change. Stakeholders from catchment to tap have a role to play in strengthening climate resilience. Water utilities, in particular, need to have sustainable and resilient water resources management to ensure water supply continuity and to fulfil their responsibility to deliver safe and secure water to their customers.

1·1 Water Safety Planning and climate resilience

Many water utilities may not see the urgency of incorporating climate variability and change impacts in their planning processes. There can be varying reasons for this. 'A range of plausible futures' can make it difficult to know how a water utility will be affected obscuring how to best prepare for climate change (Xylem, 2017). Furthermore, the control that a water utility has on the water resources it uses is often limited to treatment and distribution, while most impacts of climate change are commonly felt upstream or downstream, which may be seen as the responsibility of another agency operating at the catchment level.

Managing all aspects of the water supply system from water source to treatment to distribution, even components where the utility has not control, can be through the use of a comprehensive risk assessment and risk management approach that encompasses all steps and stakeholders of the water supply system from catchment to consumer. The described approach is **Water Safety Planning (WSP)** and is cited by the WHO Guidelines for drinking-water quality as an effective means of consistently ensuring the safety and acceptability of a drinking-water supply.

The Flood & Drought Management Tools (FDMT) project (http://fdmt.iwlearn.org) is using WSPs as an entry point to prompt utilities to consider climate information and the risks of floods and droughts in their planning procedures.

About the Flood and Drought Management Tools project

The Flood and Drought Management Tools (FDMT) project was funded by the Global Environment Facility (GEF) International Waters (IW) and implemented by UN Environment (UNEP), with DHI and the International Water Association (IWA) as the executing agencies. The project developed the Flood and Drought Portal (www.flooddroughtmonitor.com) with technical applications to support planning from the transboundary basin to water utility level by including better information on floods and droughts into planning. The project was implemented from 2014 to 2018, with 3 pilot basins (Volta, Lake Victoria and Chao Phraya) participating in development and testing of the methodology and technical applications.

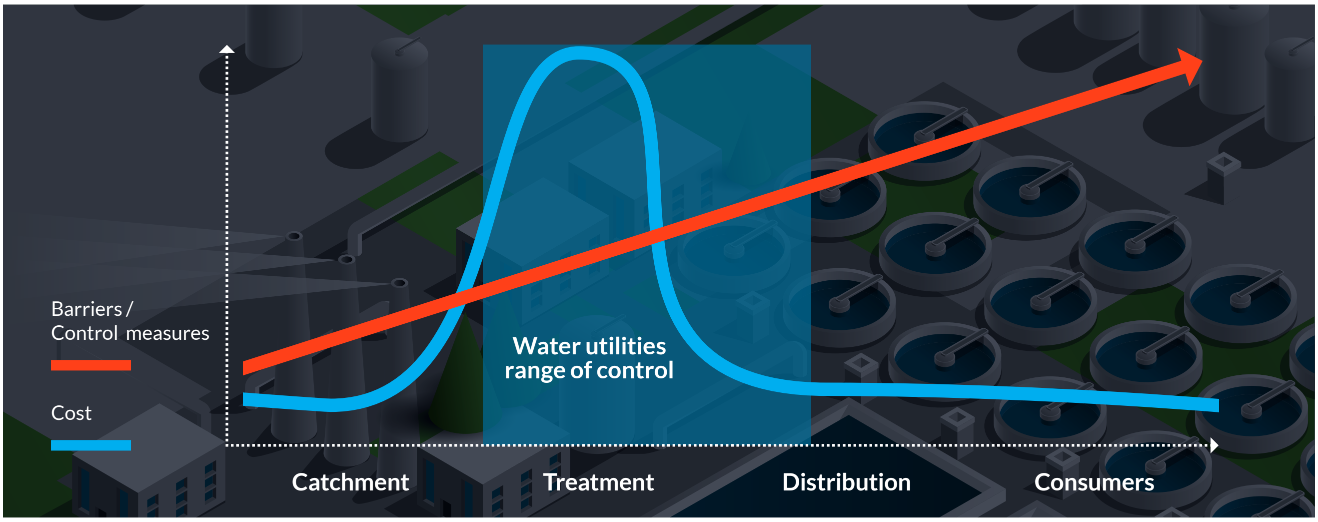
For more information on the Flood and Drought Management Tools project, visit: http://fdmt.iwlearn.org

1·2 Purpose of strategic recommendations

As previously described, planning needs to take into account climate variability and change, consequently, strategic recommendations have been developed to provide information to 1) basin organisations and related institutions and 2) water utilities on why this is important and how climate information can be integrated into planning processes.

These two groups of stakeholders were involved in the co-development, co-generation and co-evaluation of the Flood and Drought Portal, and helped test the technical applications in the Portal at different scales and with different priorities. This document focuses on strategic recommendations for water utilities on:

1. Why and how water utilities can integrate climate change impacts into planning and management of water resources, specifically through WSPs; and
2. How to use the Flood and Drought Portal (http://www.flooddroughtmonitor.com), to better include climate data and information into WSP, ensuring its climate resilience.




Flood

2 Climate change impacts on water utilities

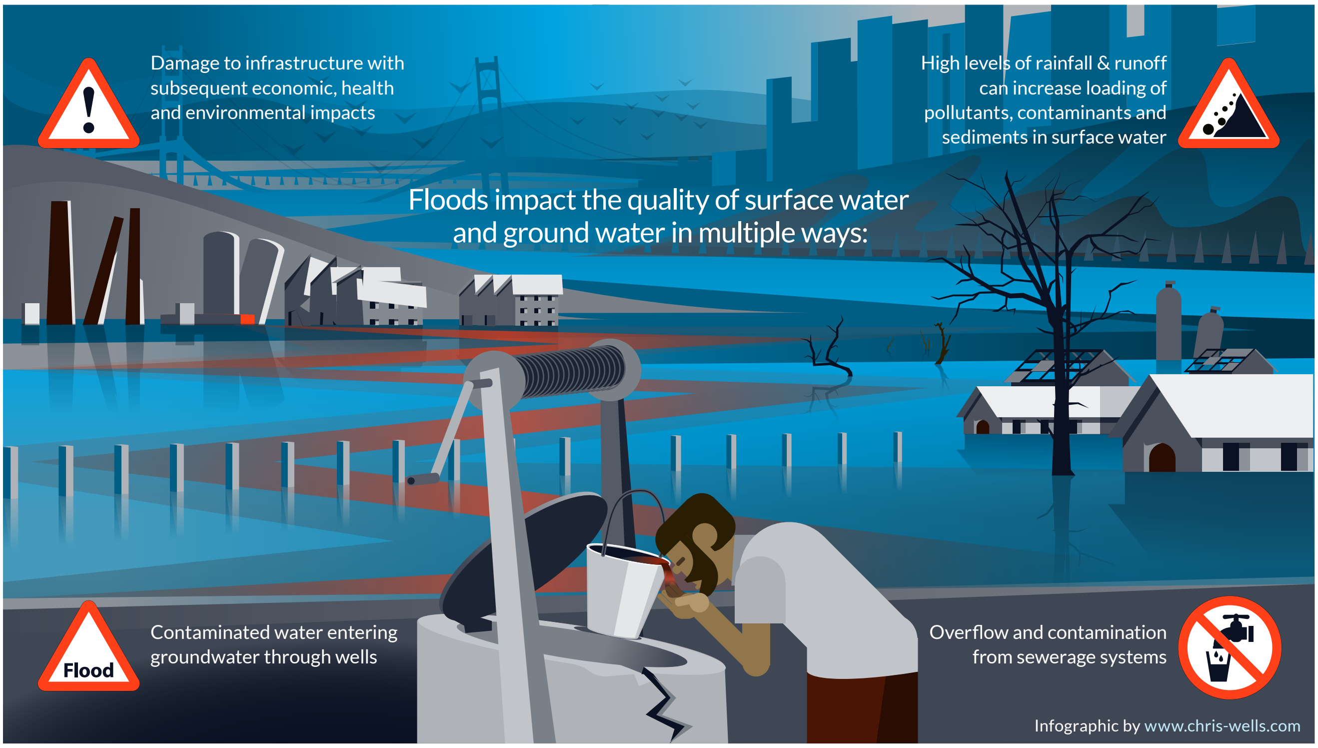
Climatic and environmental issues such as floods, droughts, increased temperature and rising sea level risks have a clear effect on a water utility's capacity to sustain water service provision and the economic viability and cost-effectiveness of treatment and distribution (WHO, 2017). These risks include declining water quality and quantity at the source, minor to major damage of assets (e.g. infrastructure), and high operation and maintenance costs.

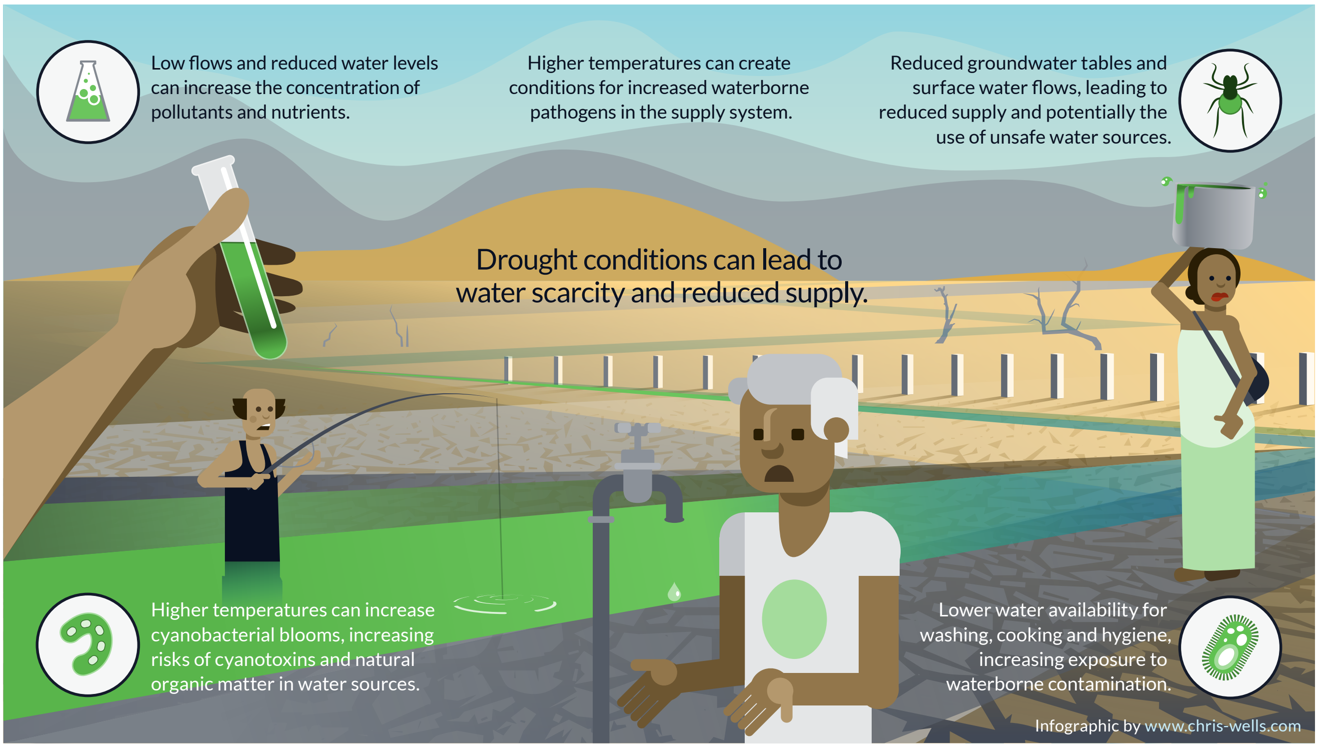
For example, increased temperature, increases in sediment, nutrient and pollutant loadings due to heavy rainfall, reduced dilution of pollutants during droughts, and disruption of treatment facilities during floods will all impact raw water quality (Jimenez et al., 2014). However, climate change is only part of the picture; water quality and supply is also affected by other factors including the type of water body, the pollutant of concern, the hydrological regime, and many other possible sources of pollution (Jimenez et al., 2014). Water supply systems need to be resilient in both current levels of climatic variability and to future changes.

An example of how climate change can lead to overall change in water resources management can be seen in the case of Western Australia (WA), where climate has changed over the last century, particularly during the last 50 years. The increase in temperature by 1°C and changes in rainfall patterns impaired the ability of the local water utility to deliver water supply for many people. In Australia, the prolonged drought experienced in 1995 prompted water sector professionals to question whether the experience was in fact due to a drought period, an overall change in climate (i.e. new reality) or poor management of water resources (DPIRD, 2018). This is a turning point for water resources management as it pushed for the integration of climate change information in long-term planning (Stratus Consulting and Denver Water, 2015).

2·1 Intense precipitation and flooding

High levels of precipitation can lead to flooding, which is one of the most costly natural hazards. For example, the cost of damage caused by flooding in Alberta, Canada in 2013 was approximately $ 6 billion (Alberta Water, 2013). The National Oceanic and Atmospheric Administration (NOAA) estimated flooding in the USA has an average cost of $4.3 billion per event (NOAA, 2018). Climate impacts on the hydrological cycle are changing the timing and intensity of rainfall, directly affecting the quantity and quality of water resources for different users. Such disruptions have significant impact on a water utility's performance. Increased precipitation and





flooding may result in increased upstream erosion and run-off, overwhelmed storm/wastewater containment systems, and consequently overwhelmed water treatment facilities or damage to assets and infrastructure (WHO, 2017).

2·2 Droughts and water scarcity

Droughts are one of the most costly natural hazards on a year-to-year basis and are significant and widespread, affecting many economic sectors and people at any one time. According to NOAA drought is the most costly disaster in the USA with an average cost of $9.7 billion per event, and the most fatal when accompanied by heat waves (NOAA, 2018).

The onset of droughts is slower than floods and the hazard footprint for droughts is larger. Droughts can disrupt water supply, and reduce water availability leading to environmental, health, social and economic impacts. Droughts are often associated with longer term poorer water quality as low flows and reduced water levels tend to increase the concentration of pollutants and nutrients (WHO, 2017). Additionally, drought has an indirect effect on drinking water supply as it often leads to increased dependence on potentially less safe alternative water sources that might otherwise be avoided (WHO, 2017). (NOAA, 2018).

Droughts can be more easily monitored because of their slow onset allowing time to assess the variability in precipitation, temperature and the status of surface water and groundwater supplies in a region. However, assessment of possible droughts needs to be meticulous, to ensure appropriate decision making.

In South Africa, the South Western Cape region experienced three of its lowest rainfall years on record from 2015 to 2017 (Wolski, 2018). The low rainfall led to a progressive depletion of water supply reservoirs and by 2018 the need for restrictive measures in an attempt to address what looked to be a very severe drought. The experience in Cape Town demonstrated a need for investment in new planning and management approaches fed with appropriate hydrological data and water demand projections and improved communication and dissemination to relevant stakeholders.

2·3 Increased temperatures

Higher temperatures combined with increased nutrient loads can result in algal blooms (WHO, 2017). An increase in algae in water is a problem because they can produce toxins which contaminate water resources (e.g. cyanobacteria produces a group of harmful algal toxins known as microcystins), as well as the water treatment facilities supplying drinking water. Warmer, less oxygenated water may also result in higher levels of metals including phosphorus and phytoplankton. Water treatment plants face a difficult task of not only removing the toxins and contaminants, but doing so in a safe and cost-effective way.

2·4 Rising sea levels

Sea-level rise can lead to saltwater intrusion into groundwater drinking supplies, especially in low-lying, gently sloping coastal areas (Union of Concerned Scientists, 2011). The impact of sea level rise is exacerbated by groundwater pumping rates. The amount of salt water that goes into fresh water aquifers increases the treatment costs of water utilities to remove salt (WHO, 2017).

3 How can water utilities respond to climate impacts?

Water utilities need to consider the impacts of climate change described in the previous chapter when designing or updating their operational capacity to ensure cost-effectiveness and cost recovery. For example, water utilities have to predict and prepare for service interruptions that could occur under normal conditions. Interruptions are likely to be amplified by climate change impacts

Therefore, water utilities need to take actions to address such climate impacts on their systems particularly through their, planning processes (e.g. WSP), operation and maintenance (O&M), and investment in infrastructure and technologies (both green and grey), and policy and regulatory context.

3·1 Operation and Maintenance

Water utilities are expected to supply large amounts of drinking water on a daily basis. Service delivery requires both long-term capital investments (CAPEX) and continuing O&M costs (OPEX). These costs increase when hazardous events occur and are likely to further grow with the unpredictability and frequency of climate change impacts on water resources and infrastructure.

The resilience of O&M of water supply services to climate change impacts should be part of the overall climate resilience of WSP. A tailor made and resilient operation and maintenance approach might include diversification of water resources to maintain continuous water supply during and after climate change related events (e.g. groundwater, recycled water) or accessing more climate information to inform better management of water resources.

Although there needs to be investment in both CAPEX and OPEX, short-term O&M priorities can distract from medium – and long-term risks associated with the impacts of climate change and variability. This issue is compounded by limited access to financial resources, different levels of technical capacities and varying access to climate information and inter-organisational information sharing cultures. This need to think longer term must be addressed as many water utilities, especially those in rural areas, have not been designed to handle the more extreme impacts of climate change such as flooding, droughts, high temperatures. Climate impact stressors on the system can demand additional or even different infrastructure such as added treatment steps (Jimenez et al., 2014).

3·2 Planning

The management of a water utility needs to ensure that climate resilience is a long-term established approach in its planning approach. Preparing a WSP that provides multiple options to ensure the sustainability of services during an event can demonstrate the resilience of the water utility. However, there is no 'one size fits all' approach when developing a WSP, and a climate resilient WSP for that matter. Each water utility has its own unique context and resources, and how climate change impacts affect them is characteristic to their geographical area. Climate change impacts on services delivery can be too costly for water utilities to handle unless there is a long-term plan that is climate aware. Therefore, it is important that water utilities adopt a climate resilient WSP that is practical and relevant to their context and existing water resources (EPA, 2015).

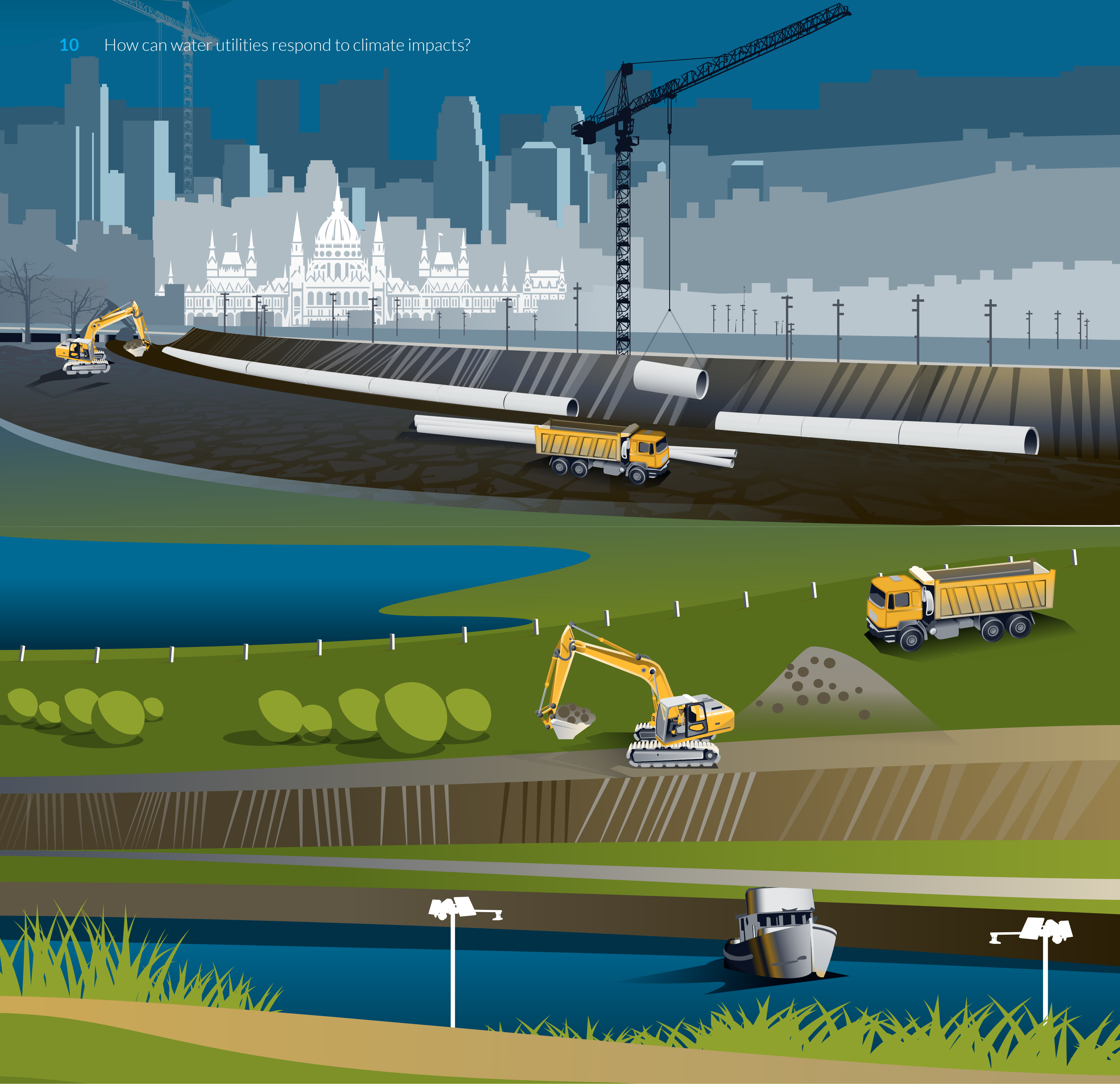
The Water Utility Climate Alliance (WUCA) highlights two key steps guiding water utilities to integrate climate change adaptation within their planning:

- **Understanding** climate change causes, the direct and indirect impacts, and understanding climate science offers a mitigation measure that helps water utilities to understand the relation between the change in climate and the change in water cycle.
- **Assessing** climate change impacts that are relevant to the local and/or regional context of each utility, whether these impacts existed or are projected, to better appreciate vulnerabilities to current and future climate change and variability.

Planning methods and tools need to allow water utilities to plan for more than one possible future to ensure resilience. In addition, integrating climate information within a holistic catchment to consumer management and planning approach will enable water utilities to meet customers' expectations for water quality and quantity during or after a climate related event (e.g. day zero in Cape town).

3·3 Technology choice and supply chain

Water utilities need to test the economic feasibility and technical viability of their technologies to collect, treat and distribute drinking water supply. Climate change related impacts can significantly influence the type of technology a water utility should adopt, which can range from digital approaches for optimising demand management to integrating Nature-Based Solutions along with the conventional grey infrastructure to cope with climate change impacts.



The implementation of technological tools and equipment, and approaches and management strategies need to be relevant for climate change adaptation. New innovations in technologies and approaches to ensure resilience will continue to emerge offering new opportunities for water utilities. However, sufficient assessment of the applicability of technologies and approaches is always encouraged.

3·4 Water policy and regulation

Regulation and policy need to adapt to the "new normal" reality of climate change impacts and provide water utilities with the flexibility to engage beyond the treatment and distribution aspects of water supply. Climate change impacts on the hydrological cycle might lead water utilities to seek solutions beyond their mandated boundaries and to introduce new investment strategies that did not exist before. For example, water utilities can invest and take part in broader basin management to influence how water resources within their basin are managed. WSP will help water utilities to meet the quality standards for drinking water, which is a legal requirement with important health benefits for water users.

The Action Agenda for Basin-Connected Cities provides a framework within which urban stakeholder, including water utilities, can work together to ensure water security and sustainable management of water resources (IWA, 2018a). Water policy and regulations are untapped opportunities towards an inclusive and resilient water sector (IWA, 2018b).

4 How to develop climate resilient Water Safety Plans?

WSP offers an entry point for water utilities to consider climate change impacts (WHO, 2017). However, water utilities might find it challenging to develop climate resilient water safety plans either due to a lack of knowledge, expertise, or financial resources). As part of the Flood and Drought Portal, a WSP supporting application was developed to help water utilities develop and document their WSP while also integrating climate change considerations in the process.

Watch the How-to video on the Issue Analysis application functionality.

This expands across all modules in the WSP process providing a thorough and accurate description of the water utility's supply system; from catchment to consumer, to risk and hazard identification for each component of the water supply system to describing control measures or improvement plans to address current and future risk to the water supply system. Risks and hazards are context specific and each water utility needs to understand the added impact of climate change or how existing hazards might be amplified by climate related impacts.

The resilience of a water utility and its WSP to climate impacts looks at the:

- Capacity to anticipate, respond to, cope with, recover from and adapt to stress and change; and
- Ability of the system to keep on functioning in a way that it maintains its essential function, identity and structure.

A climate resilient WSP helps to inform water utilities of what their climate risks are, and how to address these risk and other key concerns such as tariff setting, infrastructure development, service costs and supply. Supported by the right information and tools, climate change information can be better integrated into planning and management procedures, such as WSP.

Table 1 presents how climate questions can be integrated into the WSP process.

Table 1 Questions to integrate climate change issues into WSP modules

Climate change related question	Description	WSP module
Who will you include as a climate expert in the WSP team?	To consider and address the effects of climate change, WSP teams may require additional support in obtaining and interpreting climate-related information (e.g. climatologist, hydrologist).	Module 1: The WSP team
What part of your system is likely to be affected by climate impacts (e.g. flooding, droughts)?	To contribute to system understanding and to facilitate subsequent identification of system vulnerabilities, it is important to know what part of the water supply system will be impacted by climatic hazards. Anticipating future changes to the water supply system will enable your utility to address variations in water quality and quantity and improve management of water resources and infrastructure.	Module 2: Describe the system
What are climate change related hazards to the system?	Climate variability and change can potentially add new risks associated with hazardous events or amplify existing events that could contaminate or compromise the water supply.	Module 3: Hazards and risks
How are the hazards identified impacted by increased rainfall or lack of rainfall and high temperatures?	Climate change itself will not change the basic nature of threats to water services but it will change their likelihood and severity. Variations to water quality and quantity, due to a change in likelihood and severity of rainfall, will have significant implications on a water utility's operations.	Module 3: Hazards and risks

Table 1 Questions to integrate climate change issues into WSP modules

Climate change related question	Description	WSP module
Will the control measure be sufficient to address the associated risks?	The effectiveness of existing control measures may change with changing climatic conditions, impacting the risk assessment. Where existing controls are insufficient to adequately manage current or future risk, additional control measures will need to be identified to address these risks and ensure water service provision.	Module 4: Control measures
What new control measures can be put in place to deal with future climate risks? What improvements can be put in place?	Control measures may be specific to drinking-water systems or to facilitate improvements in water resources management which reduce risks related to natural disasters. Some control measures will be the responsibility of other basin stakeholders, which means water utilities need to work closely with these stakeholders and consider climate risks to ensure their water service provision. Existing or new measures to address the risks should be monitored to assess their efficacy or need for alternative measures.	Module 5: Improvement plan Module 6: Monitoring of control measures
What management procedures do you have that consider weather emergencies (e.g. flooding and droughts)?	A WSP can contribute to disaster risk reduction through better preparedness and contingency planning to ensure water safety and security during an emergency event as well as for faster recovery after an incident.	Module 8: Management procedures
What supporting programmes do you have to develop people's skills in implementing climate resilient WSP?	Supporting programmes include aspects of climate risk management, for example through • Capacity development (trainings and workshops) • Stakeholder engagement & outreach • Research and implementation programmes	Module 9: Develop supporting programmes
Does the WSP reflect the current conditions? What climate risk might result in an incident? What would be the impact on the water supply system (e.g. damage to infrastructure)?	A WSP can quickly be out of date through changes in the catchment, treatment and distribution, and improvement programmes which can impact the supply system and risk assessments. Such changes require a periodic review to ensure the relevance of the WSP. Furthermore, following an incident, emergency or near miss, for example a flood event or drought, a review of the WSP is necessary to update the supply system, risk assessments, control measures and supporting programmes. Maintaining an up-to-date WSP is important	Module 10: Periodic review Module 11: Review an incident

5 Flood and Drought Portal and Climate Resilient WSP

How can the Flood and Drought Portal support climate resilient WSP, and overall planning for hazardous events that may impact a water utility's water supply system?

The WSP application along with other technical applications in the Flood and Drought Portal can help a water utility prepare and respond to climate extremes such as floods and droughts. Other applications in the Portal can provide useful information for a water utility to consider climate change impacts on operations and management of water resources.

Information and knowledge drawn from the applications in the portal can complement the WSP process by helping to:

1. Identify hazards in the water supply system form catchment to tap;
2. Assess the risk level of hazards impacting water security and public health (including climatic hazards such as floods and droughts); and
3. Provide information to select indicators for monitoring hazards and their control measures.

A water utility is required to follow all modules of the WSP, however, addressing the three areas above, constitutes the core components of the WSP and the ability for a water utility to guarantee safe and secure water service provision and in the context of climate variability and change. The following sections will demonstrate how the technical applications contribute to the areas described above.

5·1 Identifying hazards

In section 2 of the strategic recommendations, impacts on water utilities were identified, focusing on those associated with climate change. As part of the WSP (Bartram et al., 2007 and WHO, 2017), a water utility is required to identify all potential hazards (biological, physical and chemical) and hazardous events associated with each step in the drinking water supply system that can result in the supply being, or becoming, contaminated, compromised or interrupted.

5·1·1 Issue Analysis application

The Issue Analysis application helps a water utility identity the causes behind environmental issues and prioritise the environmental impacts based on a rapid assessment using Causal Chain Analysis (CCA) method and the Water Resource Issues Assessment Method (WRIAM), respectively.

Causal Chain Analysis (CCA), or Root Cause Analysis, is closely related to systems thinking and the DPSIR (drivers, pressures, state, impact and response model of intervention) approach. At its most basic, a causal chain is an ordered sequence of events linking the causes of a problem with its effects. Each link in the causal chain is created by repeatedly answering the question why? There are three "causes" categories:

- **Immediate causes** are the direct technical causes of the problem. They are predominantly tangible (e.g. reduced water availability), and with distinct areas of impact (with the exception of causes such as atmospheric deposition or climate change). Immediate causes are the most straightforward to quantify, prioritise and geographically locate using maps. Immediate causes are often the easier to address with the results more immediately felt however not often long lasting.
- **Underlying causes** are those that contribute to the immediate causes. They can broadly be defined as underlying resource uses and practices, and their related social and economic causes. Governance related causes are often identified here. Resource uses, and practices will tend to fall into areas such as land uses (reclamation/drainage operations, deforestation, agriculture, etc.), damaging or unsustainable practices (intensive livestock production, lack of treatment technology, etc.), uses of water (diversion, storage, etc.), lack of investment, operation and maintenance, poor awareness or education, governance failures, legislation, regulation or enforcement.
- **Root causes** are linked to the underlying social and economic causes and sectoral pressures but they are often related to fundamental aspects of macro-economy, demography, consumption patterns, environmental values, and access to information and democratic processes. Many of these may be beyond the scope of project and programme interventions, but it is important to document them for two reasons:
  1. Some proposed solutions might not be effective if the root causes of the identified issue are overwhelming.
  2. Actions taken nearer to the root causes are more likely to have a lasting impact on the issue.

Examples are provided in Figure 1. This information can be potentially used to identify hazards that may affect the water system, as well as where control measure might be effectively implemented.

Watch the How-to video on the Issue Analysis application functionality.

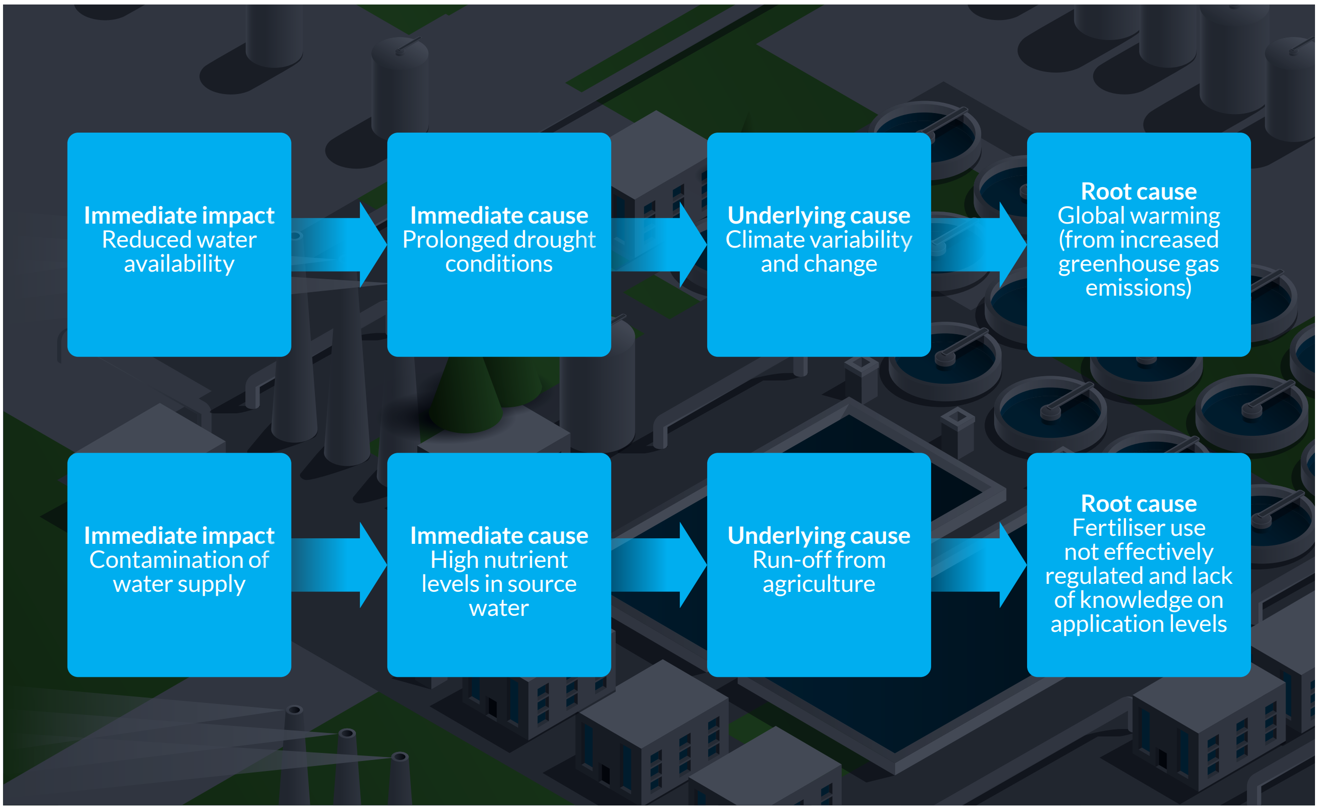


Figure 1: Casual change analysis examples

5·1·2 Data and Information application

The Data and Information application gives a water utility access to global data sets including historical, near real-time satellite data (approximately 48 hours), short-term and seasonal forecast data for up to nine months, and projected climate information on rainfall, temperature and evapotranspiration. The data and information is spatially distributed for any transboundary basin in the world drawn from several sources including NASA: https://lpdaac.usgs.gov/dataset_discovery, Copernicus (ESA): http://land.copernicus.eu, NOAA: https://www.ncdc.noaa.gov/data-access.

The information can be used to identify current and future hazards such as intense rainfall, high temperature or lack of rainfall, which can impact safe and secure water service provision.

Although access to this data is useful, many water utilities may lack the capacity to interpret the data and integrate the information into planning and/or operations.

Watch the How-to video on the Data and information application functionality.

5·2 Assessing the risk level across the water supply system

Having identified the hazards and hazardous events across the water supply system, the associated risk presented by each hazard and hazardous event should be evaluated. The risk is a combination of likelihood of the hazard or hazardous event occurring (over some time frame) and the severity of the consequences of the hazard or hazardous event if and when it occurs. The risk should not simply be an assessment of what has occurred in the past but what might occur in the future.

Evaluating the associated risk of hazards and hazardous events to the supply system is an important component of the WSP due to the potential impact on public health. (Bartram et al., 2007 and WHO, 2017)

While the basic nature of the threats to the water supply system will not change under climate variability and change, the likelihood and the severity of the consequences arising from the hazard or hazardous event are likely to change (as well as their spatial extent). (WHO, 2017)

5·2·1 Data and Information application

Aside from the application offering climate data, a better assessment of selected data sets from the Data and Information application can provide the required information to adjust the risk matrix in WSP and reassess the likelihood and severity of all hazards and hazardous events considering the impacts of climate change, and subsequently prioritise actions to address the more significant risks.

Water utilities can use the methodology described in section 6, to guide them in the process of integrating climate information into their WSP and how this can be used to reassess the risk of hazard and hazardous events within the context of climate change. Incorporating the new risk ratings in WSP and subsequently, if identified actions are implemented to address the risks, a water utility will be more resilient to climate change impacts, including those associated with floods and droughts.

5·2·2 Drought Assessment application

Drought monitoring is an important component of risk management. The Drought Assessment application enables users to identify current or upcoming drought hazards and provides an assessment of the associated risk related to the hazards. The main objective of a drought early warning system is to detect when and if a drought hazard might occur and the location and severity of the hazard. Drought warnings could be expressed based on the hazard itself or on the associated risk towards specific vulnerable sectors or areas.

The application converts relevant data into drought indices which provide a hazard categorisation (e.g. from normal to exceptional drought conditions), an indication of impacted areas which may affect parts or all of the water supply system, and provides a warning and associated risk assessment. This information is useful for water utilities as it helps improve planning and response to drought events and helps protect the infrastructure needed to secure water service provision.

Watch the How-to video on the Drought Assessment application functionality.

5 • 2 • 3 Flood Assessment application

The Flood Assessment application is developed to gather all data and tools related to flood risk assessment. The application helps users locate and identify flood hazards, estimate impacts and provide risk assessments by providing all relevant data and indices from the Data and Information application (fixed and near real-time satellite data). Furthermore, a hydrological model is included allowing the user to run, calibrate and execute forecasted and projected simulations of flows based on historic, forecasted and climate change data included in the portal.

For a water utility, accessing this type of information is useful for prevention and mitigation of risks associated with floods. Understanding the potential impact to the water supply system can help a water utility plan and better respond or prepare for future risks and protect current infrastructure while developing new and more resilient infrastructure.

Watch the How-to video on the Flood Assessment application functionality.

5•3 Provide information to select indicators for monitoring hazards and their control measures

Monitoring of hazards to the water supply system and their control measures implies the use of routine measurements to detect changes. Monitoring key water parameters can help better understand the impact of hazards and hazardous events on the quality and quantity of water, and inform the selection of appropriate control measures to address conditions when water safety and security is significantly at risk. (Bartram et al., 2007 and WHO, 2017)

In order to address water quality and quantity issues, correct monitoring and reporting based on indicators and indices is important. Indicators refer here to single parameters to measure water quality (e.g. salinity, pH, temperature, turbidity, etc.) or quantity (e.g. water level, water use/consumption, ground water recharge, etc.), whereas indices relate to combinations of indicators. There are a large set of indicators and indices available to water utilities, however there is a lack of systemic overviews of the indicators and indices, and of their application in practice.

5 • 3 • 1 Water Indicator application

The Water Indicator application provides a library of indicators with information on the data needed and how to apply an indicator; information needed to measure an issue (rainfall) causing a hazard (reduced water availability). The applications is therefore helpful for water utilities to identify relevant indicators to assess the current state of water resources, the changes in these resources and the required intervention to produce the desired effect on water quality and quantity. Additional governance, physical and socio-economic indices are available to water utilities.

The application supports water utilities in selecting relevant indicators based on a specific issue or hazard. As a starting point, default indicator frameworks are available which can be adjusted to reflect the users' needs and priorities. As an online application, a water utility is able to share its indicator frameworks internally, ensuring consistency with measurements and monitoring practices (i.e. it helps if you are all measuring the same thing).

Indicators are also useful for measuring the effectiveness of control measures that are put in place to mitigate hazards, e.g. source water protection zone to reduce contamination by activities in the intake area. Accessing the right information can help monitor potential improvements in the condition, or the need to identify an improvement plan to address an ongoing issue or hazard.

Watch the How-to video on the Water Indicator application functionality.

6 Integrating climate information into risk assessment for improved planning

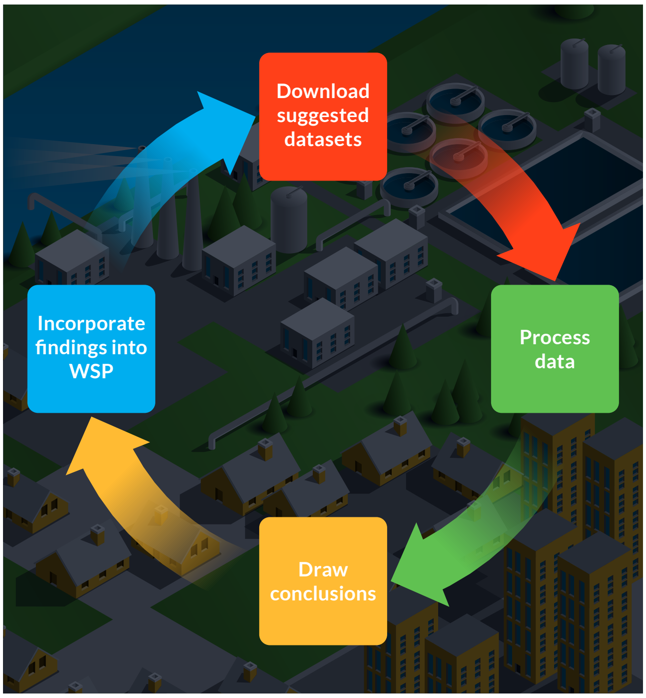


Figure 2: How to determine and incorporate risks into WSP

This section focuses on how water utilities, by using the Data and Information application in the Flood and Drought Portal, can determine the risk of wetter or drier conditions and incorporate the risk assessment in their WSP. The Portal provides water utilities with a wide range of information that can be used to identify hazards, forecast climatic conditions, prepare and plan more inclusively through climate resilient WSP. However, it is often challenging for water utilities to understand the relevance of climate information for their planning. Furthermore, water utilities might find it difficult to interpret some of the information and incorporate the findings into WSP processes and operations (Damons, 2018).

A methodology, "Guideline for Interpreting Climate Information for Application in Water Safety Planning", is proposed to assist water utilities in analysing climate related data and incorporate those findings into their WSP 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 (Emanti, 2018).

The process of risks identification and incorporation in WSP should be understood as a continuous cycle, where water utilities are continuously assessing, evaluating and updating their WSP (see Figure 2).

6·1 Which dataset?

The Flood and Drought Portal provides water utilities with near real-time climate data sets (rainfall, temperature, evapotranspiration, etc.) to indices, and governance, physical and socio-economic data through the Data and Information application. The methodology described recommends key datasets – read "Linking Flood and Drought Data to Water Safety Planning: Part 2" for more information on selecting datasets for analysis – for analysis informing the risk assessment approach of the WSP process; the methodology focuses on rainfall and temperature data.

The information, classified as short-term datasets and long-term data sets, can help respond to the different needs of water utilities. For example, water utilities can use short-term data to determine whether there is a current wetting or drying trend (e.g. through the likelihood of rainfall). Long-term datasets addresses long-term climate projections (e.g. rainfall projections, temperature projects, etc.). Table 2 shows the selected data sets under each category.

Table 2 Example of selected datasets for short – and long-term climate analysis

	Short-term: Climate analysis datasets
1	Rainfall (TRMM)
2	Temperature (MOD11A1)

	Long term: Climate analysis datasets
1	Rainfall (CRU) – Rainfall (mm/month) (CRU)
2	Precip. RCP 4.5 2016—2035
3	Temperature – CRU Temperature C
4	TEMP RCP 4.5 2016—2035

6·2 Interpreting climate information for risk assessment

When accessing the climate information and indices in the Data and Information application, water utilities are able to view the datasets in different formats, including charts, tables and GIS maps. The information can be viewed in the application itself or downloaded and processed using tools at the disposal of a water utility. While much can be interpreted from the different datasets, for water utilities carrying out a risk assessment for their water supply system, it is recommended that both short – and long-term dataset be used to interpret the effects of floods and droughts.

The observable effects are that floods bring wetter conditions and droughts, drier conditions. Water utilities are recommended to use the described methodology to determine if conditions are wetter or drier using the selected datasets. The methodology calculates the percent of normal (or historical mean) for rainfall, and for temperature the deviations from the mean.

For rainfall, if the 'percent of normal' is more than 100%, then the physical conditions are wetter than normal. If 'percent of normal' indicated conditions less than 100% then the physical conditions are drier than normal. There are four physical conditions that describe 'wet' conditions, and four physical conditions that describe 'dry' conditions (Table 3). The physical conditions are used to describe the rainfall severity, from extremely we to extremely dry.

Table 3 Percent of normal ranges and their corresponding physical conditions

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

For temperature, if the deviations indicate values that are more than 0°C, then the physical conditions indicate an increase in temperature. If temperature deviations indicate values less than 0, then the physical conditions indicate a decrease in temperature. There are four physical conditions describing increased temperature conditions and four physical conditions describing decreased temperature conditions (Table 4). The physical conditions are used to describe the temperature severity, from major increase to major decrease in temperature.

Table 4 Temperature deviations and their corresponding physical conditions

Temperature deviation (°C)	Physical conditions
3 to 5	Extremely wet
2 to 3	Very wet
1 to 2	Moderately wet
0 to 1	Mildly wet
0	Normal
0 to -1	Mildly dry
-1 to -2	Moderately dry
-2 to -3	Very dry
-3 to -5	Extremely dry

A more detailed description is available in the methodology: Guideline for Interpreting Climate Information for Application in Water Safety Planning.

6·3 Incorporating climate information into risk assessment

Water utilities can start with classifying climate change impacts (hazards) according to the physical condition calculated from rainfall and temperature. For example, this can be:

- Hazards affected by wetter conditions (e.g. floods), e.g. changes in seasonal runoff and loss of snowpack.
- Hazards affected by drier conditions (e.g. droughts), e.g. lower lake and reservoir levels.
- Hazards affected by both wetter and drier conditions, e.g. saltwater intrusion into aquifers.
- Hazards unaffected by either wetter or drier conditions, e.g. operation restrictions determined by local legislation.

After identifying the hazard category, the findings need to be incorporated in a water utility's WSP through its defined risk matrix (see Figure 3). Each hazard has to have a risk rating, which can be retrieved from the water utility's current WSP or identified by the WSP team (if there is no current WSP).

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**

Figure 3: Example risk matrix for a water utility

In order to determine how hazards and hazardous events would be affected by climate change, two matrices can be used; a 'likelihood change factor matrix' (Figure 4) and a 'severity change factor matrix' (Figure 5). A 'likelihood change factor matrix' is determined by counting the number of months where rainfall and temperature was higher than normal, and the number of months rainfall and temperature was lower than normal. A 'severity change factor matrix' is the average percent of normal for the previous 12 months and the average temperature deviation for the previous 12 months. These change factor matrices indicate by how much the risk rating and risk score for hazards and hazardous events may change under a wetter or drier period. The following example provides the steps a water utility takes in this process.

Example: The WSP team has completed the analysis and has determined that their water utility is experiencing an overall 'drier' trend. Therefore, they should only consider amending hazards and hazardous events that are affected by drier conditions (which is discussed by the WSP team).

- Rainfall
  - Likelihood (Likelihood matrix):
    - 5 out of 12 months had rainfall that exceeded the average/mean.
    - 7 out of 12 months had rainfall that were below the average/mean.
  - Severity (Severity matrix): mildly dry
- Temperature
  - Likelihood (Likelihood matrix):
    - 3 out of 12 months had temperatures that exceeded the average/mean.
    - 9 out of 12 months had temperatures that were below the average/mean.
  - Severity (Severity matrix): near normal

Rainfall							
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

Figure 4: Likelihood matrix – to learn more details visit this blog

Rainfall										
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								

Figure 5: Severity matrix – to learn more details visit this blog

Using this above information (Likelihood matrix and Severity matrix), the WSP team can determine the change factors for likelihood (+1) and severity (+0) using the Likelihood and Severity matrices. The change factors determined using the above matrices should be added to the current risk scores (see Figure 6). The new risk score can be put into the WSP risk matrix. This will indicate how the risk score and rating have changed (see Figure 7). These change factors should be applied to each hazard and hazardous event affected by the associated physical condition.

Likelihood		Severity	
Current	Change factor	Current	Change factor
2	+1	3	0
Amended likelihood: 2 + 1 = 3 (Moderate)		Amended severity: 3 + 0 = 3 (Moderate)	

Figure 6: Adding change factors to current likelihood and severity – to learn more details visit this blog

Figure 7: 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**

The change in the 'new' risk score indicates that the effects of the hazard and hazardous event may have worsened under this physical condition, and the water utility may have to consider measures to limit the impact to the water supply system. A water utility might also consider the types of investments needed across the water supply system to secure water service provisions in the face of current and growing variability in rainfall and temperature patterns now and in the future.

7 Recommendations to water utilities

Climate variability and change are influencing the availability and quality of water resources. With 20% of the world's population living in river basins that are likely to be affected by increased climate hazard by the 2080s (IPCC 2007), it is critical that the resilience and capacity to mitigate the impacts are strengthened to sustain economies, society and the environment. Water resources are fundamental to the provision of drinking water, for industrial and agricultural use and ensuring the evolution of ecosystems.

For water utilities, sustainable and resilient water resource management is simply a necessity to ensure water supply continuity and to fulfil their responsibility to deliver safe and secure water to their customers. This document recommends:

Water Safety Planning as an effective means of consistently ensuring a safe and secure drinking water supply through the use of a comprehensive risk assessment and risk management approach that encompasses all steps of the water supply system from catchment to consumer. Water Safety Planning is a formally recognised approach to consistently ensuring the safety and acceptability of drinking water supply by the WHO Guidelines for drinking-water quality. Water Safety Planning is not a one-size-fits-all approach, allowing utilities to tailor the approach to their context.

Climate variability and change be integrated into long-term planning for adequate and safe supply of drinking water. Integrating this information into a Water Safety Plan can help to manage associated health risks. This considers the broader issues of climate change, regional climate vulnerability assessments, disaster risk reduction and integrated water resources management within the Water Safety Planning process.

The Flood and Drought Portal which has a useful set of applications that assists water utilities with assessing how components of their system that may be affected by climate change. The Data and Information application provides a variety of climate change related datasets enabling water utilities to identify and monitor climate hazards, and how these conditions change over time. The Flood and Drought Portal as a tool can help incorporate information on climate variability and change into Water Safety Plans.

The use of a methodology to integrate climate information in the risk assessment approach of Water Safety Planning. This allows utilities to assess how climate impacts can affect the likelihood and severity of all hazards to the system. Such information can help with assessing the risk level with climate as well as identifying appropriate control measures and what needs to be monitored to ensure the effectiveness of control measures prioritising what risks to address.

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