Water Resilience Assessment Framework

Guidance for Water Utilities

Water Resilience Assessment Framework: Guidance for Water Utilities
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Guidance Authors

Paul Fleming
WaterValue LLC
https://thewatervalue.com/

John H. Matthews
Alliance for Global Water Adaptation
https://www.alliance4water.org/

Ashok Chapagain
Gregg Brill
Deborah Carlin
CEO Water Mandate; Pacific Institute
www.ceowatermandate.org
www.pacinst.org

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Project partners
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Project Overview
The project was launched in 2019, with seed funding from BHP, initially to develop a common water accounting framework. The scope evolved to speak more directly to climate change and focus on water resilience, given the urgent and critical need to build long-term resilience in basins around the world.

The Water Resilience Assessment Framework was launched in 2021. For more information and to download the framework, guidance documents and associated tools for implementation, please visit https://ceowatermandate.org/resilience-assessment-framework/

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Glossary

(Resilience) actions: Interventions made by stakeholders to bolster specific aspects of system's resilience.

Basin: A basin or river basin follows the same principles as a catchment of capturing water across a geographical zone, however at a wider scale. A basin can also be considered along management or political lines.

Catchment: The geographical zone in which water is stored, flows through and is eventually discharged at one or more points.

(Resilience) characteristics: Specific aspects of resilience to be considered to ensure resilient actions align and support the selected resilience strategy.

Indicators: Qualitative and/or quantitative metrics to track the impacts of the actions on the resilience of the system and/or stakeholder(s).

Resilience: The ability of an individual, institution or system to respond to shocks and stresses, and survive and thrive despite the impacts of those shocks and stresses.

Resilience strategy: A systematic approach to enhance resilience by understanding and addressing shocks and stresses. Resilience strategies fall into three categories: persistence, adaptation and transformation.

Stakeholder: A stakeholder can be a person, group, sector, company, agency, community or organization that influences or is influenced by the use and governance of a common set of resources. Ecosystems can also be stakeholders, though they may need to be represented by a proxy, such as via expert opinion or a legal representative.

Stress test: The process of assessing the impact of actions intended to build resilience under a range of plausible future scenarios. The stress test clarifies how well the actions respond to shocks and stresses, and supports the goals of the selected resilience strategy.

System: A catchment area around a facility or community is a system with interconnected components, categorized as socio-economic, institutional (governance and management), and biophysical (including infrastructure and ecosystem functions) that influence that catchment. It's defined by both hydrological and administrative/political boundaries.

- **System boundary:** The spatial and temporal limits of the water system, as defined through stakeholder goals and interests.

System scale: Water systems are not uniform and differ in size and scope. The spatial, temporal and institutional elements that are included in the system inform the scale of the system. A system scale can range from the individual or institution—such as a company, organization, community or utility—to a catchment and then beyond, to key elements of that system that may exist outside of a catchment—such as the data, electrical and water grids, supply chain networks, and distribution networks. Impacts at different scales can affect the resilience of stakeholders and systems.

Water accounting: A detailed account of the total water resources (e.g., water available for abstraction, rights to abstract, actual abstraction, water quality, water to support ecosystem services and environmental flows, and other relevant measures of water) within a system. Catchment water accounting provides these accounts at the catchment scale and is important for water users within this system.

Water status: The historic and current water attributes in the system as defined through qualitative and quantitative variables, such as water quantity and quality, storage, uses and other eco-hydrological characteristics.

Water trends: The course of future water states, predicted using quantitative or qualitative approaches, based on impact of ongoing or projected drivers.

Abbreviations & Acronyms

DES	Department of Environmental Services
GI	Green Infrastructure
CSO	Combined Sewer Outflows
CSS	Combined Sewer System
O&M	Operations and Maintenance
ReST	Resilience Scoring Tool
SC	Steering Committee
WG	Working Group
WASH	Water, Sanitation and Hygiene
WRAF	Water Resilience Assessment Framework

Resilience is About Making Effective Decisions Across Multiple Scales, in an Evolving System Characterized by a Great Deal of Uncertainty

Executive Summary

Multiple challenges are affecting water systems around the world. These challenges are impacting all dimensions of water, including availability, quality and accessibility, as well as the health and functioning of aquatic ecosystems interacting with our water management. As the world's population continues to grow and becomes increasingly urban, many of the water-related challenges will need to be addressed by the utilities that provide water services to cities and urban centers.

Utilities are tasked with addressing basic human needs, such as safe, clean, accessible and affordable drinking water and sanitation for all. While not everyone has access to these services, utilities are often relied upon as the primary providers. In addition, utilities often are responsible for balancing out-of-stream requirements with in-stream needs to ensure there are sufficient water supplies for nature to thrive.

Utilities can play a significant role as catalysts for building long-term resilience within a community or region given the centrality of water to a community's health and vitality, and utilities' experience anticipating risk to ensure reliability and performance. Therefore, utilities should consider and account for numerous shocks and stressors that can affect or hinder the pursuit of resilience. The Water Resilience Assessment Framework is intended to be flexible enough to be applied across different scenarios, contexts and geographies, and to address the impact of multiple shocks and stresses (water scarcity, flooding, pandemics, etc.). For purposes of this document, the interplay between water and climate is emphasized. If water is central to climate resilience, then water utilities are often the primary delivery vehicles for resilience, economic development, prosperity and equity.

For utilities, a resilience approach is about making effective decisions across multiple scales in an evolving system characterized by a great deal of uncertainty. Fundamental to managing this uncertainty is cultivating the capacity to reorganize when conditions undergo profound shifts. In practice, this means understanding when to bounce back and focus on recovery from shocks and stresses and knowing when to bounce forward to adapt or transform to new, emergent issues. The capacity to reorganize and build resilience requires connecting and understanding the full spectrum of the operating environment for utilities, including the geographic, political, financial, regulatory, infrastructure, governance and management, and ecological contexts.

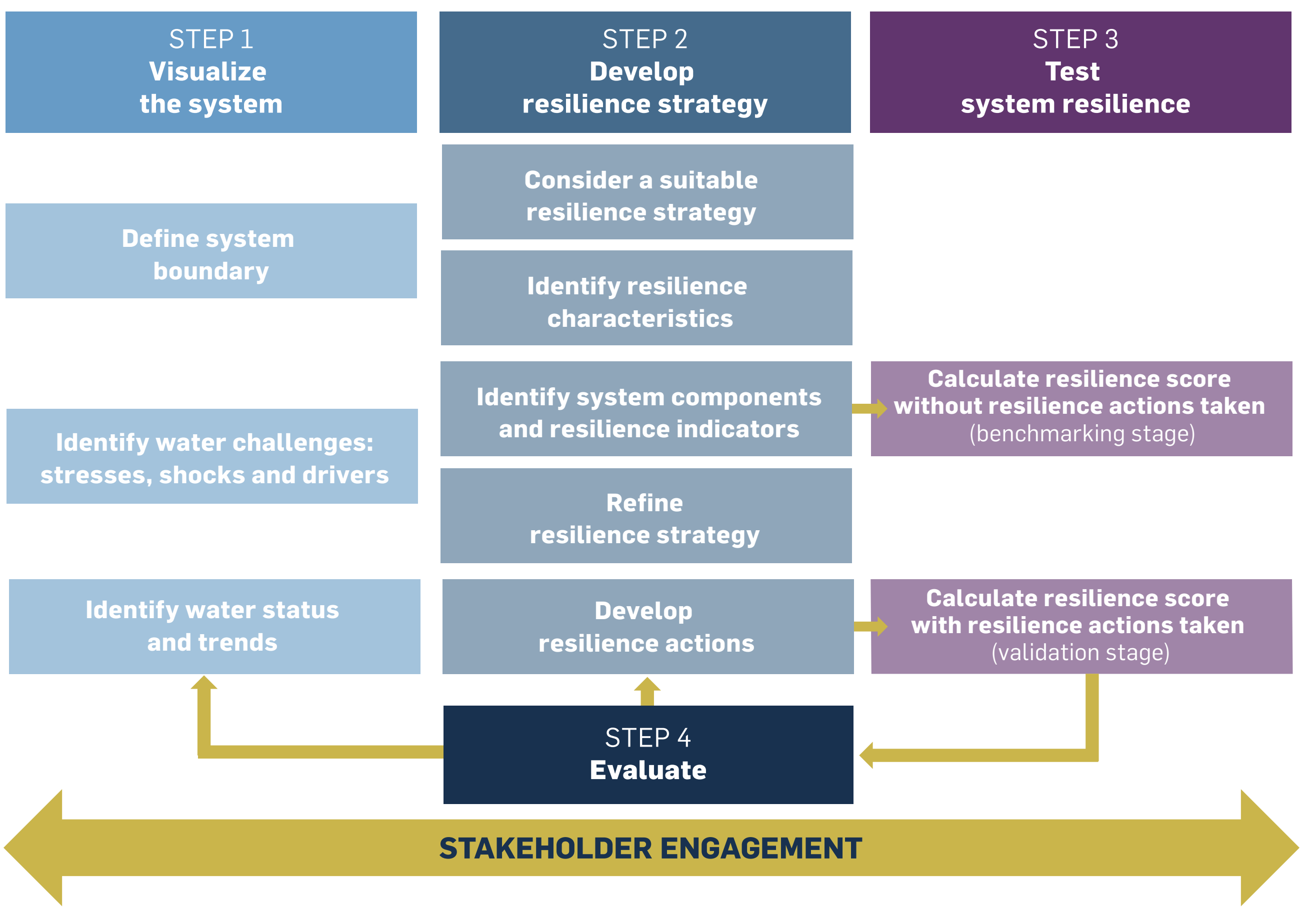
Managing legacy infrastructure[1] for a diverse population in a changing climate is complicated and potentially overwhelming. Utilities operating in various hydrological and jurisdictional basins must navigate geographic considerations for water resource availability and quality. Collaborating with governments and stakeholders is crucial for political support, while the confluence of financing, revenue sources and climate risks may necessitate innovative funding approaches. Adapting within rigid regulatory frameworks can pose challenges, potentially hindering the development of resilience strategies. Intricate, long-lasting infrastructure, designed and managed under outdated climate and socio-economic conditions, can create path dependency, thereby limiting future options. Balancing stakeholder expectations, fostering shared resilience visions, and upgrading data analytics are vital for effective governance and management. Additionally, utilities' reliance on ecosystems

1 The use of the term 'legacy infrastructure' is intended to capture the conventional, centralized water infrastructure paradigm that has been deployed by utilities over the past several decades and usually designed assuming a stationary climate.

for services like water purification highlights their environmental impact and underscores the need for carefully considered decisions. This guidance is designed to assist utility managers in navigating these complex water management challenges by adhering to the guiding principle of water resilience.

Both public and private water utilities face similar challenges in building water resilience, despite their structural and stakeholder differences. Our hope is that this guidance document serves as a valuable resource for both domains, providing an overview of water resilience challenges, case studies, and a toolkit of resources and tools. Our goal is to enable utilities to assess their resilience, develop improvement plans, engage stakeholders, and foster consensus on water resilience strategies.

The Water Resilience Assessment Framework, published in 2021, supports resilient decision-making and prevents shocks and stresses from escalating into crises. The framework is comprehensive, flexible, and easy to use. It can be used to assess the current resilience of an organization, identify gaps, and develop plans/strategies to improve resilience. It can also be used to engage with stakeholders and build consensus on water resilience strategies. This Utility Guidance, the second in the series of sector guidance documents, offers a robust framework for building water resilience for utilities. It offers step-by-step guidance for utilities to take actions either in a modular fashion (one system component or unit at one time) or system wide.



This guidance document is valuable for:

- **Developing a resilience strategy:** The framework can help utilities determine how individual projects or programs align with broader political and economic development goals, fostering an institution-wide approach to resilience. Additionally, it can identify real limits to adaptation or political or stakeholder considerations that may require technical decision-makers to escalate to a strategic decision-maker level.
- **Creating a clearer understanding of the impact of climate change:** By understanding the specific climate change impacts they face, as well as other crucial factors such as demographic or economic changes, utilities can better assess project success or failure.
- **Identifying resilience indicators:** The framework can assist utilities in defining resilience in a tangible manner that can be tracked and communicated to key stakeholders. Resilience indicators can extend beyond regulations and conventional performance mechanisms.

Water utilities can use the Water Resilience Assessment Framework to assess their own resilience and develop plans to improve it. This guidance can help water utilities to embark on and strengthen their journey to build and strengthen their water resilience and adapt to the challenges of climate change and other stresses.

Why Should Utilities Engage in Water Resilience?

Water utilities around the world, in both highly developed countries and emerging economies, face challenges from climate change that are often quite distinct from other types of entities, even other institutions working actively on water quantity and quality issues. Special considerations for utilities around climate change include:

- A significant dependence on long-lived physical assets, such as hard infrastructure. In many cases, these assets represent legacy investments that have high repair, replacement or modification costs, designed for climate regimes that may be long departed, or for social, economic, funding and political realities that are long past. Even new investments risk becoming stranded assets in a rapidly evolving climate, while major adjustments to physical, ecological or hydrological infrastructure may involve long design, approval and construction periods that increase the risk of disrupted service, loss in reliability, or political and economic strains. In addition, utilities are typically dependent upon a suite of ecosystem services at high risk for being disrupted or modified by a changing climate.
- The need to work within longstanding and often rigid governance and regulatory frameworks. In the same way that physical assets may limit options and restrict choices, water allocation, governance and regulatory agreements and frameworks may have been designed under quite different conditions than may exist now or in the future. Adjusting or renegotiating these frameworks may be as difficult as modifying or updating physical assets.
- Low tolerance from stakeholders, including service delivery recipients, ratepayers and political actors, for disruptions in service or changes in institutional arrangements. Perceived failures in progress, solutions that are expensive or hard to explain, variations in service, or modifications to regional planning may induce backlash from voters or funders, political and social conflict, and increases in inequity.

> **“A common thread for all utilities is that they are rooted and anchored to a specific locale.**

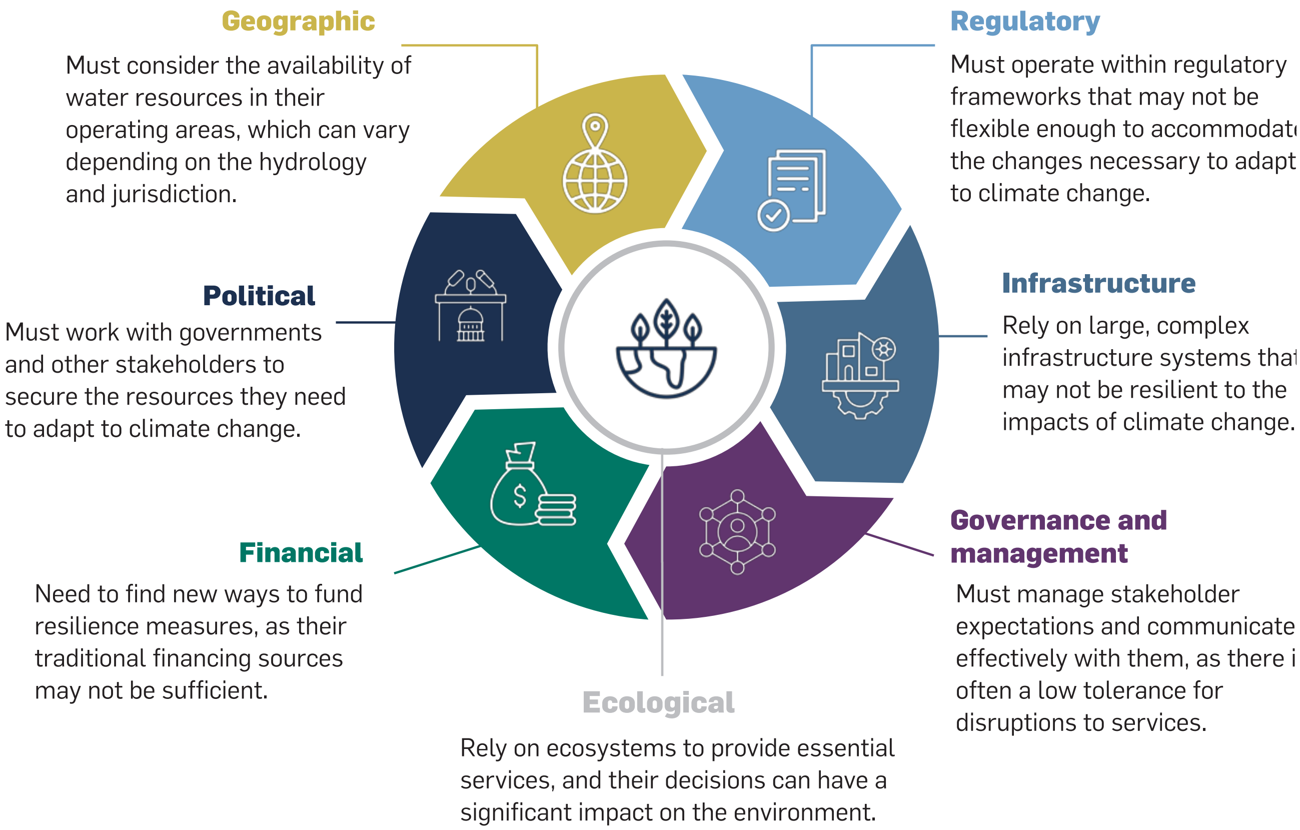
- Financing and revenue sources that may not be aligned with emerging or potential climate risks. The ‘additional’ costs of reducing climate risks, especially for impacts that are not certain to happen or that may be long-term concerns but hold the potential for consequence and influence, may be hard to justify with ratepayers, regulatory bodies and/or financial institutions. Equity, influence and impact may also be important elements in determining who can pay for resilience, how much they can pay, and their willingness to pay, based on past experience.
- Capacity, planning and political gaps around identifying potential climate risks and opportunities, and developing a strategic, shared, forward-looking vision of a water-resilient utility. The role of utilities in enabling community resilience may require major shifts in how utilities, decision-makers and stakeholders view their collective future.
- Pre-existing modes for collecting, interpreting and reporting data that may have been effective in past decades are often limited in how well they can detect or address novel and emerging

issues. Many of our data analytics are designed to solve well-understood concerns, often with an implicit assumption that resilience exists only in a mode of persistence and bouncing back to conditions before experiencing a shock like an extreme flood or drought event. Those analytics and their underlying data may not be as effective in telling us how the system itself may be changing in fundamental ways. More traditionally, water managers face issues with data: how to access it, how to be an informed consumer of that data, how accurate and reliable the data is, how to interpret and translate data into insights and actionable information, and how to discuss data analysis findings (and its associated confidence and uncertainties) with a wide range of audiences.

None of these issues are theoretical, marginal in importance, or easily resolved. Moreover, climate change is not happening in isolation, especially for a resource as cross-cutting and fundamental as water. As a result, there is no single recipe or template for designing a resilient utility, just as the population, hydrology and history of the population served by a utility are distinct. These issues are compounded for multi-service utilities, such as joint electrical-water suppliers, which may experience competition between services, such as between urban water supply and storage vs water-intensive energy generation or agricultural consumption. In many cases, these alternative services have been optimized for an established set of climate conditions, but if those move beyond operational and design boundaries, very difficult trade-offs may be prompted. Although public and private institutions may differ in structure and how they define stakeholders, they face similar types of challenges from climate change.

A common thread for all utilities is that they are rooted and anchored to a specific locale. This place-bound quality is one key differentiator for utilities with other sectors, as it binds them to the long-term resilience of a specific community and economy. Understanding the contexts in which a utility is embedded is essential to building resilience. The seven key contexts suggested for utilities are: geographic, political, financial, regulatory, infrastructure, governance and management, and ecological (Figure 1). A detailed explanation of these contexts is presented in Appendix A.

FIGURE 1. UTILITY-SPECIFIC CONTEXTS IN BUILDING WATER RESILIENCE



Ecological resilience is the foundation for building resilience across social and economic systems. Ecological resilience is the ability of an ecosystem to absorb disturbance and reorganize while undergoing change to retain essentially the same function, structure, identity and feedback. Ecological resilience is important to broader system resilience because it helps to buffer the system against shocks and stresses. When an ecosystem is resilient, it is more likely to be able to recover from a disturbance without major changes to its function or structure. This can help to protect the ecosystem from collapse and can also help to protect the goods and services that the ecosystem provides to humans and nature. Resilient ecosystems provide us with clean air, water, fuel, fiber and food. They also help to regulate the climate and protect us from natural disasters. When ecosystems are resilient, they are more likely to be able to provide these essential services to humans (Walker et al., 2004).

RESILIENCE BUILDING APPROACHES AND THE WATER RESILIENCE ASSESSMENT FRAMEWORK

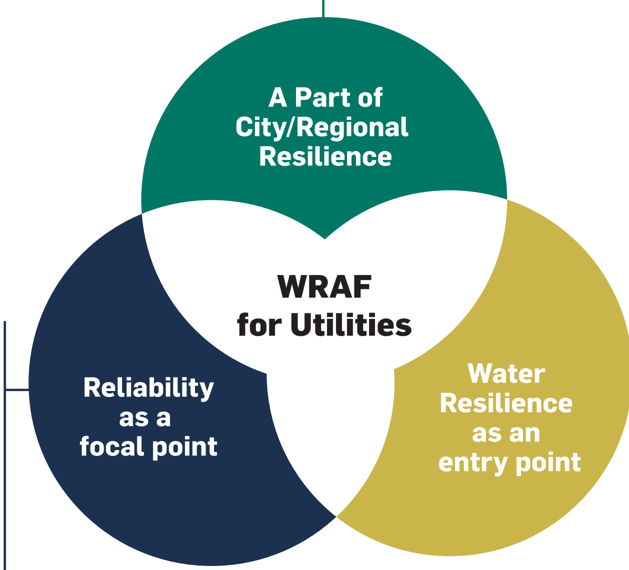
Utilities have been exploring issues of climate adaptation and resilience since at least the early 2000s, with many significant advances in thinking, implementation, finance and policy emerging over the past 20 years. The existing approaches to address these challenges can be broadly categorized into three groups based on the entry point in the resilience assessment (Figure 2).

1. City/Region focused: region/city as the central point where utility is a part of the whole;
2. Utility focused: exploring the reliability of water utility under shocks and stresses; and
3. Water resilience and water management focused.

FIGURE 2. COMMON APPROACHES IN BUILDING WATER RESILIENCE BY UTILITIES

Anticipating and managing climate impacts on cities as a whole and/or sensitive or highly exposed audiences, of which a water utility is a component but not central to the overall focus.

Example:
Rockefeller's 100 Resilient Cities.



Exploring the reliability of water utilities relative to ongoing and projected climate impacts.

Examples:
The US EPA Utility Risk Framework, World Bank Decision Tree Framework.

Water resilience and water management decisions used as entry points. The utility is a key player, but not the only water-relevant institution or agency.

Examples:
The Arup City Water Resilience Approach (CWRA),
US Water Alliance One Water.

These methodologies may view resilience quite broadly, inclusive of social, economic and equity issues. They represent a partial list of groundbreaking or existing approaches to water and community resilience. One Water, for example, views risk and resilience as terms that cover an extensive range of issues which are not limited to climate change.

Moreover, the first two approaches (city-focused, utility-focused) often target operational limits for utilities, such as risks associated with sea-level rise, increasing drought frequency, and shifting flood risk. 'Water' for these approaches is usually referencing water as a threat or hazard (flood risk, tropical cyclones) or water as a sector, such as the utility and water supply or treatment system.

The third (water resilience and water management focused) approach differs most significantly by seeing water as a connector for institutions, diverse sectors (like energy and agriculture), and the city. This more integrative role of water shares a system-level understanding with whole-city approaches to urban resilience. This approach also recognizes that water management decision-making, governance and water infrastructure can present specialized risks. This approach goes further than both by recognizing that water is often deeply embedded and hidden within institutions, policies and economic activities, including healthcare, data, energy, manufacturing, agriculture and global trade. This illustrates how water can facilitate dialogue amongst stakeholders and be a connector within a community and region, and/or across sectors, and can ultimately play an integral role in collective resilience. In many ways, these methods are also about engaging stakeholders and decision-makers in urban resilience. They are not simply about reducing climate risks, but about communicating a resilient future vision for a specific urban landscape.

OBJECTIVES OF THE GUIDANCE

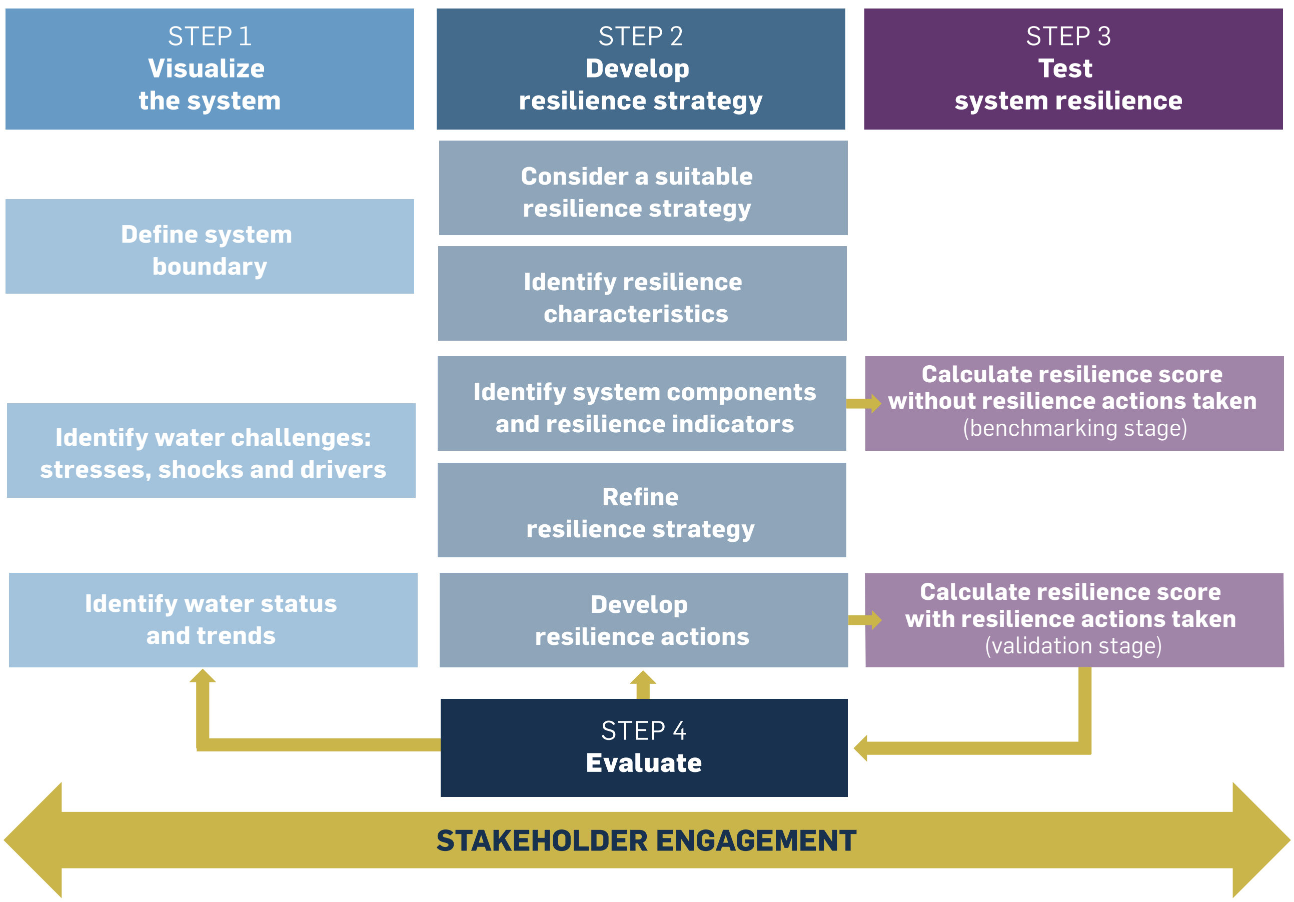
The Water Resilience Assessment Framework (WRAF) provides an overarching framework for assessing the resilience of water systems (Chapagain et al., 2021). The WRAF is further elaborated in a series of sector-specific guidance documents with implementation examples. The current guidance is developed specifically for water utility sectors. The guidance aims to provide:

- A step-by-step approach for utilities to apply the WRAF to build water resilience across departments, facilities and system levels;
- A logical framework to develop resilience actions for a selected set of resilience goals; and
- A useful set of resources for performing the various steps of the WRAF, including resilience indicators, actions, tools and methods.

OPERATIONALIZING THE WATER RESILIENCE ASSESSMENT FRAMEWORK

The WRAF provides an overarching framework for assessing the resilience of water systems (Chapagain et al., 2021). The WRAF encompasses four steps which can be undertaken in a stepwise approach, or in a modular way. This document adapts the WRAF to best align with existing practices, tools and approaches specific to utilities (Figure 3).

FIGURE 3. THE WATER RESILIENCE ASSESSMENT FRAMEWORK FOR UTILITIES



Source: Adapted from Chapagain et al., 2021

Stakeholder engagement is essential across all stages of the WRAF process. An inclusive stakeholder engagement process is an important first step in the design and implementation of the WRAF. By engaging with these stakeholders, water utilities can gain a better understanding of the challenges and opportunities facing the water sector, and they can develop more effective water management plans.

STAKEHOLDER ENGAGEMENT

Utilities should look to engage a wide range of stakeholders, including:

- **Tiers of government:** Responsible for setting water policies and regulations, undertaking management and governance elements, and can provide guidance and support to water utilities.
- **Local authorities:** Can provide water utilities with access to data and resources and can help coordinate water management efforts.
- **Community groups:** Can provide valuable insights into the needs of local communities and help build support for water conservation measures.
- **Indigenous communities:** Have a deep understanding of water resources in their traditional territories and can provide valuable insights into how to manage these resources sustainably.
- **Farmers:** Generally major water users in any basin and can provide valuable insights into how to improve water efficiency in agriculture.
- **Other water users, including businesses, industries and households:** Can provide valuable insights into how to reduce water consumption.
- **Environmental organizations:** Can provide water utilities with technical expertise and support and can help to raise awareness of water conservation issues.
- **Experts:** Can provide water utilities with technical expertise and support and can help develop and implement water management plans.
- **Recreational and sporting groups:** Can provide valuable insights into how to manage water resources for recreation and tourism.
- **Energy-generation companies/utilities:** Can provide valuable insights into how to reduce water use in power generation.
- **Navigation services:** Can provide valuable insights into how to manage water resources for navigation.
- **Transport and logistics companies:** Can provide valuable insights into how to manage water resources for transportation.

Stakeholder engagement can be done through a variety of methods, such as one-on-one discussions, workshops and surveys. There are also several formal approaches that can assist in the engagement processes. The City Water Resilience Approach is a good example of a formal process for collecting stakeholder input. In Mexico City, this approach was used to forge a shared vision for the future of water security and climate justice for the urban poor, which was identified as a key issue. By sharing a common goal and understanding the risks of transformation, many groups can align their efforts and investments to ensure long-term security of water systems.

STEP 1: VISUALIZE THE SYSTEM

The first step in the WRAF is to understand the system, its boundaries, and the challenges and threats it faces. This includes identifying and engaging key stakeholders. The goal of this step is to plan the implementation of the WRAF process and to clarify the objectives, tasks and responsibilities of the key stakeholders operationalizing the WRAF. This step also structures how to collect data and information to update the status and trends of the challenges, stresses, shocks and drivers.

1.1 DEFINE SYSTEM BOUNDARY

Defining the system boundary in which a utility operates is essential for effectively collecting information and identifying the relevant system components and stakeholders, key drivers of shocks and stresses, water status, trends, and the impact of decisions on communities and the environment.

A utility's operating context typically extends beyond the hydrologic basin from which it derives its supply to include wider political, technical and regulatory realms, as well as stakeholders that operate outside of the hydrologic basin of interest. When defining a system boundary, there must be a balance between understanding and including these wider contexts while also ensuring the boundary is manageable and practical. Boundaries should be consistent with a utility's capacity for dealing with complexity, knowing that those boundaries are not fixed and can be cultivated and expanded over time.

The broader the system boundary, the easier it is to anticipate how decisions will reverberate throughout the system. However, if the system boundary becomes too complex, it can make the subsequent steps of the WRAF process unworkable. In this case, basic heuristics can be used as a starting point, if potential blind spots are recognized. A reasonable depiction of system boundaries would build off the various utility-specific issues identified in the previous section and interrogate them with the following question: 'Could this variable (e.g., source of supply, stakeholder, regulation, etc.) have a reasonable chance to affect the ability of my utility to meet its obligations and responsibilities?'

1.2 IDENTIFY WATER CHALLENGES: STRESSES, SHOCKS AND DRIVERS

After defining the system's boundaries and components, the next step is to identify the current and anticipated challenges within the system, such as water availability, water quality, accessibility, and decline in system functions. These challenges can be difficult to tackle due to ongoing or anticipated stresses and shocks. The impact of these stresses and shocks on the existing challenges can be further amplified by various drivers.

Stresses are incremental changes in the system, such as temperature and precipitation changes over time, sea-level rise, long-term droughts, etc. Shocks are sudden changes in the system, such as flooding, coastal storms, earthquakes, fire, cybersecurity breaches, terrorism, violent conflict, epidemics/pandemics, etc. Drivers are the external factors that influence changes in the system. They can include a broad range of elements that may be interacting with climate change, such as demographic change, economic trends, or regulatory shifts.

While it may be tempting to zero in on biophysical shocks and stresses, it is also essential to identify stresses and shocks for the institutional and socio-economic components, what the interactions are across them, and how the components may dampen or amplify shocks and stresses in each other. The effort should consider both acute and chronic stresses and be informed by history but not be bound by it; risks will need to be assessed for novel conditions that may increase in frequency and intensity due to climate change.

For the past two decades, utilities, planners and decision-makers have actively explored the incorporation of climate data and projections into their assessments, and an extensive set of frameworks and methodologies have emerged as a result. In general, two categories of approaches have emerged: top-down and bottom-up. These approaches include methods such as the 'chain of models' method (Vogel et al., 2015), Climate Risk Informed Decision Analysis (CRIDA) (Mendoza et al., 2018 and United Nations Educational, Scientific and Cultural Organization, 2023) and The World Bank's Decision Tree (Ray and Brown, 2015). The Decision Tree Framework adopts a bottom-up approach to risk assessment that aims at a thorough understanding of a project's vulnerabilities to climate change in the context of other non-climate uncertainties (for example, economic, environmental, demographic or political).

A more recent pair of publications (Wasley and Kaatz, 2021; Wasley et al., 2020) describe how a utility can map climate exposure—and climate information needs—to critical business functions across the utility enterprise, which considers climate comprehensively, across all business functions, and not just those that are focused on water resource management.

It is recommended that this exercise be viewed as a bottom-up, system-centric risk assessment that identifies known conditions or previous incidents that have compromised the system's functionality. It can serve as an opportunity to engage operational and management staff of the utility and leverage their experience in a way that brings them into, and makes them part of, the first steps in the resiliency journey. The tacit knowledge of the utility's staff, along with asset performance data and customer feedback, should be leveraged to inform this exercise. This will include the development of resilience indicators based on their knowledge of the system (Step 2.3).

The identification of drivers, shocks and stresses can also be informed by the outcome of Step 1.3, where data on current water status, trends and predicted changes are collected. In turn, Step 1.3 (water status and trend) is directly linked to the identification of the key water challenges of the system and the current and anticipated stresses and shocks (Step 1.2). It may therefore be required to revisit Step 1.2 after completing Steps 1.3.

1.3 IDENTIFY WATER STATUS AND TRENDS

Water status is the current state of a water system's attributes, such as water quantity and quality, storage, uses, connectivity, legal and institutional elements, and eco-hydrological characteristics. Water trends are the historical, current or predicted future water status of a system, based on historical data and quantitative or qualitative modeling approaches. These trends also reflect predicted changes due to ongoing, planned or probable shifts in the policies or activities impacting the system. As such, a solid understanding of baseline water conditions and policy shifts should be established.

Water status and trends provide a baseline against which to measure the current situation of and changes in the water system. This is important for understanding how the system is responding to stresses and shocks, and for identifying potential vulnerabilities. Water status and trends can also be used to predict or understand key water challenges, their state, and to help visualize the system. For example, if water trends indicate that water availability is declining, this information could be used to develop new measures to strengthen the system's resilience, such as conservation measures or investment in new water-storage infrastructure.

It is worth acknowledging that some of the steps in the WRAF may have been completed by a utility as part of other planning processes. For example, risk assessment processes or strategic plans may have already included some of the steps in the WRAF. In this case, these processes and reports can be reviewed through a resilience lens and updated as appropriate.

STEP 2: DEVELOP RESILIENCE STRATEGY

The WRAF's focus on setting a resilience strategy is one of its key differences from other methodologies designed to reduce climate risks and threats. Evaluating climate risks is standard best practice in many regions, but there are ongoing debates about the best methods. A climate risk assessment identifies tangible and potential threats to an institution, operational regime or physical asset; by enumerating a set of realized or projected risks, it outlines ways to eliminate, reduce or delay those impacts. This is often referred to as 'de-risking' in the finance sector.

A resilience *strategy* is quite different from de-risking as typified in a risk assessment and, in practice, not yet widely used. If de-risking is intended to ensure financial or operational feasibility, resilience describes broader conditions and values, such as ensuring that a community maintains economic and ecological prosperity and health despite climatic, demographic, and social changes. In effect, a resilience strategy provides a clearer definition of what you hope to *achieve*, not just what to *avoid*.

2.1 CONSIDER A SUITABLE RESILIENCE STRATEGY

The WRAF defines three resilience strategies that are aligned with differing perspectives of resilience. These strategies are based on the types of change a utility is facing. These strategies, adapted from the WRAF (Chapagain et al., 2021), are:

- **Persistence:** Persistence refers to the ability of a system to return to its original state after a disturbance or shock. Utilities worldwide typically follow a persistence strategy. This means that they design their sites and surrounding systems to perform similar functions after a major shock or under ongoing stress. For example, a water utility can invest in fixing existing infrastructure instead of replacing it with more efficient or contemporary options. This strategy emphasizes shoring up key weaknesses in the system against shocks but does not require a radical overhaul of current operating practices.
- **Adaptation or incremental change:** Adaptation is an effective strategy for responding to gradual and predictable climate impacts. This approach expects that the site and system will face a future that is different from the status quo, but that these changes will happen gradually over time. This allows for the preparation of additional changes that can be seen coming. For example, a water utility could install water meters that can track water usage and send alerts to customers when they are approaching their allocated water allowances during drought periods. Another example could be educating customers about water conservation and the importance of reducing water use through behavior change. An adaptation strategy emphasizes maintaining current needs while simultaneously preparing for more drastic future changes.
- **Transformation:** A transformation strategy assumes that the site and system face major changes to current or future conditions. These conditions or changes could happen suddenly or gradually, but the system will need to reorganize itself with new eco-hydrological, socio-economic and/or institutional elements. This may require a fundamental rethinking of the system. Historically, periods of transformation have often been relatively brief. For example, if some of the existing water sources become untenable to operate in the future or do not meet demand, water scarcity could become a major challenge. In such cases, water utilities could think beyond simple demand

management or investments in physical infrastructure or alternative supply options. For example, if the surface water supply is not 100 per cent reliable, a utility could transform their supply options by investing in groundwater supplies, desalination and other technologies. This requires a complete transformation of the water system through policy shifts, infrastructure investments, pricing changes and other measures.

Choosing the wrong resilience strategy could have serious implications for a utility. For example, if a utility adopts a persistence strategy while significant ongoing climate changes are occurring, its operations may be at growing risk of disruption and, with time, even stranding of key assets.

The selection of a resilience strategy should be based on a serious discussion with key members of the utility leadership and operational departments, and should realistically match the experience and perception of utility staff. In many cases, the strategy will be the outcome of an analysis of trends and projections for what may be happening in the system's boundary. It is also important to discuss the potential uncertainties, and to consider alternative futures and storylines. In many utilities, planning timelines may be defined by institutional or regulatory policies, such as 5–10 years. However, it is important to remember that trends can change over time, and utilities should be dynamic in how they approach their resilience strategies and actions.

Here are additional questions to consider when developing a resilience strategy:

Status and trends

- What are the current and future status and trends of the system? These include climatic, eco-hydrological, population and demographic trends. It is important to consider vulnerable communities and populations as well.
- Do the trends align with each other, or are there significant divergences?
- How will anticipated shocks and stresses influence the status and trends, or how will these affect operations?

Resilience goals and priorities

- What are the resilience goals or priorities of the utility?
- Which resilience strategy best aligns with these goals?
- Do the goals need to be updated?
- Do the goals also support ongoing efforts to build resilience for communities and the environment? If not, what changes are needed to align the goals with strategic goals and deliver multiple benefits to communities and nature?

Governance and resources

- How much agency does the utility have in addressing system resilience?
- How do administrative and organizational structures hinder or foster addressing resilience?
- How much capacity is available?
- What other actors need to be involved?
- Can resilience be addressed jointly across organizational or geographic boundaries?

After selecting a resilience strategy, a utility can identify resilience characteristics that capture the system attributes that they will strive to develop and achieve through their actions and overall strategy.

2.2 IDENTIFY RESILIENCE CHARACTERISTICS

Two central tenets of the WRAF are that (a) resilience must be able to be measured to know if progress is being made, and (b) traditional sustainability measures are probably not useful for measuring resilience. Any resilient system portrays specific characteristics that can be used to help assess the state of resiliency using appropriate indicators. This guidance provides six resilience characteristics (adapted from Chapagain et al., 2021) that can help track, measure and assess the status of the resilience of the water system.

- **Robustness:** The system is designed to perform at or beyond the levels of high-confidence, low-uncertainty risks.
- **Redundancy:** The system has spare capacity intentionally created to accommodate disruption, extreme pressures or demand surges.
- **Flexibility:** The system can be altered and adapted in response to potential shocks and stresses or adjusted to take advantage of opportunities.
- **Integration:** The system components are linked and coordinated while also able to be isolated.
- **Inclusiveness:** The system has effective mechanisms for broad consultation and engagement of individuals and communities, including the most vulnerable.
- **Justice and Equity:** The system ensures that all stakeholders within a system are provided with equitable water access, rights and allowances.

Although all resilience characteristics should be considered over time to build long-term resilience, a utility can prioritize a few to focus on at first. For example, the robustness of financial systems for water utilities is one of the most important resilience characteristics to consider (OFWAT, 2021), as shocks and stresses can trigger issues around operations, liquidity, debt maintenance, credit ratings, and short-term resource mobilization. Another example could be a utility with a history of water reliability issues that might select 'Robustness' and 'Redundancy' to meet their immediate resilience goals. A system with limited stakeholder trust and prior governance issues might select 'Inclusiveness' and 'Justice and Equity' characteristics.

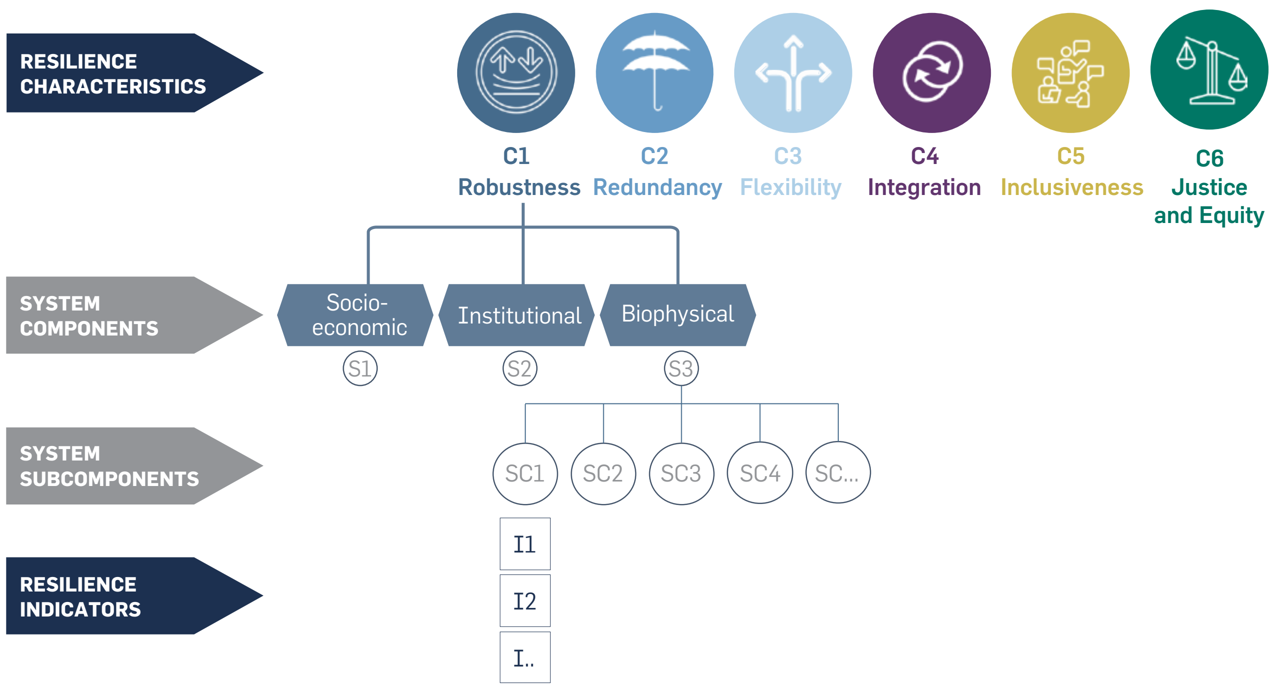
The information from Step 1 will inform the selection of the appropriate resilience characteristics. The priority water challenges in the system, and the current status and trends, will point to which characteristics require greater attention and more active intervention.

The WRAF is designed to be iterative, so this step can be revisited after reviewing subsequent steps or updated as the WRAF is repeated at a later time.

2.3 IDENTIFY SYSTEM COMPONENTS AND RESILIENCE INDICATORS

To strengthen the selected resilience characteristics of the system, the utility can examine it at a much more granular level by breaking it down into smaller, more manageable parts. This will help the utility better understand the system and identify areas where it can be improved (Figure 4). The components and subcomponents of the system can be selected based on how they influence the two resilience characteristics.

FIGURE 4. PROCESS FLOW TO SELECT SPECIFIC RESILIENCE INDICATORS TO MEASURE RESILIENCE CHARACTERISTICS



Note: Includes an example from resilience characteristic 'Robustness' for system component 'Biophysical,' and subcomponent 'SC1.'

2.3.1 *Identify system components*

The WRAF broadly delineates three interrelated system components: socio-economic, institutional and biophysical. Each system component can have a range of subcomponents that are applicable based on the type of utility and local context. The following questions can help identify these subcomponents:

- Which factors are significant with respect to resilience?
- What influence (whether direct, indirect or none) does a utility have over those factors?
- Which factors should be monitored against key performance indicators?

The resilience characteristics identified in Step 2.2 need to be examined and strengthened for each system component. For example, a utility might identify that the socio-economic factor of social connectivity is significant for building resilience. The utility could then examine how it can strengthen social connectivity in its community, such as by funding community programs or providing support for social enterprises. Similarly, if a utility has limited access to funds, it may be less able to invest in new infrastructure or to maintain existing infrastructure. This could make the utility more vulnerable to shocks such as droughts or floods. Or, if a utility has weak governance, it may be more likely to experience corruption or mismanagement. This could also make the utility more vulnerable to shocks and stresses. By understanding the subcomponents that affect the resilience of their utility, utilities can take steps to strengthen their resilience and reduce their vulnerability to shocks and stresses. Some examples of these system subcomponents are presented in Table 1.

TABLE 1. EXAMPLES OF SYSTEM SUBCOMPONENTS ACROSS PRIMARY SYSTEM COMPONENTS

Socio-economic	Institutional	Biophysical
• Access to funds/ resources • Access to services • Demand management • Knowledge systems • Available capacity • Cultural and Indigenous knowledge systems	• Economic ability (affordability) • Governance (financial ability, willingness, competency, transparency, trust, accountability, maturity, environmental justice, etc.) • Operations/system management (decision making, flexibility, etc.) • Regulations (practicality, maturity, compliance, etc.) • Built and/or natural infrastructures (policies/mechanisms) • Legal frameworks (allocation, operation and management) • Corruption, accountability and transparency	• Supply (types, reliability in quantity and quality, adequacy, interconnections and independence) • Built infrastructure (suitability, capacity to operate, technology, reliability and capacity of structures, etc.) • Natural infrastructure (capacity, connectedness, quantity and quality) • Operations/system management (access to technology and tools) • Biodiversity (aquatic and terrestrial)

2.3.2 Identify resilience indicators

Once the resilience characteristics and the system components have been selected, the utility needs to identify appropriate resilience indicators to measure their resilience. This guidance provides two tiers of resilience indicators: Tier 1 and Tier 2 (Appendix A). Tier 1 indicators are snapshot indicators that assess a resilience characteristic at a high level. Tier 2 indicators allow for a more granular assessment of resilience characteristics for each relevant system component and subcomponent. The list of Tier 1 and Tier 2 indicators provided in Appendix A is illustrative and should be tailored to the local context. The purpose of the indicators is to track progress towards strengthening the resilience characteristics that a utility has prioritized. These indicators are also captured in the Resilience Scoring Tool (ReST) (Chapagain and Brill, 2024).

Developed by the project team, the ReST is a user-friendly tool that is a scoring system to help organizations assess their levels of resilience. The tool is based on expert knowledge and available metrics and includes appropriate score ranges for each indicator. Users select the score that best represents the outcomes from their benchmarking or validation stress tests. The tool can be used for both Tier 1 and Tier 2 resilience assessments, depending on the needs of the users.

After identifying a selection of indicators, a utility should conduct an initial stress test (Step 3.1) using the ReST to assess the current state of resilience in their system (benchmarking stage).

The benchmark stress test will indicate the strength of the selected resilience characteristics. Attention should be paid to the indicators receiving the lowest or weakest scores (red), as these indicators will best inform the selection of a suitable resilience strategy and appropriate actions to improve overall resilience. An example of such a test for resilience characteristics 'Robustness' at the benchmarking stage is presented in Table 9 in the Step in Practice section.

2.4 REFINE RESILIENCE STRATEGY

An effective resilience strategy should be monitored and adjusted as needed. This is because the strategy may need to change due to new information, changes in priorities, or new knowledge. Monitoring should be an active process that informs decision-making about how to improve resilience.

For complex systems, multiple resilience strategies may be necessary. This is because different parts of the system may be affected by different factors, and it may be necessary to tailor the strategy to each part. For example, some cities in northern China receive water from the South-North Water Reallocation Project. This project links the cities' water supply systems to distant basins that may be experiencing different conditions. Therefore, the cities may need to have different resilience strategies for their water supply systems and delivery systems.

Determining a utility's resilience strategy is more than just selecting a proposed trajectory. It is a means to build long-term resilience through the development of appropriate resilience actions. The benchmark assessment reveals several resilience indicators performing poorly or average where a set of suitable resilience actions can be selected based on the resilience strategy preferred. For example, if the indicator 'access to funds' is poor, a persistence strategy is not enough, and one must transform the funding priority. However, the organization may be inclined to prioritize other resilience indicators to tackle first. Understanding whether a utility needs to persist, adapt or transform will inform the nature, scale and scope of appropriate actions to meet the objectives of this selected strategy.

2.5 DEVELOP RESILIENCE ACTIONS

After selecting an appropriate resilience strategy, resilience actions must be developed. These actions should be designed to improve the selected resilience characteristics of the system. It may also be useful to develop categories of actions, as this can help to challenge a utility to think of actions that go beyond their historic domain of building and operating physical infrastructure. This could potentially identify new opportunities to extend its influence and build new strategic alliances.

KEY CATEGORIES OF RESILIENCE ACTIONS SUITABLE FOR UTILITIES

- **Operational:** Typically, utility systems are dynamically managed to respond to variable patterns of demand and supply. This can be done by leveraging existing infrastructure, tacit knowledge and latent capacity. However, this approach may not be sufficient for utilities on a transformation path, where adjusting how the existing system is managed may not be enough.
- **Structural:** Utilities can improve resilience by investing in new infrastructure, including green infrastructure, nature-based solutions, and land-based strategies. It is also important to have high-quality, reliable asset data as part of an overall asset management program. The rapid evolution and deployment of sensors, internet of things, and artificial intelligence technologies coupled with asset management principles provide tremendous opportunity in this regard.
- **Financial:** Utilities typically collect revenue from the sale of water or the flow of wastewater off properties. This relationship with customers can be used to send price signals that can be designed to drive desired outcomes. For example, tiered and seasonal rate structures can be used to manage peak demand during periods of constrained supply.
- **Legal, Regulatory and Policy:** Utilities often have special powers or the ability to establish policies that can require certain actions to be taken for a customer to be provided with a service. This can be perceived as being heavy-handed, but if deployed correctly, it can be incorporated into the terms of service. In addition, utilities can consider the legal and policy landscape in which they operate and assess if any of the current rules and regulations hinder their ability to pursue a resilience strategy. If so, they can pursue adjustments in the policy landscape to remove roadblocks to resilience.
- **Behavioral:** Utilities have an established relationship with their customers, which can be used to nudge customer behavior regarding the use of water. Communication and social marketing campaigns can be developed to encourage customers to use water more efficiently and in a way that is aligned with the utility's strategic objectives.

These are just a few of the key categories of resilience actions that utilities can pursue. The specific actions that are most appropriate for a particular utility will depend on the specific context and challenges that the utility faces.

These categories are not exhaustive, and they can be pursued together as part of an overall portfolio approach to building resilience. The breadth of the categories should help to illustrate potential resilience actions that go beyond building and operating infrastructure. This expanded approach enables utilities to identify resilience actions that are less sensitive to the uncertainties of climate change and other societal and environmental challenges.

The design of infrastructure to manage combined sewer overflows (CSOs) is heavily dependent on assumptions about future precipitation patterns and extreme events. If these assumptions are incorrect or based on inappropriate models or risk assessments, then the infrastructure may not be able to effectively manage CSOs.

One way to manage this uncertainty is to take a broader portfolio approach that includes multiple tactics. This allows the utility to include solutions that are less sensitive to future rainfall patterns, or that can be deployed to manage the residual risk of that uncertainty. For example, conventional gray infrastructure could be deployed to provide a base level of service, with decentralized green infrastructure effectively serving as an urban amenity during 'normal' conditions while also providing an additional level of stormwater retention, detention and/or infiltration function during higher precipitation events.

Another option is to choose a hybrid approach that relies on infrastructure to provide a base level of service, with complementary approaches deployed to manage residual risk. These complementary approaches could pull from the other categories and be activated to provide levels of services that are in addition to what is provided by the traditional infrastructure.

A portfolio diversity approach is more robust than relying on a single tactic for managing CSOs. By including a variety of resilience actions, utilities can better adapt to future uncertainty and be more resilient.

STEP 3. TEST IMPACT OF RESILIENCE ACTIONS ON RESILIENCE CHARACTERISTICS

Stress testing resilience actions can help us identify how they will perform under specified conditions. This is a relatively new idea in resilience planning, but it is a valuable way to explore assumptions and make decisions with confidence.

Stress testing is done in two stages: benchmarking (Step 3.1) and validation (Step 3.2).

3.1 BENCHMARKING STAGE

In the benchmarking stage, utilities assess their current level of resilience. This is done by using appropriate resilience indicators to estimate or measure how the system is performing with respect to the selected resilience characteristics for the selected system components and subcomponents. For example, to measure the 'Robustness' of biophysical system components, a utility could select one of the subcomponents, 'built and/ or natural infrastructure', using the indicator 'state of infrastructure to withstand shocks and stresses'. The 'Robustness' of the selected system component is measured collectively using the outcomes of this test for all the subcomponents under it.

Step 3.1 is carried out immediately after Step 2.3 (Identify system components and resilience indicators). The validation stage only comes after Step 2.5 (develop resilience actions). See the Step in Practice section for an example.

3.2 VALIDATION STAGE

During the validation stage, utilities can test the impact of resilience actions or different scenarios to determine how the actions proposed will improve (or worsen) the selected resilience characteristics for the selected system component/subcomponent, and ultimately the system resilience.

There are several ways to test resilience actions, and the best approach will vary depending on the specific situation. By using stress testing, decisions can be based on available information, while also being prepared for unexpected events. For utilities, stress testing can help them to meet regulatory targets and to provide water and sanitation services to a growing population. Stress tests can help to identify the parts of a system that are most vulnerable to unexpected events by breaking the system model, whether quantitative or qualitative, under theoretical conditions. This can help to identify the parts of the system that are most responsive to violations of assumptions or trigger unexpected cascades of responses.

Here are a few examples of stress testing methods that can be used to test the impact of resilience actions, ranging from basic approaches to complex modeling exercises.

- **Sensitivity analysis:** It is useful if a quantitative or semi-quantitative hydrological model for the system exists that also allows for the manipulation of key climate-sensitive water variables. A sensitivity analysis involves systematically changing key variables in a model to see how they affect the system. This can be done in a basic spreadsheet by systematically changing key variables, individually or in combination, to see when the system begins to fail to achieve key performance indicators. Sensitivity analysis is a powerful tool for stress testing resilience strategies, but it does not consider the likelihood of different climate conditions. This is a limitation, as the likelihood of different climate conditions can affect the prioritization of adaptation actions and interventions.

- **Risk-surface:** A more sophisticated approach to stress testing is to develop a ‘risk surface’, a methodology adopted and promoted by groups such as the World Bank, Deltares, the US Army Corps of Engineers and others. Risk surfaces are based on a handful of climate variables and a well-defined performance indicator. They can be used to mix and visualize different forms of data, which can be helpful for decision-making. Risk surfaces often use data from many dozens of climate models, which can provide a better understanding of the likelihood of different climate conditions. Creating risk surfaces is typically based on a handful of climate variables (air temperature, annual or seasonal precipitation, etc.) and a well-defined performance indicator, such as service reliability. They can be used to mix and visualize different forms of data, which can be helpful for decision-making. Climate adaptation risk analyses over the past two decades have often relied on data from a single climate model or scenario. This is problematic, because it does not provide a good understanding of the likelihood of different climate conditions. Risk surfaces in a decision scaling approach can help identify the most likely climate conditions by using data from several climate models, including actual metered data, paleoclimate data, etc. that serve as a good proxy for credibility and likelihood of violating assumptions (St. John et al., 2019).
- **Digital twins:** Some utilities have developed or are developing digital twins, which allow for comprehensive and sophisticated modeling approaches. Digital twins ideally model many parts of the hydrological and infrastructure system, and stress testing can be more time-consuming because of the additional levers that can be manipulated alone or in combination. However, they may also be more likely to reveal more subtle flaws and gaps (Tzachor et al., 2022).
- **Other practices:** Many more utilities perform desktop or tabletop studies that are effectively stress tests. These studies typically draw on a combination of analytical models and human technical experience and expertise. They can be less time-consuming than digital twin-based stress tests, but they may not be as comprehensive or sophisticated. For example, WSP and AGWA combined the Water Utilities Climate Alliance risk assessment framework (Grubert et al., 2022) to develop guidelines for such an exercise process using the WRAF overlap. The resulting methodology suggests a quite sophisticated approach to considering risk and resilience for a utility that blends both quantitative and qualitative methodologies.

By the end of Step 3, a set of actions should be developed or selected for implementation. Keep in mind that actions with longer time horizons and investments may require more stress testing. For long-term actions, such as increasing water supplies during lean flows, utilities may need to manage demand and invest in storage or other infrastructure with a long horizon. For shorter-term actions, such as increasing flexibility in operation and maintenance, utilities can draft a policy relatively quickly, the impact of which is immediate.

STEP 4. EVALUATE

Evaluating a resilience strategy can be challenging. First, it is difficult to determine what constitutes 'good enough' resilience. This is because the concept of resilience is subjective and depends on the specific context, including the size of the system, the local climate, challenges faced, etc. Second, it is difficult to attribute how actions contribute to resilience in a dynamic system. As resilience is a complex approach with many interacting parts, it is difficult to isolate the effects of individual actions and determine how they contribute to the overall resilience of the system.

If the selected resilience strategy fails to achieve the desired outcome, the decisions made in the previous steps of the WRAF need to be assessed. The WRAF evaluation could include revisiting all the steps from visualization of the system to developing resilience strategies and actions, to stress testing the impact of resilience actions.

- **Re-visualize the system:** Review how the system has been defined and consider if it has been scoped too narrowly or too broadly. If so, the utility may need to develop multiple resilience strategies or reconsider how the system has been defined if the system has greater exposure than accounted for.
- **Challenges: stresses, shocks and drivers:** Failure of the selected resilience strategy, and resulting resilience actions taken, could also be because of insufficient understanding of current and anticipated stresses, shocks and their drivers. Revisiting the stresses, shocks and drivers selected and refining them will help the utility identify appropriate actions to adapt or mitigate the impacts.
- **Selection of resilience characteristics, indicators and resilience strategy/strategies:** Based on the outcome of the challenge assessment, the utility can identify the cause of the impact and use this information to hone the refinement or development of resilience characteristics and indicators to meet the additional resilience needs of the system characteristics and components. At this point, the utility can assess if there are any additional characteristics or nuances that should be incorporated into the strategy and determine whether the indicators provided the requisite estimates and signal for a course correction that would have enabled the utility to avoid the conditions that caused the failure. Finally, deciding on whether the appropriate resilience strategy was selected will help determine if changes need to be made to the overall approach by a utility. The stress test combined with the evaluation of the resilience strategy are an invaluable way to diagnose how well the overall strategy performs in simulated conditions and real-world situations and where it can be improved.
- **Check if we have done enough:** Traditional approaches to climate risk assessments can provide a false sense of confidence. In practice, many types of climate risk should prompt larger questions, such as what is the nature of the utility's services? Should they be operating in the current modus operandi? And for persistent, adaptive or transformative issues, what is our tolerance for risk? For example, reliability standards for provisioning water may currently be at a level of a return to full operational service within 24 hours following any major disruption. In a region with long-term declines in water sources (e.g., from declining snowpack or increased evapotranspiration trends), some standards may be challenging or impossible to meet without extensive new investments, such as increased storage, water recycling, desalinization, or long-distance water transport. Resilience can also be a process of engaging with stakeholders and decision-makers to redefine trade-offs and describe what is optimal now. A compromise position, for instance, may prioritize certain users at the original standard (low-income areas, essential services such as healthcare

and schools) relative to other users. In this sense, resilience may look like negotiated short- and long-term prioritization processes.

- **Align resilience with financial and political priorities:** Financing and funding processes for utilities are politically sensitive in almost all countries. For instance, in Jordan, local utilities have a place in national decision-making, while in the UK, utilities are highly regulated private businesses that provide public goods. In Australia, utilities are most intensively managed through local governance systems. The system may also consist of layers of overlapping and sometimes independent public and private jurisdictions, lines of authority and management, and administrative boundaries, which can make investment itself complex if several cities, the private sector, state/provincial governments, and multiple national authorities are all involved. Utilities often have large capital and operational budgets, which means that shifts in investment and operations often have both financial and political implications. Investing in resilience can heighten these implications, especially where multiple authorities or departments within the same organization may need to develop a more coherent and coordinated approach.

In many countries with long-established public utilities, ratepayers are often the most important source of income for operational expenses. Capital investments are often financed through bonds and other forms of debt, which are factored into utility rates and paid off over time by ratepayers.

Integrating resilience often requires new capital investment as ratepayers do not contribute to new capital investments. Modes of finance are critical to consider, as they can have different costs and benefits from a resilience perspective. Appendix C outlines a wide variety of financial modalities and instruments that water utilities often draw upon, though not all options are available or meaningful in all countries.

The new category of investment generally referred to as 'climate finance' or 'Paris-aligned investment' is a good example, which is itself quite diverse with a particular focus on climate mitigation and/or adaptation outcomes. 'Paris alignment' is an increasingly widespread approach being applied by many national agencies, including bilateral organizations (e.g., overseas development assistance), multilateral organizations (e.g., multilateral development banks, environmental and climate funds), philanthropic groups such as foundations, pension funds (e.g., public sector pension groups), green and climate bonds, and private sector finance institutions (private equity, hedge funds and commercial banks). Many governments are now also creating specific national or subnational funds or loan programs to address climate risks, and some are also mainstreaming climate risk management components.

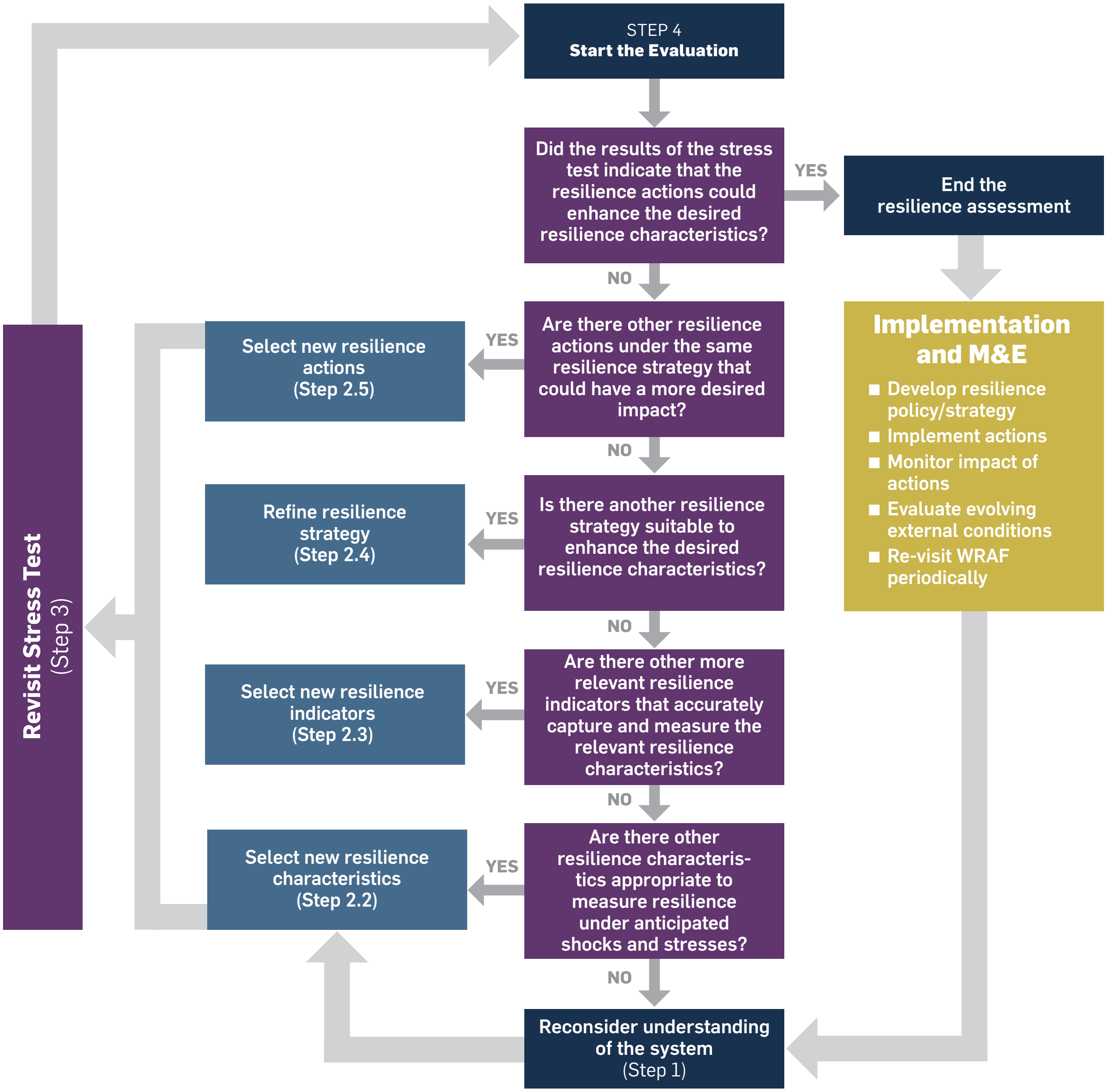
Certification programs for water resilience investments have been established for green and climate bonds (UNDRR, 2023). These programs ensure that both bond issuers and investors have a sense of accepted standards, expectations and confidence in the quality of the work. The implications of the 2015 Paris Agreement are beginning to proliferate across finance and funding institutions, as they are seeking to ensure that their investments align with key climate change policy instruments, such as Nationally Determined Contributions, five-year national climate mitigation and adaptation commitments, the first of which became active in 2021, and National Adaptation Plans, most typically found with least developed countries and often representing project shopping lists for overseas development assistance).

The mode of finance is important for resilience because it can have implications on the overall resilience assessment. For example, investments that are funded through climate finance channels may require additional climate assessment, potentially with a 'climate narrative' that describes how the project addresses specific societal and environmental issues such as addressing specific sensitive ecosystems, Indigenous or sensitive minority populations, women and girls, or other aspects of equity, loss and damage, or climate justice. The WRAF can also help with these issues by tracking a broader set of resilience indicators.

Additionally, the mode of finance can have implications for the cost of an investment. For example, climate finance through some channels, such as the Green Climate Fund, may only cover a portion of the 'additional costs' required for a project. This can necessitate blended (i.e., multi-source) financing to fully fund the investment, as well as higher transaction costs with loan qualification and preparation (Altamirano, 2021).

A decision tree (Figure 5) can be used to evaluate which parts of the overall assessment need to be evaluated and adjusted. The WRAF evaluation should conclude with the utility implementing the most appropriate resilience actions and monitoring their impact. Stakeholder engagement will be a key consideration during the evaluation step, as the impact of resilience actions should be assessed across all sectors and communities where possible. The decision tree provides a structured way to assess which aspects of the overall resilience assessment need to be adjusted based on the results of the stress test. While a sequential application of the steps in the decision tree is desirable, utilities may find it easier to do several steps in parallel or prioritize certain sub-steps based on the resources available. For example, a utility may want to start by adjusting the resilience characteristics of the strategy, and then move on to adjusting the actions, indicators and system boundary. Alternatively, a utility may want to prioritize adjusting the actions that are most likely to have a significant impact on the overall strategy.

FIGURE 5. EVALUATION AND FEEDBACK STEPS IN THE WATER RESILIENCE ASSESSMENT FRAMEWORK



Steps in Practice

This, Steps in Practice (SIP), section guides readers through the WRAF process using a hypothetical example of an urban utility in a large coastal metropolitan area in the United States. The organization is referred to as the Utility, and the metropolitan area it serves is the City. While not a detailed case study, this example highlights key elements of the WRAF process that will be helpful for practitioners.

SIP STEP 1: VISUALIZE THE SYSTEM

The Utility, a wastewater management entity under the City's Department of Environmental Services (DES), operates an extensive network of over 6,500 miles of sewer pipes that connect to 10 major wastewater treatment facilities across the City. These facilities collectively treat approximately 4 million cubic meters of wastewater daily, discharging the treated effluent into several surrounding water bodies.

The Utility caters to over 6.5 million residents in the City, encompassing both residential, commercial and industrial users. Extreme weather events pose a significant challenge to the Utility's service continuity, particularly in vulnerable communities. A notable instance occurred in 2010 when a major storm caused widespread structural damage, delayed emergency response times, and exposed frontline communities to floodwaters contaminated with raw sewage and hazardous waste.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Half of the City's sewerage system employs a combined sewer system (CSS), where a single pipe conveys both stormwater runoff and sewage to treatment plants. These plants are designed for a specific flow capacity, and during heavy rainfalls, untreated sewage and stormwater are often discharged directly into water bodies, known as combined sewer overflows (CSOs). CSOs degrade water quality and disrupt the biological integrity of local water bodies, hindering their ability to provide essential ecosystem services, such as recreation. The City has 500 sewage outfalls susceptible to CSO events.

The remaining half of the City utilizes a municipal separate stormwater system, which isolates stormwater in a dedicated piping system and directs it untreated into waterways. To mitigate pollution and reduce CSO events, the City initiated a green infrastructure (GI) investment program following the major storm in 2010, promoting the installation of rain gardens, green roofs and permeable pavements to slow, absorb and filter stormwater runoff.

STAKEHOLDER MAPPING

To initiate the WRAF process, the Utility organized a multi-stakeholder workshop, inviting representatives from community boards, local non-governmental organizations, academic institutions, businesses, fellow utility providers, government agencies and internal stakeholders.

Identifying and engaging key stakeholders is crucial for any WRAF project. The Utility, under the purview of the DES, collaborates with numerous stakeholders vested in maintaining the quantity and quality of the City's water resources. These stakeholders include:

- **Department of Environmental Services (DES):** The DES manages drinking water, wastewater, stormwater, GI and the City's waterways. These key mandates are all interconnected, and representatives of each unit should be included in this WRAF planning process. Aside from water-related matters, the DES also manages regulations and initiatives for air quality, resilience, recreation, education and more. This broad mandate supports the City's efforts to build long-term societal resilience.
- **Water Council:** The City's water and sewer infrastructure is funded by the revenue it collects through water and sewer rates. The Water Council is responsible for setting these rates and must ensure that they can fund the water and sewer system's operating and capital needs. The Water Council strives to set equitable and fair rates that encourage resilience and are easily understood by customers.
- **State Environmental Department:** The State Environmental Department seeks to conserve, improve and protect the environment and to prevent and control all forms of pollution. The organization enforces a variety of regulations and policies related to water quality and flooding, as well as legislation aimed at promoting environmental justice, mitigating climate change, and creating green jobs.
- **Environmental NGOs and civil society groups:** Several organizations and civil society groups are focusing on freshwater systems in and around the Utility's service area. These include
    - **Water Watch:** The mission of the Water Watch is to protect and restore the ecological integrity and productivity of the water bodies within and surrounding the City, which includes rivers and bays. The organization seeks to end pollution, improve public access, restore aquatic

habitats, support legislators and community organizations in resilience planning, and aid state regulators and citizen groups in planning for a sustainable watershed.

    - **River Warriors:** This organization serves to protect the freshwater habitats within the City. Their mission is twofold: to hold polluters accountable, often taking legal action, and to run a variety of public programs, workshops and volunteer events.
    - **Others:** Several other national environmental and conservation organizations were also invited to participate in the workshop. These NGOs and other organizations play key roles in driving the conservation agenda in the basin, facilitating collective actions, and empowering communities.
- **Community Board Representatives:** Community boards represent the 45 community districts that make up the City. The role of a board member is to consider the needs of the district that it serves and to advise elected government officials on matters that will impact the community. Community board members either reside, own a business, or have other significant interests in the district that they serve, and can therefore bring local perspectives to the WRAF planning process.

FORMULATING THE WRAF STEERING COMMITTEE AND WORKING GROUP

The Utility established a project Steering Committee (SC) to represent all stakeholders and make recommendations to decision-makers. The SC is responsible for the strategic direction of the WRAF implementation. To help operationalize the WRAF, the SC formed a Working Group (WG) to implement the WRAF. The SC also drafted the scope, mandate and governance structure of the WG, and shared a draft project plan with the Utility's management for refinement and approval.

The WG includes representatives from multiple user groups, sectors, levels of government and other key stakeholders identified in the mapping exercise. The goals and mandate of the WG are supported by a formal proclamation. The WG is responsible for implementing all stages of the WRAF and communicating the outcomes with all parties within the system regularly. The resource needs for the WG were identified and secured for the project.

Based on the WRAF steps being explored and the duration of piloting the framework, the WG elects to meet monthly. Workshops are held at the offices of the DES and are generally a half-day or all-day event.

Various subgroups were also formed to dive deeper into different elements of the WRAF. These subgroups included members from different departments working directly on or responsible for decisions, managing and operating relevant system components. For example, engineers, hydrologists and plant operators comprised the subgroup to cover the 'Robustness' of the infrastructure, whereas the legal department and communications experts were included in the subgroup to cover the 'Inclusiveness' of the system. During the monthly WG meetings, subgroup leads reported back on activities and outcomes. The structure of the WG and subgroups continued throughout the multiple WRAF iterations.

Once the WG was formed, the first task was to bring together all the relevant stakeholders to plan the implementation of the WRAF process. To do this, the WG organized an onboarding workshop. At the workshop, key stakeholders were clarified on the objectives of the project, the various tasks, and their key responsibilities. The workshop also helped to gather preliminary information that was useful for starting the implementation phase of the WRAF, beginning with the visualization of the system.

SIP STEP 1.1: DEFINE SYSTEM BOUNDARY

The system boundary for the WRAF is established based on the goals and resources available to the Utility in building resilience. The workshop attendees decided to do a system-level resilience assessment. To do that, they overlapped the local hydrological and administrative boundaries. It was decided to define the system boundary as the City's municipal boundary, as well as any surrounding water bodies where treated or untreated wastewater discharge may enter. This includes water bodies that are shared with parts of surrounding smaller municipalities. This boundary indicates the operational area of the Utility and is a suitable scale to undertake a system-level resilience assessment.

It was also decided that broader system-level resilience assessments could be undertaken at a later stage, which would potentially expand the system boundary to include watersheds that provide drinking water to the City.

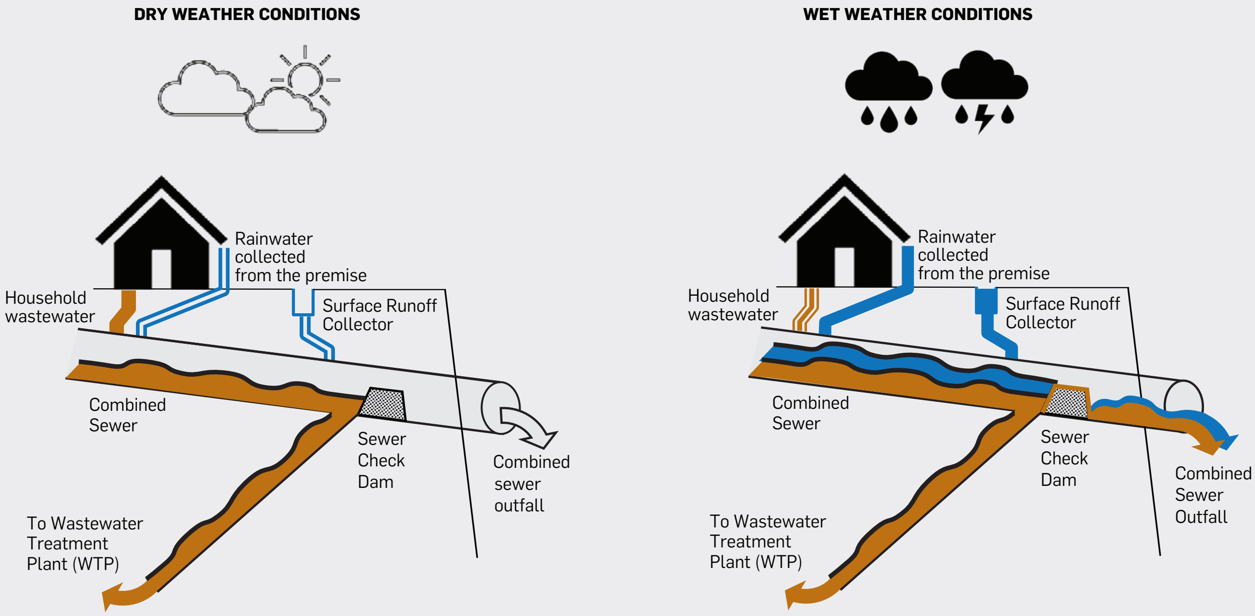
SIP STEP 1.2: IDENTIFY WATER CHALLENGES: STRESSES, SHOCKS AND DRIVERS

Following system boundary delineation, the WG prompted workshop attendees to consider the current and anticipated water-related challenges experienced within the system. Lists of common examples of challenges, stresses, shocks and their drivers are provided for the attendees to consider, refine and add in the context of the Utility.

In the workshop, several breakout tables were formed, where workshop attendees discussed and debated the most pressing water challenges. The workshop attendees collectively identified the following three critical challenges faced by the Utility:

- **Flooding, storm surge and sea-level rise:** Flooding can cause sewer overflows, which pollute waterways and put more stress on the CSS. Floodwater from storm surges can flood critical equipment at treatment plans, leading to spills of partially treated or untreated sewage into waterways. Additionally, sea level rise can exacerbate this flooding by blocking outfalls, making it harder for the sewer system to drain. It can also cause flow released from the wastewater treatment plants to back up during heavy rains, limiting the capacity of some plants and leading to CSO events (Figure 6). Nearly 15 per cent of the City's land area is in the 100-year floodplain. This area has more than 450,000 residents. The floodplain will encroach further inland with sea level rise.
- **Water quality:** The City's surrounding water bodies have historically suffered from high levels of pollution due to a range of factors, including industrial discharges, sewage overflows, and illegal dumping. While there have been tremendous efforts to improve water quality since the passage of the Clean Water Act, this historical damage persists, and water quality is still regularly impacted by CSO events and urban runoff.
- **Ecosystem functioning:** Because of these historic and current pollution issues, ecosystem services and local biodiversity have significantly declined. Pollution, combined with the historic overharvesting of shellfish and fish, has led to shifts in dominant aquatic species, further exacerbating water quality problems and encouraging the presence of invasive species.

FIGURE 6. COMBINED SEWER SYSTEM IN DRY AND WET WEATHER CONDITIONS IN THE CITY



The workshop attendees unanimously agreed that the City's sewer system is facing increasing pressure from population growth and climate change. Extreme weather events can overwhelm the system and lead to untreated sewage discharge. The attendees also agreed that these are the key challenges facing the City's sewer system and that it is important to act now to protect the City's water quality and public health.

After the workshop, the WG compiled a table of ongoing and anticipated stresses (Table 2) and shocks and their relevance to the challenges identified in the workshop (Table 3). These tables will inform later stages of the WRAF process.

TABLE 2. ONGOING/ANTICIPATED STRESSES AND THEIR DRIVERS IN THE SYSTEM

Stresses	Drivers	Remarks
Increasing sewage volumes	• Population growth • Extreme weather events • Urbanization	• Growing population leads to increase in wastewater volumes • Extreme weather events lead to increase in stormwater volumes • Urban planning practices and increases in hard surfaces channels stormwater into sewer systems, resulting in rapidly increasing volumes
Poor state of infrastructure	• Socio-economic priorities • Operations and maintenance	• Inadequate budgetary allocations across operations and maintenance functions • Retrofitting and maintenance of aging infrastructure is not matching the growing demand on sewer systems
Slow uptake of green infrastructure	• Socio-economic priorities • Political factors	• Budget/planning for rapid acceleration of GI projects are not adequate • Slow uptake from decision-makers in adopting GI projects
Institutional capacity	• Socio-economic priorities • Political factors • Operations and maintenance	• Inadequate staffing budgets • Lack of political will to capacitate departments • Lack of institutional capacity to handle increased demands on system operation
Regulatory environment	• Political factors • Poor governance and management	• Rigid and outdated regulations can influence the uptake of investments in GI, water quality/pollution measures, etc. • Lack of political will to adapt to new regulatory and practical measures.
Declining ecosystem function and biodiversity loss	• Operations and maintenance • Climate change • Population growth • Urbanization • Socio-economic priorities • Political factors	• Release of untreated wastewater and stormwater into water bodies can impact the health of aquatic ecosystems • Land use change impacting aquatic habitat • Awareness of the importance of ecosystem services can influence greater uptake and investments in GI and conservation projects • Introduction of alien species can impact local species and ecosystem functioning
Increasing non-point-source water pollution	• Inadequate infrastructure • Poor operation and maintenance • Population growth • Urbanization • Socio-economic priorities • Political factors	• The capacity of the infrastructure is not enough for increased sewer volumes • Existing infrastructure is poorly operated and maintained • Inappropriate waste management policy and behavior
Poor WASH services	• Inadequate infrastructure • Poor operations and maintenance • Population growth • Urbanization • Socio-economic priorities • Political factors	• Poor funding/ maintenance of services in poorer regions • Affordability of WASH services • Rapidly increasing populations in some locations exceeds the ability of utilities to provide adequate WASH services to all

TABLE 3. POTENTIAL SHOCKS AND THEIR DRIVERS IN THE SYSTEM

Shocks	Drivers	Remarks
Extreme events (storms, rainfall and snow)	• Climate change	• The frequency and magnitude of storm and rainfall events increased due to climate change
Infrastructure failure	• Operations and maintenance • Poor governance and management • Inadequate infrastructure • Socio-economic priorities • Political factors	• Lack of maintenance leads to increases in CSO events • Failure of infrastructure, e.g., wastewater treatment plant breaks, or is unable to handle the increased sewer volumes • Lack of policy, political will or appropriate risk assessments around emergency measures
Regulatory shifts	• Poor governance and management • Political factors • Operations and maintenance	• Changes in political priorities can influence investments, departmental mandates and overall projects and programs • Changes to regulations can require significant alterations to current infrastructure requiring major investment
Spiked point-source pollution	• Urbanization • Socio-economic priorities • Political factors	• Urbanization accelerating spikes in toxic chemicals or waste releases • Illegal dumping activities could result in significant water pollution and impacts to ecosystem functions

SIP Step 1.3: Establish water status and trends

At the workshop, attendees were asked to identify what data is available to measure and assess the magnitude of the current challenges, how it is collected, and who is responsible for collecting it. Table 4 provides a few examples of the challenges and the status and trends of these challenges.

TABLE 4. EXISTING/ANTICIPATED CHALLENGES, STATUS AND TRENDS IN THE SYSTEM

Challenges	Status	Trend
Extreme weather events		
Flooding, including tidal flooding	• 100-year flood already happened three times in the last five years	• Increasing frequency of flooding events
	• The 100-year floods submerge almost 15% of the total land area regularly	• Increasing magnitude of flooding events • Storm surges pushing the flood area further inland
	• 30 annual CSO events because of sewer system overload from flooding	• Increasing frequency of CSO events is increasing

Challenges	Status	Trend
Extreme rainfall events	• Historical records of surge level exceeded three times in the last five years	• Increasing magnitude of storm surges • Increasing frequency of storm surges
	• Two wastewater treatment plant and pumps were impacted by the surges in the last five years	• Increasing proportion of damage and threats
	• Category 3 hurricanes have occurred twice in the last six years	• Increasing magnitude of hurricanes • Increasing frequency of hurricanes
	• Over three decades, there has been an increase of 6"/15 cm of snowfall • Eight of the 10 biggest snowstorms in the City have happened between 1980 and 2020	• Increasing depth of snow cover • Increasing duration of snow cover
Coastal storm surge	• Approximately two wastewater plants impacted annually	• Upward trend due to climate change
	• Average of five pumps impacted annually leading to CSO events	• Increasing frequency of pumps submerged due to sea level rise • Increasing frequency of failure of pump operations
	• 120,000 residents impacted by coastal flooding	• Upward trend in duration of flooding • Increasing number of people impacted by coastal storm surges
Sea level rise	• Sea levels have risen one foot over the last 100 years • Sea levels expected to increase 10 to 30 inches by the 2050s, and 15 to 80 inches by the end of the century	• By the 2050s, the number of people living in the 1% annual chance floodplain could more than double
Water pollution		
Water pollution levels	• Water pollution levels exceeded repeatedly at 20 testing locations • Oil and other chemical waste are frequently washed into water bodies • High concentrations of hormones, microplastics and phthalates found in water and aquatic substrates	• Increasing dissolved oxygen levels • Increasing bacteria and pathogen levels • Other categories of pollutants worsening in many locations • Increasing concentration of oil and other chemical waste in water bodies • Increasing concentrations of hormones, microplastics and phthalates
Water quality standards breached	• Current water quality standards are often not maintained at key locations • More than 30 water quality standards breached annually as a result of CSO events	• Increasing frequency of breaching water quality • Increasing CSO events
Functioning of ecosystems		
Ecosystem health index	• Water quality standards are often not met • The Index of Biological Integrity is not optimal during CSO events	• More frequent breaches in water quality leading to loss in aquatic biodiversity • Overall decline in ecosystem health • Declining Index and other ecosystem health indicators

Challenges	Status	Trend
Aquatic biodiversity and population	• On average, water quality has improved in the last 50 years, leading to increases in bait fish, and subsequently the return of whales, dolphins, harbor seals and sharks	• Declining local endemism • Fewer migratory birds counted each year • Declining populations of shellfish and other invertebrates • Increasing oyster population through restoration efforts
Eco-hydrological connections	• Decreased vegetation cover due to increased urbanization • Siltation and other issues impacting flow regimes • Flooding or breaches of embankments breaking flow regimes • Reduced water quality impacting aquatic biodiversity	• Decline in key indicators of eco-hydrological connectivity

During the workshop, attendees also decided to identify the status and trends for each of the shocks, stresses and drivers. The granularity of assessment was important for this organization but may not be necessary for all contexts. The workshop attendees identified a range of relevant data and information for each challenge category. They also discussed how to collect further data and information for each challenge, stress, shock and driver to update the status and trends of the system after the workshop. This work will be further elaborated on by the WG after the preliminary assessment that happened during the workshop.

SIP STEP 2: DEVELOP RESILIENCE STRATEGY

By the end of Step 1, the WG and SC have a better understanding of the system boundaries and the challenges present within the system. They are also better positioned to understand the status and trends of different elements within the system. Using this information, they are now able to proceed to Step 2 and begin to examine their current resilience strategies and the elements influencing their current state of resilience.

SIP STEP 2.1: CONSIDER A SUITABLE RESILIENCE STRATEGY

As a key starting point under Step 2.1, the WG looked at their current strategies across different elements and departments of the Utility and categorized them into one of the three resilience strategies.

The current persistence strategy taken by the City is:

- **Investing in current infrastructure:** continue to invest in existing infrastructure to manage CSO events.

The current adaptation strategies taken by the City are:

- **Investing in new infrastructure:** invest in new infrastructure, such as storage tanks and treatment facilities, to help reduce the frequency and severity of CSO events.
- **Using green infrastructure:** use GI, such as rain gardens and permeable pavement, to capture stormwater before it reaches the sewer system.
- **Educating the public:** educate the public by providing information about how to prevent flooding of their homes and businesses.

The outcome of identifying the Utility's current resilience strategies helps them to better understand their current standing on resilience and to see where future changes in strategy and direction can occur. In some cases, the current resilience strategies may be appropriate to the nature and scale of the system and the challenges present in the system. In other cases, utilities may have to look at adopting alternative strategies to better align with the elements of the system.

SIP STEP 2.2: IDENTIFY KEY RESILIENCE CHARACTERISTICS

The WRAF process exposed the WG group to the key resilience characteristics present in the water system. They needed to determine which of these characteristics are important to the desired level of resiliency, given their current organizational goals, available resources, and current specific resilience practices across different departments. These practices include strategies for addressing various challenges, such as CSO events.

To select relevant resilience characteristics, the workshop attendees decided to prioritize one key challenge from the list of questions as well as those identified in Step 1. This challenge relates to improving GI throughout the City with a focus on historically underserved communities and those near wastewater treatment plants.

The WG discussed the merits of each resilience characteristic and landed on two, 'Robustness' and 'Inclusiveness,' which they felt were most in need of being addressed to build immediate resilience and improve on current functions. 'Robustness' is the ability of a system to withstand and recover from disturbances, while 'Inclusiveness' refers to the degree to which all stakeholders are involved in decision-making.

However, the WG also noted that several other key resilience characteristics are missing or weaker in the system. As strengthening all the resilience characteristics would help long-term water resilience goals, they also prepared a prioritized list of remaining resilience characteristics to implement next.

SIP STEP 2.3: IDENTIFY SYSTEM COMPONENTS AND RESILIENCE INDICATORS

SIP Step 2.3.1: Identify system components

The Utility's current priority is to provide wastewater management services under current and future climate conditions while achieving the highest degree of stakeholder inclusion. The selected resilience characteristics, **'Robustness'** and **'Inclusiveness,'** support this organizational priority. To enhance these two resilience characteristics, the WG assessed the components and subcomponents that comprise elements of these characteristics. This more granular approach will help the Utility better understand the elements of the system in more manageable pieces. These system components and subcomponents are selected based on how they influence the two selected resilience characteristics.

They used the ReST to identify different system components and subcomponents for each characteristic relevant to the Utility (Tables 5 and 6).

TABLE 5. SYSTEM COMPONENTS/SUBCOMPONENTS RELEVANT IN BUILDING 'ROBUSTNESS'

System component	System subcomponent	Notes
Socio-economic	Access to funds	• Ensures there is enough money available to finance and maintain water infrastructure. This is essential for preventing water systems from becoming degraded or failing.
Institutional	Regulatory	• Helps ensure that water infrastructure is designed and operated in a safe and sustainable manner. It also helps to prevent pollution and other environmental damage.
	Governance	• Ensures that water systems are managed effectively and efficiently. It also helps to ensure that there is a clear plan for the future of water resources.
	Operations/system management	• Ensures that water systems are operated and maintained in a way that minimizes risks and maximizes efficiency. It also helps to ensure that water is distributed fairly and equitably. • Helps ensure that we have the knowledge and skills necessary to manage water resources effectively. It also helps to develop new technologies and practices for water resilience.
Biophysical	Supply	• Ensures water quantity, quality from independent sources.
	Built and/or natural infrastructure	• Includes the physical structures that are used to store, transport and distribute water. It also includes the natural ecosystems that help to filter and purify water
	Operations and system management	• Ensures access to emerging tools and practices for the system to operate reliably and effectively.

TABLE 6. SYSTEM COMPONENTS/SUBCOMPONENTS RELEVANT IN BUILDING 'INCLUSIVENESS'

System component	System subcomponent	Notes
Socio-economic	Access to funds	• The level and frequency of stakeholder engagement will vary by utility. However, it should not be a superficial exercise. Utilities should sincerely solicit stakeholder input and provide clarity and transparency on how feedback is incorporated into decision-making. These budgets could cover the operational expenses of stakeholder engagement processes by the utility, as well as a ring-fenced fund to allow stakeholders to travel to these engagements or to hold such engagements where stakeholders are not burdened by travel costs.
	Knowledge systems	• Engagement/inclusion processes must consider integration of local and Indigenous knowledge into decision-making processes. Recognizing the value of local and Indigenous knowledge in building system resilience would ensure a more inclusive process. This will generate feeling of ownership by the local stakeholders.
Institutional	Affordability	• Does everyone have access to affordable water? This key question goes beyond just price. It considers if the system helps people from all walks of life, including low-income families, pay for water. Are there assistance programs or a basic allowance available? Does the community have a say in how water is managed? An inclusive system ensures everyone can afford and contribute to this vital resource.
	Governance	• Utilities can erode trust when they fail to deliver on promises, such as when they promise to provide a certain level of service but then fail to do so. Utilities should have review processes in place to assess incidents, such as flooding events, and to measure how well they are delivering on agreed-upon service levels. Utilities should also use their stakeholder engagement processes to develop service-level agreements with their stakeholders and explain how climate change may affect service delivery and the funding that may be needed to maintain those levels.

The workshop attendees were informed by the WG leads that the outcome of this exercise will inform the indicators selected for testing. This list was revised following Step 3, when the WG assessed the outcomes of the first round of resilience assessment.

SIP Step 2.3.2: Identify key resilience indicators

To measure the state (degree of effectiveness) of the resilience characteristics, the WG needed to identify suitable resilience indicators that can be measured either qualitatively or quantitatively. They identified indicators per resilience characteristic and system subcomponent such that the performance of these indicators under shocks and stresses reflects the strength of the resilience characteristic for the selected system subcomponent. The WG started by assessing the system at a high level using Tier 1 indicators. This assessment provided insight into how the system is performing under current conditions for the two selected characteristics. However, to implement practical resilience actions, a deeper assessment using Tier 2 resilience indicators is needed. The WG used the ReST and other existing approaches (e.g., risk assessment indicators, sustainability indicators) from their policies and operations to measure the current state of selected resilience characteristics.

The Tier 2 resilience indicators identified by the WG to measure the strength of the two selected resilience characteristics are presented in Tables 7 and 8. As resilience assessment is a new and evolving science, there are no extensive libraries of such indicators. A full list of Tier 1 and Tier 2 resilience indicators for general utilities applying the WRAF are presented in Appendix B.

TABLE 7. TIER 2 RESILIENCE INDICATORS FOR 'ROBUSTNESS'

System component	System subcomponent	Tier 2 resilience indicators
Socio-economic	Access to funds	Economic ability to finance/fund existing/planned operations and system maintenance
		Economic ability to finance/fund new or enhanced system infrastructure
Institutional	Regulatory	Level of regulatory compliance
		Ability of regulatory, policy and legal frameworks to enable new operational and infrastructure solutions
		Maturity of the legal and policy frameworks
		Practicality and applicability of the legal and policy frameworks
	Governance	Degree that investments in new infrastructure development is prioritized
		Degree to which investments in infrastructure operations and maintenance is prioritized
		Degree of authority over water infrastructures and services
	Operations/ system management	Level of competency of system operators/managers
		Capacity to operate the available technology reliably and effectively
		Ability to adaptively manage system infrastructure
		Presence of disaster preparedness and emergency management plans
		Frequency of data collection
		Quality of data collection
		Knowledge to operate the available technology reliably and effectively
Biophysical	Supply	Degree of independence of different available water sources
		Degree of diversity of water sources
		Degree of reliability of water quantity from different sources
		Degree of reliability of water quality from different sources
	Built and/or natural infrastructure	Suitability of infrastructure design and placement
		State of infrastructure to withstand shocks and stresses
		Level of maintenance of infrastructure
		Ability of the constructed/natural ecosystem to provide goods and services
		Ability of infrastructure to withstand shocks and stresses
	Operations/ system management	Access/availability to technology for the system to operate reliably and effectively
	Technology	Level of effectiveness of infrastructure monitoring systems
	Biodiversity	Degree of environmental monitoring and evaluations

TABLE 8. TIER 2 RESILIENCE INDICATORS FOR 'INCLUSIVENESS'

System component	System subcomponent	Tier 2 resilience indicators
Socio-economic	Access to funds	Economic ability to sufficiently fund regular stakeholder participation in system planning
	Knowledge systems	Level of integration of local and Indigenous knowledge into decision-making processes
Institutional	Affordability	Economic ability of stakeholders to afford services from the system
	Governance	Ability of stakeholders to participate in decision-making processes
		Presence of processes to overcome barriers to participation
		Level of diversity of stakeholders included in decision-making
		Level of trust, engagement and cooperation between stakeholders
		Level of accountability in implementation

The WG moved on to Step 3.1 to understand the current state of resilience for the selected resilience characteristics. They used expert knowledge, existing system performance assessment results, staff/expert group surveys, and other methods to score each indicator.

This benchmark resilience assessment using the ReST provided a 'resilience scorecard' that helped the WG identify which resilience indicators are performing well and where they need to be prioritized per system subcomponents (Table 9).

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TABLE 9. BASELINE RESILIENCE STRESS TEST (BENCHMARKING STAGE) USING TIER 2 RESILIENCE INDICATORS FOR 'ROBUSTNESS'

System component	System subcomponent	Tier 2 resilience indicators	Without resilience actions
Socio-economic	Access to funds	Economic ability to finance/fund existing/planned operations and system maintenance	Poor
		Economic ability to finance/fund new or enhanced system infrastructure	Good
Institutional	Regulatory	Level of regulatory compliance	High
		Ability of regulatory, policy and legal frameworks to enable new operational and infrastructure solutions	Medium
		Maturity of the legal and policy frameworks	High
		Practicality and applicability of the legal and policy frameworks	High
	Governance	Degree that investments in new infrastructure development is prioritized	Medium
		Degree to which investments in infrastructure operations and maintenance is prioritized	Medium
		Degree of authority over water infrastructures and services	High
	Operations/ system management	Level of competency of system operators/managers	High
		Capacity to operate the available technology reliably and effectively	High
		Ability to adaptively manage system infrastructure	Good
		Presence of disaster preparedness and emergency management plans	Low
		Frequency of data collection	Medium
		Quality of data collection	High
		Knowledge to operate the available technology reliably and effectively	High
Biophysical	Supply	Degree of independence of different available water sources	Low
		Degree of diversity of water sources	High
		Degree of reliability of water quantity from different sources	High
		Degree of reliability of water quality from different sources	High
	Built and/or natural infrastructure	Suitability of infrastructure design and placement	Good
		State of infrastructure to withstand shocks and stresses	Poor
		Level of maintenance of infrastructure	Good
		Ability of the constructed/natural ecosystem to provide goods and services	Good
		Ability of infrastructure to withstand shocks and stresses	Poor
	Operations/ system management	Access/availability to technology for the system to operate reliably and effectivelY	Excellent
	Technology	Level of effectiveness of infrastructure monitoring systems	High
	Biodiversity	Degree of environmental monitoring and evaluations	High

Note: The resilience scores are color coded where green means the indicator is performing at the optimum level, orange means the performance is just average and there is room for improvement, and red means the indicator has failed/is performing poorly and needs immediate attention/prioritization.

SIP STEP 2.4: REFINE RESILIENCE STRATEGY

The resilience scorecard revealed that some system subcomponents are performing poorly or only at medium for several resilience indicators. The WG found this information eye-opening and shared the resilience scores with the full SC. They also found that their selected resilience strategy for individual system components may need adjusting in light of the resilience scorecard. After consultation, the WG used this information to prioritize where to focus on refining resilience strategies (Step 2.4) and developing appropriate resilience actions (Step 2.5).

For complex systems, such as those in the Utility, multiple resilience strategies may be applicable, as different parts of the system may be affected by different factors. Therefore, it may be necessary to tailor the strategy to each system component/sub-component.

For example, to strengthen the resilience characteristic 'Robustness,' the economic system subcomponent needs adaptation strategies such as finding new funding. The institutional subcomponent also needs adaptation strategies, such as increasing investment. However, three indicators for the system subcomponent 'built and natural infrastructure' scored good, and two scored poorly. Each of these subcomponents may need a different strategy to improve the performance of these indicators (Table 10).

TABLE 10. EXAMPLE STRATEGY SELECTION FOR THE SYSTEM SUBCOMPONENT 'BUILT AND NATURAL INFRASTRUCTURE' UNDER THE SYSTEM COMPONENT 'BIOPHYSICAL' FOR THE RESILIENCE CHARACTERISTIC 'ROBUSTNESS'

System component	System subcomponent	Tier 2 resilience indicators	Without resilience actions	Suggested resilience strategy
Biophysical	Built and/or natural infrastructure	Suitability of the infrastructure design and placement	**Good**	Persistence/ Adaptation
		State of infrastructure to withstand shocks and stresses	**Poor**	Adaptation/ Transformation
		Level of maintenance of infrastructure	**Good**	Persistence/ Adaptation
		Ability of the constructed/natural ecosystem to provide goods and services	**Good**	Persistence/ Adaptation
		Ability of infrastructure to withstand shocks and stresses	**Poor**	Adaptation/ Transformation

The Utility implemented a resilience strategy tailored to its current needs. The strategy will be monitored and adjusted as needed, as new information, priorities or knowledge may emerge.

SIP STEP 2.5: DEVELOP RESILIENCE ACTIONS

The WG developed a plan to implement the resilience strategies they had chosen for each system subcomponent. They consulted with experts in the field to create a list of activities that could improve the resilience score for the identified indicators per system subcomponent. Some of these activities required new work plans, while others had existing work plans that could be improved with some fine-tuning. For example, the WG could develop a new work plan to increase the robustness of the system's infrastructure, or they could improve an existing work plan by adding more training for staff on how to respond to emergencies. The WG also held several consultations with stakeholders through open hall meetings, online and in-person meetings, and surveys. This engagement process helped the WG to refine the resilience actions (Table 11) they had selected for stress testing (Step 3) before implementation. For example, the WG learned from stakeholders that they were concerned about the reliability of the system's communication channels. This feedback led the WG to add a new activity to their plan to upgrade the system's communication infrastructure.

TABLE 11. RESILIENCE ACTIONS SELECTED TO ENHANCE 'ROBUSTNESS'

System component (subcomponent)	Tier 2 resilience indicators	Benchmark resilience score	Selected resilience actions
Socio-economic (Access to funds)	Economic ability to finance/fund existing/planned operations and system maintenance	**Poor**	• Release or redistribute additional budget for capital expenditure or operational expenditure functions • Apply for additional budget through municipal or federal budget or infrastructure grant processes • Plan for future budget in next project funding period
	Economic ability to finance/ fund new or enhanced system infrastructure	**Good**	• Release or redistribute additional budget for capital expenditure or operational expenditure functions • Apply for additional budget through municipal or federal budget or infrastructure grant processes • Plan for future budget in next project funding period
Institutional (Regulatory)	Ability of regulatory, policy and legal frameworks to enable new operational and infrastructure solutions	**Medium**	• Undertake systematic reviews of existing policies to ensure appropriate scope and practicality • Develop new policies to incentivize or promote new operational and infrastructure solutions • Develop a strategy to reduce/avoid discharge of untreated sewage into waterways by 2060
Institutional (Governance)	Degree that investment in new infrastructure development is prioritized	**Medium**	• Develop policies and mandates that prioritize development of new infrastructure • Develop minimum flood resilience standards for shoreline assets • Develop a stormwater flooding adaptation plan to establish a citywide flood protection target for stormwater infrastructure • Develop infrastructure to capture stormwater at the source • Ensure proper planning timing to ensure that infrastructure design and implementation elements are adequately considered and prioritized
	Degree that investment in infrastructure operations and maintenance is prioritized	**Medium**	• Develop policies and mandates that prioritize development of new or existing infrastructure • Ensure proper planning timing to ensure that infrastructure design and implementation elements are adequately considered and prioritized

System component (subcomponent)	Tier 2 resilience indicators	Benchmark resilience score	Selected resilience actions
Institutional (Operations/ system management)	Ability to adaptively manage system infrastructure	**Good**	• Undertake skills assessment to ensure that all system operators are appropriately trained • Provide additional training to system operators where appropriate • Ensure the appropriate number of key system operators • Ensure that demand does not outstrip the supply of goods and services by key infrastructure • Ensure appropriate guidelines and operating instructions to ensure appropriate compliance and performance
	Presence of disaster preparedness and emergency management plans	**Low**	• Assess existing plans/processes to determine areas for improvement • Develop suitable disaster management plans and provide resources to undertake it • Host workshops and events to enhance knowledge and capacity on emergency management
	Frequency of data collection	**Medium**	• Create a timetable/schedule for data collection • Ensure that personnel have sufficient time dedicated to data collection • Ensure that there are adequate personnel dedicated to data collection
Biophysical (Supply)	Degree of independence of different available water sources	**Low**	• Increase desalination capacity • Consider inter-basin water transfer • Import water virtually in embedded in water intensive commodities
Biophysical (Built and/or natural infrastructure)	Suitability of infrastructure design and placement	**Good**	• Undertake risk assessment to ascertain suitability of siting and design elements • Determine cost/benefit ratios for mitigation or response options
	State of infrastructure to withstand shocks and stresses	**Poor**	• Undertake risk assessment to ascertain state of infrastructure • Run simulation models to determine outcomes of best- and worst-case scenarios • Determine cost/benefit ratios for mitigation or response options
	Level of maintenance of infrastructure	**Good**	• Undertake maintenance and operational expenditure reviews over a certain period • Determine cost/benefit ratios for mitigation or response options
	Ability of the constructed/ natural ecosystem to provide goods and services	**Good**	• Undertake risk assessment to ascertain ability/suitability of GI options • Run simulation models to determine outcomes of best- and worst-case scenarios • Create nature-based stormwater management solutions that provide multiple functions, including shade, water and air quality improvement, and wildlife habitats • Restore wetlands for flood risk reduction, conservation and open space benefits • Expand the implementation of the City's GI investment program
	Ability of infrastructure to withstand shocks and stresses	**Poor**	• Undertake infrastructure risk assessment • Re-design/rehabilitate or add safety measures to the existing infrastructures • Replace risky infrastructures/components with more robust ones

SIP STEP 3: TEST IMPACT OF RESILIENCE ACTIONS ON RESILIENCE CHARACTERISTICS

SIP STEP 3.1: BENCHMARKING STAGE

The Utility used a two-step process to assess the resilience of its water system. In Step 3.1, they conducted a benchmark resilience assessment to determine the current level of resilience using the indicators identified by the WG. This testing was carried out immediately after selecting system subcomponents and resilience indicators in Step 2.3. The scoring outcomes of the benchmark assessment were used to refine the resilience strategy and develop appropriate resilience actions.

SIP STEP 3.2: VALIDATION STAGE

In Step 3.2, the WG conducted a second stress test to assess the impact of the newly developed/selected resilience actions and prepared a second resilience scorecard. The WG used a combination of analytical models and human technical expertise to investigate the impacts of the resilience actions. As they found that the Utility is not expected to achieve the appropriate level of resilience for all the indicators after the exercise, they will revisit the WRAF steps. They may need to add other available resilience actions from Step 2.5. The anticipated resilience scores for the selected resilience characteristic 'Robustness' if all the selected resilience actions were implemented are presented in Table 12. The Utility notified the outcome of the process to internal and external stakeholders and will further engage with them in the next round of the WRAF.

TABLE 12. RESILIENCE STRESS TEST (VALIDATION STAGE) FOR 'ROBUSTNESS'

System component (subcomponent)	Tier 2 resilience indicators	Resilience score	
		Without resilience actions (benchmarking)	With resilience actions (validation)
Socio-economic (Access to funds)	Economic ability to finance/fund existing/ planned operations and system maintenance	**Poor**	**Good**
	Economic ability to finance/fund new or enhanced system infrastructure	**Good**	**Excellent**
Institutional (Regulatory)	Ability of regulatory, policy and legal frameworks to enable new operational and infrastructure solutions	**Medium**	**Medium**
Institutional (Governance)	Degree to which investment in new infrastructure development is prioritized	**Medium**	**High**
	Degree to which investment in infrastructure operations and maintenance is prioritized	**Medium**	**High**
Institutional (Operations/system management)	Ability to adaptively manage system infrastructure	**Good**	**Good**
	Presence of disaster preparedness and emergency management plans	**Low**	**Somewhat**
	Frequency of data collection	**Medium**	**High**
Biophysical (Supply)	Degree of independence of different available water sources	**Low**	**Medium**
Biophysical (Built and/or natural infrastructure)	Suitability of the infrastructure design and placement	**Good**	**Medium**
	State of infrastructure to withstand shocks and stresses	**Poor**	**Medium**
	Level of maintenance of infrastructure	**Good**	**Medium**
	Ability of the constructed/natural ecosystem to provide goods and services	**Good**	**Excellent**
	Ability of infrastructure to withstand shocks and stresses	**Poor**	**Medium**

SIP STEP 4: EVALUATE

During the last workshop held for the inaugural WRAF assessment, the WG acknowledged that the resilience actions are improving the performance of several individual resilience indicators, indicating that long-term resilience is being enhanced for the selected resilience characteristics. However, it is also important to evaluate the overall WRAF process using the evaluation schematic (see Figure 5) for the remaining resilience characteristics. The Utility has decided that the resilience actions for 'Robustness' do not need revision at this stage, though some aspects of 'Inclusiveness' can be improved. Through this evaluation step, the Utility can identify new characteristics, indicators and actions to further enhance its long-term resilience. The next step is to develop resilience actions for the rest of the resilience characteristics and undertake a stress test to evaluate their effectiveness. If they find that their chosen strategy under some characteristics is not suitable for different kinds of shocks and stresses, they may need to revisit strategy selection.

The WRAF can be applied in a modular fashion and should be revisited periodically. The Utility focused on two specific resilience characteristics with a narrow boundary in the first round of the WRAF assessment and implementation, which can be expanded in the future with additional characteristics as relevant.

Several scenarios could trigger another round of the WRAF, such as changes in system subcomponents, shocks and stresses, resilience goals, or other internal factors. They may re-evaluate their resilience using the WRAF on a regular timeline (every five years) depending on the context and scenario.

Conclusions

Climate change is amplifying the uncertainties, shocks and stresses that have always been endemic to managing water systems and, in some cases, introducing new drivers. Successfully navigating these shoals will require utilities to integrate resilience thinking into all facets of utility management, from operations to long term planning. This guidance is intended for all utilities interested in enhancing resilience, whether they are exploring resilience for the first time or are looking to enhance existing resilience efforts.

The WRAF is a methodology to assess the resilience of water systems and to ensure that efforts to enhance resilience are strategic, coherent and effective. WRAF should be viewed as an iterative process given that new shocks and stresses may emerge, and the system itself may evolve over time. Not all of these drivers will be negative, and not all of them will be climate related. For example, if a new system subcomponent is added to the water management system, the WRAF can be used to assess how this change will affect the overall resilience of the system. Similarly, if a new shock or stress emerges, the WRAF can be used to assess the vulnerability of the system to this new threat. As a result, it is important to regularly assess the resilience of a system and adjust as needed to ensure that it remains capable of meeting its objectives.

The WRAF can also help utilities prepare for multiple future scenarios by identifying key choices and trade-offs needed to build resilience. The guidance presents the key resilience steps that utilities can take to start implementation of the WRAF. This includes illustrative examples of resilience indicators, as presented in the ReST, that can be used to assess an organization's state of resilience during the WRAF process. As utilities gain experience and build capacity, they may expand the scope of their assessment to include broader collective action, which can be supported by the resources provided in the guidance. It is hoped that this document is the start of a process for building a larger community of resilience practice for utilities worldwide.

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OTHER RELEVANT LINKS AND RESOURCES

City Resilience Framework: a unique framework developed by Arup, with support from the Rockefeller Foundation, based on extensive research in cities. It provides a lens to understand the complexity of cities and the drivers that contribute to their resilience. Looking at these drivers can help cities assess the extent of their resilience, identify critical areas of weakness, and identify actions and programs to improve the city's resilience. [Link]

US EPA Climate Resilience and Awareness Tool (CREAT): provides users with the knowledge needed to prepare for and address impacts due to extreme weather events. Designed for water, wastewater and stormwater utilities, CREAT uses a series of intuitive modules, as well as projection data and monetized risk results, to help users complete a risk assessment. [Link]

'**City Water Resilience Approach (CWRA):** provides clear insights on water program sequencing and prioritization, helping clients engage with water system complexity and prepare for demand and use changes. It also helps unlock investment and funding for water infrastructure, prioritizing nature-first interventions over hard infrastructure where possible. [Link]

US Water Alliance One Water Approach: an integrated and inclusive approach to water management that cuts across silos and encourages holistic thinking. It is about diverse stakeholders coming together to solve water challenges. [Link]

Appendices

APPENDIX A: UTILITY SPECIFIC CONTEXTS

GEOGRAPHIC

The amount of water in a basin sets the stage for the availability of supply, making the geographical context for utilities a crucial one. Utilities often operate in multiple hydrological basins, including those that are not connected hydrologically, but rather through water transport and storage infrastructure and services. Hence, a utility may have different hydrological boundaries (basins) connected by the management boundaries (transport of water, connecting infrastructures, governing authority, etc.). For example, the City of Los Angeles operates entirely within the Colorado River basin (a fraction of which is geographically located in southern California), while most other California municipalities rely on water from in-state basins, managed by the California State Water Project.

POLITICAL

The constituents of a utility are the customers they serve, which frames the immediate political context of their operations. The delineation of the utility's basin of interest, however, has the potential to dramatically expand the political boundaries that a utility must operate within—following the previous distinction between the hydrological and management boundaries. If a utility, for example, is deriving its supply from only a single basin or catchment, the political boundaries should mirror these hydrological boundaries. In addition, given how intertwined water is with other aspects of society, such as agriculture, energy production, recreation, ecological functions, etc., they will likely have to contend with and address the multitude of issues that play out within that basin.

Although the reach of utilities may transcend political boundaries, they typically serve customers within a specific political boundary and are therefore governed by those political entities, whether it be municipal, county, regional or state/provincial. In some cases, several decision-makers from different departments, organizations or tiers of government are required to collaborate on the governance and management of the water system. This multi-partner decision-making can be very strategic in some contexts, and very onerous and ineffective in others.

FINANCIAL

Alignment of financing and revenue sources is a key balancing act for most utilities. The funding base for utilities is often derived largely from the sale of water and water-related services to its customer base, with the revenue being a product of the rate charged for these goods and services and the volume of water sold. The rates charged are typically approved by the governing body of the utility and/or other utility regulators. This layered set of constituencies—direct customers that use water supplied by the utility, non-customers who may be affected by the utility's reach and seek to affect the utility's operations and elected and/or appointed officials who can set the policy and financial direction of the utility—ultimately all affect and drive utility decision-making. This means that utilities may need to find new ways to fund resilience measures.

Additionally, utilities often have a patchwork of modern and legacy investments, which can make it difficult to plan appropriately. For example, a utility may have some new, efficient water treatment plants, but it may also have some older, less efficient plants that are still in use. Effective integration or strategic planning (including retiring some infrastructure) is needed to ensure optimal operations and maintenance across the system.

REGULATORY

Water utility regulations are a fundamental and longstanding component of modern economies. A large and complex set of regulations and statutes are frequently essential aspects of the utility operating environment. For example, in the United States, the Safe Drinking Water Act and the Clean Water Act are major statutes that establish standards for utilities, and also drive budgets and capital planning. In the European Union, the Water Framework Directive and voluntary UNECE Protocol on Water and Health (UNECE and WHO, 1999) play similar roles.

There is a constant push and pull on how regulations can either support or constrain financial and capital planning decisions for water resilience. For example, the US Clean Water Act can drive investments towards water quality improvements, but this may limit how much capital can be directed towards other resilience issues such as urban flooding. Additionally, in many countries, emerging climate-related regulations are more likely to focus on greenhouse gas emissions and fuel consumption than water resilience issues.

Regulations can become inflexible and difficult to change. Altering or changing them is often a significant undertaking and by no means expedient. As a result, change happens very slowly and methodically, often with much deliberation and litigation. Rigid regulations can be a barrier to developing a resilience strategy, especially if the strategy requires significant changes to the way water utilities operate. Outdated regulations may not be able to accommodate the necessary changes, and regulations that are copied from other contexts may not be feasible in the local context. Additionally, regulations that are not enforced can create the illusion of a regulatory system, but they do not actually provide any protection.

INFRASTRUCTURE

Utilities need to carefully consider the needs of their communities, the availability of resources, and the financial implications of their decisions when planning. The following are the unique infrastructural contexts that make it difficult for utilities to plan effectively:

- **Infrastructure-intensive sectors:** Utilities are responsible for managing large, complex infrastructure systems that are essential to the functioning of our society. For example, the Seattle Public Utilities drinking water system includes more than 2,700 kilometers of pipes buried below the streets of the city.
- **Long-lived assets:** Many utility assets are designed to last for many decades, which means that future options are highly constrained by past and current decisions. For example, a water treatment plant that was built 50 years ago may still be in use today, even though it may not be as efficient or effective as newer plants.
- **Stranded assets:** Some utility assets may become stranded, meaning that they are no longer relevant, efficient or useful, even though they may be quite functional. This can happen due to changes in water demand, technology or regulations. For example, a water pipeline that was built to serve a small town may become stranded if the town grows and the pipeline is no longer needed.

- **Engineering mindset:** Water utilities have traditionally focused on building physical infrastructure, such as distribution networks, sewer systems and treatment plants. This is because capital funding for infrastructure development has been more readily available than operational or maintenance funding. This engineering mindset has led to a focus on efficiency and reliability, but it has neglected financial sustainability. To address this challenge, water utilities need to complement their focus on physical assets with other strategies, such as financial signals, marketing and behavior modification. These strategies can help ensure financial sustainability and reliable water services.
- **Management, operation and maintenance:** The management of utility infrastructure varies globally, depending on the ownership, regulatory environment and availability of funding. The funding can come from governments, private companies, development banks, funding institutions or international organizations. The responsibility for management typically falls to government agencies, private companies or regulatory authorities. In the United Kingdom, private companies run public water services, but they face pressure to minimize investment. As a result, both private and public utilities often take the path of least resistance by making do with current investments and systems.
- **Meeting current and future water demands:** Water utilities must meet the needs of both current and future populations, while also planning for climate change. This is a challenge, as it requires building out the current system while also providing essential, reliable service. This standard is not yet met for billions of people, but it is an expectation in most high- and middle-income countries and an aspiration for most low-income countries.

GOVERNANCE AND MANAGEMENT

Generally, there is a low tolerance from stakeholders for disruptions in service or changes in institutional arrangements. This means that utilities need to be careful to manage expectations and communicate effectively with stakeholders. There is often a lack of shared vision on building resilience for utilities, implying that they need to work together to develop a common understanding of the challenges and opportunities.

Many utilities have conventional modes for collecting, interpreting and reporting data. Many of the data analytics used by water utilities are designed to address well-understood concerns. However, the challenges posed by climate change are complex and evolving, and these traditional analytics may not be effective in predicting how the system will change.

ECOLOGICAL

Ecosystems are dynamic systems that interact with water resources in complex ways. They can affect the transport, timing, quantity and quality of water, and they can be affected by these factors in turn. Utilities rely on ecosystems to provide these services, but they can also have a negative impact on natural systems. For example, dams can disrupt the natural flow of water, which can lead to flooding and erosion. Water pollution can also damage ecosystems, making them less able to provide the services that utilities need. Traditional engineering approaches often ignore the role of ecosystems, but this is a mistake. Ecosystems are essential for the long-term management and reliability of water utilities. If we value and recognize the role of ecosystems, we can restore, manage or conserve them through nature-based solutions and other approaches to make our water utilities more resilient.

APPENDIX B: WATER RESILIENCE INDICATORS FOR UTILITIES

ILLUSTRATIVE LIST OF TIER 1 RESILIENCE INDICATORS

Resilience Characteristic	Tier 1 Resilience Indicator	Measure	Score Range	Notes
Robustness	Percentage of the time that service levels are being met under current and future climate conditions	Low Medium High	Low (<80%) Medium (80–99%) High (>99%)	Service availability can be measured by assessing the frequency and duration of service interruptions, as well as the time it takes for services to be restored after an interruption. Does the system continue to operate and deliver levels of service even under different conditions/scenarios (e.g., normal versus shock events or through persistent stresses)? Ideally the levels of service are mutually agreed upon between the utility and stakeholders through an inclusive process. The higher the percentage, the more robust the system is.
Redundancy	The ability of backup components to perform key or critical functions during system failure	Low Medium High	Low (<2%) Medium (2–5%) High (>5%)	The system is designed with extra resources or capacity built in to support any deficit in capacity due to outages, stresses or shocks. The existence of such back-up systems is not sufficient for robustness, however. The backup components must be in place, operational and reliable.
Flexibility	The degree to which a system can adapt to change by making strategic choices and realizing new options in key and critical system functions	Low Medium High	Qualitative assessment/ value judgment	The higher the willingness or inbuilt capacity, the greater the flexibility. Examples could include willingness and ability to re-write and implement planning and policy documents, invest in alternate solutions, or operate the system to meet changing demands.
Integration	The existence of practices, policies and regulations that enable the upside benefits of integration while minimizing the potential downside risks	None Minimal Sufficient	Qualitative assessment/ value judgment	The integration of systems and organizations can be assessed across policies, projects, programs and infrastructural elements. A high score for integration indicates that all system components are well-integrated and can be isolated or severed. However, integration can also introduce security vulnerabilities and coordination challenges. Therefore, it is important to carefully assess the risks and benefits of integration before implementing it.
Inclusiveness	Level of inclusion of diverse stakeholders in decision-making for the system	Low Medium High	Qualitative assessment/ value judgment	Inclusive decision-making is the process of involving all stakeholders in making key decisions. This includes considering the perspectives of all stakeholders and adopting them as appropriate. Inclusive decision-making can lead to higher levels of inclusiveness, but it is not always possible or necessary. For example, real-time or near-term operational decisions may not be able to accommodate the input of all stakeholders.
Justice and Equity	Degree of provision of fair and equitable water-related services for all users in the system	Low Medium High	Qualitative assessment/ value judgment	A system with a high degree of justice and equity is one where most water-related services are fairly distributed to all stakeholders. This includes access to water of suitable quality and sufficient quantity to meet demand.

ILLUSTRATIVE LIST OF TIER 2 RESILIENCE INDICATORS

RESILIENCE CHARACTERISTIC: ROBUSTNESS

System Component	System Sub-component	Tier 2 Resilience Indicator	Measure	Score Range	Notes
Socio-economic	Access to funds	Economic ability to finance/fund existing/ planned operations and system maintenance	Poor Good Excellent	Poor (<70%) Good (70-95%) Excellent (>95%)	Mobilization and expenditure of the operations and maintenance budget is effective and efficient for both planned and unplanned expenditure under shifting climatic and other conditions (e.g., demographic change, economic change, etc.).
	Access to funds	Economic ability to finance/fund new or enhanced system infrastructure	Poor Good Excellent	Poor (<70%) Good (70-95%) Excellent (>95%)	Mobilization and expenditure of the capital budget is effective and efficient - for both planned and unplanned expenditure under shifting climatic and other conditions (e.g., demographic change, economic change, etc.)
Institutional	Regulatory	Level of regulatory compliance	Low Medium High	Qualitative assessment/ value judgment	Willingness and ability of utilities to abide by laws, by-laws, policies etc. Compliance can be attained via incentives, fines, guidance, behavior and mindset changes. Utilities that follow/abide by rules and regulations create a more reliable and effective system.
	Regulatory	Ability of regulatory, policy and legal frameworks to enable new operational and infrastructure solutions	Low Medium High	Qualitative assessment/ value judgment	Intended to capture the ability of organizations to work within current regulatory structures to enable new approaches, e.g., NBS, to be implemented.
	Regulatory	Maturity of the legal and policy frameworks	Low Medium High	Qualitative assessment/ value judgment	This indicator assesses the extent to which a water system's legal and policy frameworks are well-developed, comprehensive, and effectively implemented to support the system's overall effectiveness and reliability. The more mature these regulations are, the more predictable and stable the utilities' operations become.
	Regulatory	Practicality and applicability of the legal and policy frameworks	Poor Good Excellent	Qualitative assessment/ value judgment	Having a comprehensive national framework that deals with reliability and effectiveness is essential, at the same time we need appropriate local level laws/by-laws to be more specific in the local context.
	Governance	Degree that investment in new infrastructure development is prioritized	Low Medium High	Qualitative assessment/ value judgment	Level of priority in allocating sufficient capital budget to ensure reliability and effectiveness. The higher the degree of prioritizing capital investment, the greater potential for building robustness in the system.
	Governance	Degree that investment in infrastructure operations and maintenance is prioritized	Low Medium High	Qualitative assessment/ value judgment	Level of priority in allocating sufficient operations and maintenance budget to ensure reliability and effectiveness of existing infrastructure. The higher the degree of prioritization, the greater potential for building robustness in the system.
	Governance	Degree of authority over water infrastructures and services	Low Medium High	Qualitative assessment/ value judgment	Utilities have the authority/mandate to develop appropriate resources and infrastructure, demand management mechanisms, impose restrictions, etc. Those with a high degree of authority can effectively execute necessary functions to ensure effective the delivery of water related goods and services. On the other hand, limited authority can hinder a system's ability to adapt to changing conditions or respond to emergencies, potentially compromising the service delivery.
	Operations/ system management	Level of competency of system operators/ managers	Low Medium High	Qualitative assessment/ value judgment	Effective water-related goods and services delivery hinges on the ability of system managers to operate and execute essential functions. Are employees sufficiently trained to implement and operate available technology? Effective technology operation is crucial for organizations to achieve their goals and optimize operational efficiency. Does a utility have either in-house capacity with the necessary understanding of resilience to develop an action plan, or the ability to outsource this role? Does the capacity have requisite quantitative and semi-quantitative approaches, making use of data, sensitivity analysis, modeling, and measurements of uncertainty and confidence?

System Component	System Sub-component	Tier 2 Resilience Indicator	Measure	Score Range	Notes
Institutional	Operations/ system management	Capacity to operate the available technology reliably and effectively	Poor Good Excellent	Qualitative assessment/ value judgment	This indicator assesses whether the utility has sufficient employee resources with the necessary skills and expertise to implement, operate, and maintain available technology effectively.
	Operations/ system management	Ability to adaptively manage system infrastructure	Poor Good Excellent	Qualitative assessment/ value judgment	This is intended to capture how well the infrastructure can be operated in an adaptive manner to manage climatic changes or additional demands or challenges in the system.
	Operations/ system management	Presence of disaster preparedness and emergency management plans	No Somewhat Yes	Qualitative assessment/ value judgment	A water utility should possess documented disaster preparedness and emergency management plans specifically tailored to its operations. These plans must outline the availability and deployment of emergency supplies, resources, and capabilities relevant to the water infrastructure and its potential vulnerabilities. Additionally, the plans should incorporate operational manuals and relevant governing regulations to ensure a coordinated and effective response during water-related emergencies.
	Operations/ system management	Frequency of data collection	Low Medium High	Qualitative assessment/ value judgment	How regularly an organization collects data on water quality, quantity, access, biodiversity, etc. will inform how well the system dynamics can be understood. If, for example, data is only collected once a month, then this could skew how data is interpreted. A higher frequency of data collection enables more accurate baselining, average value estimation, and trend analysis, leading to more informed decision-making.
	Operations/ system management	Quality of data collection	Poor Good Excellent	Qualitative assessment/ value judgment	Trustworthy data fuels impactful decisions. Quality assurance is maintained by checking the data collection practices. This means collecting enough relevant data, regularly calibrating equipment and employing effective qualitative measures.
Biophysical	Supply	Degree of independence of different available water sources	Low Medium High	Qualitative assessment/ value judgment	One critical way to measure independence is by how correlated supply sources are. For example, if a utility decides to partner with another jurisdiction to tap into their supplies, but that new supply has similar timing of flow regimes, weather patterns and supply accumulation then the sources may be highly correlated. Given that set of circumstances one could argue that the sources are not independent, at least as it relates to supply availability.
	Supply	Degree of diversity of water sources	Low Medium High	Low (1-2 sources) Medium (3-4 sources) High (>4 sources)	Variability in sources (e.g. the total supply of water is composed of 10% from desalination plants, 30% from groundwater, and 60% from surface water sources). This indicator is to be read in conjunction with the indicator on supply reliability (see below).
	Supply	Degree of reliability of water quantity from different sources	Low Medium High	Low (<80%) Medium (80-99%) High (>99%)	The degree of reliability should be measured under different scenarios. For example, under normal conditions there could be 99% certainty to get water from dams; 50% certainty to get water from groundwater; 99% certainty to get water from desalination; etc. Under extreme conditions, this level of certainty could change. The degree of reliability should be measured under different scenarios. This can inform long-term planning about the need to adjust the overall supply mix.

System Component	System Sub-component	Tier 2 Resilience Indicator	Measure	Score Range	Notes
Biophysical	Supply	Degree of reliability of water quality from different sources	Low Medium High	Low (<80%) Medium (80-99%) High (>99%)	The degree of reliability with respect to the quality of water could change under different conditions. For example, under normal conditions, a utility receives high-quality water from dams, and medium to low-quality water from other sources. Under extreme conditions, this degree of reliability in water quality could change. The degree of reliability should be measured under different scenarios. This can inform long-term planning about the need to adjust the overall supply mix.
	Built and/ or natural infrastructure	Suitability of the infrastructure design and placement	Poor Good Excellent	Qualitative assessment/ value judgment	This indicator evaluates how well the infrastructure fits its location and purpose. For example, a dam may be a stranded asset if it is built in an area with low water availability or high environmental risks.
	Built and/ or natural infrastructure	State of infrastructure to withstand shocks and stresses	Poor Good Excellent	Qualitative assessment/ value judgment	Evaluates factors such as structural integrity, and ability to adapt to changing environmental conditions. For example, it examines whether desalination plants can handle increased salinity caused by sea level rise or if the pump power supply can withstand sudden surges in power supplies.
	Built and/ or natural infrastructure	Level of maintenance of infrastructure	Poor Good Excellent	Qualitative assessment/ value judgment	The level of infrastructure maintenance measures the effort put into maintaining the infrastructure to an appropriate standard and reflects the structural integrity and stability of infrastructure in the face of extreme events and ongoing stresses reflecting its ability to withstand extreme events, as well as ongoing stresses and wear and tear.
	Built and/ or natural infrastructure	Ability of the constructed/natural ecosystem to provide goods and services	Poor Good Excellent	Poor (<20%) Good (20-50%) Excellent (>50%)	Constructed and naturally occurring habitats (for example wetlands and riparian and aquatic habitat) can store, treat and release water. These goods and services are dependent on the size, location and condition of the habitat. For example, the larger the size, the greater the ability to hold and filter water; upstream habitat location can provide additional benefits to downstream locations; the more intact the wetland system the greater the ability to function optimally.
	Built and/ or natural infrastructure	Ability of infrastructure to withstand shocks and stresses	Poor Good Excellent	Qualitative assessment/ value judgment	It reflects the degree of robustness of the infrastructure to cope with shocks and stresses and maintain structural integrity. For example, desalination plants located in coastal areas are susceptible to damage from rising sea levels and tidal surges. These infrastructures are exposed to shocks and stresses such as flooding, intrusion of saline water or erosion and structural damage, etc. The higher the ability of the desal plants to cope with these threats, the more robust is this infrastructure and ultimately the system.
	Operations/ system management	Access/availability of technology for the system to operate reliably and effectively	Poor Good Excellent	Qualitative assessment/ value judgment	This indicator first checks whether appropriate technology is immediately deployable. For example, in a desalination-based system, this includes effective, locally obtainable pumping, filtration, and distribution systems to meet the demand.
	Technology	Level of effectiveness of infrastructure monitoring systems	Low Medium High	Qualitative assessment/ value judgment	An effective monitoring system seamlessly integrates various utility processes and monitoring components. It helps proactively identify and anticipate potential synergies, conflicts and bottlenecks.
	Biodiversity	Degree of environmental monitoring and evaluations	Low Medium High	Qualitative assessment/ value judgment	This indicator seeks to determine whether regular monitoring and evaluation of environmental systems are conducted, and whether mechanisms exist to track and protect aquatic flora and fauna.

RESILIENCE CHARACTERISTIC: REDUNDANCY

System Component	System Subcomponent	Tier 2 Resilience Indicator	Measure	Score Range	Notes
Socio-economic	Access to funds	Percentage of contingency financial reserves to operate and maintain the system	Low Medium High	Low (<2%) Medium (2-5%) High (>5%)	This indicator measures whether there is sufficient budget ring-fenced specifically for operations and maintenance during emergency situations, e.g., disaster risk reduction funding, rainy day funds, parametric insurance, etc. or not. The score ranges are only representative; they would need to be tailored to individual utility circumstances.
Institutional	Governance	Level of reserve capacity to govern water systems	None Insufficient Sufficient	Qualitative assessment/ value judgment	This indicator assesses the preparedness of water systems to handle situations where typical functioning is impacted (e.g. emergencies, no capacity, pandemic, etc.) by evaluating the alternative governance options available. For example, if a unit or department is not able to perform their mandate, then other actors could step in to perform these roles and responsibilities.
	Operations/ system management	Level of reserve capacity to manage water systems	None Insufficient Sufficient	Qualitative assessment/ value judgment	Number of staff able to fulfill their roles in the organization. If the system engineer goes for an unexpected absence, are there enough existing personnel to handle the roles and responsibilities to meet the shortfall?
	Operations/ system management	Presence of contingency plans for disaster preparedness and emergency management	No Somewhat Yes	Qualitative assessment/ value judgment	Contingency plans for disaster preparedness and emergency management exist in the form of emergency provisions in operational manuals and governing regulations, which allow for flexibility in responding to disasters without requiring cumbersome approval processes.
Biophysical	Built and/ or natural infrastructure	Level of reserve capacity built into the biophysical components	None Insufficient Sufficient	Qualitative assessment/ value judgment	This indicator measures the additional capacity built into infrastructure that allows essential goods and services to be delivered even in emergencies. For example, a backup UV filtration system ensures water purification continues even if the primary system fails. Additionally, emergency supply reserves enhance reliability and resilience.
	Built and/ or natural infrastructure	Degree of reliability of the backup system	None Insufficient Sufficient	Low (<80%) Medium (80-99%) High (>99%)	This indicator assesses the ability of backup infrastructure and components to resist shocks and stresses. It evaluates whether regular maintenance and operation ensure the backup system's readiness when needed.
	Built and/ or natural infrastructure	Factor of safety in physical infrastructure design	Low Medium High	Low (<20%) Medium (20-50%) High (>50%)	This indicator assesses the margin of safety built into existing infrastructure designs. A factor of safety (FS) of 1 implies the design just meets calculated load demands, while an FS of 2 indicates it can withstand double the anticipated load. The question is: what is the current safety margin before infrastructure performance deteriorates? For example, a flood embankment designed for a 1250-year flood event exhibits greater redundancy compared to one designed for a 500-year event. The chosen return period influences the level of built-in safety and redundancy.

RESILIENCE CHARACTERISTIC: FLEXIBILITY

System Component	System Subcomponent	Tier 2 Resilience Indicator	Measure	Score Range	Notes
Socio-economic	Operations/ system management	Willingness to consider and adopt alternative types of water in operations	Poor Good Excellent	Qualitative assessment/ value judgment	This indicator assesses the organization's readiness/ willingness to explore and adopt alternative water sources such as non-potable water and treated wastewater in production processes when appropriate. By leveraging these alternatives, they can contribute to the conservation of valuable potable water resources. Higher the willingness, the more flexible the system is.
	Demand management	Willingness to invest in and adopt demand management and efficiency measures	Poor Good Excellent	Qualitative assessment/ value judgment	A utility with foresight to further invest in efficiency measures, can exercise more flexibility in demand management during times of crisis, using the tools such as taxes, fees, regulations, pressure management, and reduced access. The efficiency measures could be technical upgrades, new technologies, investing in process efficiency, etc.
	Access to funds	Economic ability to secure supplies from different sources	Poor Good Excellent	Qualitative assessment/ value judgment	If the primary source of water is not sufficient, viable or accessible, can the utility easily shift funds or budgets around to make capital available to establish alternative supply options, such as a desalination plant or sink a borehole for groundwater abstraction to meet immediate needs?
	Access to funds	Level of flexibility in reallocating budget	Low Medium High	Qualitative assessment/ value judgment	This indicator measures the ability of the utility to dynamically shift funds between different budgets or units within the organization. For example, can the utility shift maintenance funds to operations during a crisis, or vice versa, such as to purchase additional supplies or to cover unexpected costs.
	Operations/ system management	Degree of dynamic decision-making in planning	Poor Good Excellent	Qualitative assessment/ value judgment	This indicator measures the flexibility in the internal decision-making processes to operate in tandem with regulatory flexibility. For example, though the regulatory framework may allow a higher degree of flexibility, can a decision be easily made to flip between different sources - such as from surface water to groundwater or dams to desalination? Can the operations manager flip easily from one source to another or does a decision need to be escalated upwards that would delay decision-making and the ability to switch between sources?
	Operations/ system management	Degree of dynamic decision-making in operations	Low Medium High	Low (no to little changes can be made) Medium (slight changes can be made) High (significant changes can be made)	This indicator assesses the flexibility to adjust practices or processes in response to changing circumstances, such as resource limitations. The possibility of delaying some elements of water use when water is limited so that other areas of work can continue. This is a short-term demand-management measure.
	Operations/ system management	Degree of dynamic decision-making in investment	Poor Good Excellent	Qualitative assessment/ value judgment	This indicator measures the decision-makers' ability to invest in different infrastructure options in response to changing needs and conditions. For example, can budget managers invest in: • Multiple supply options • Purchasing new ground water pumps or filtration units etc.

System Component	System Subcomponent	Tier 2 Resilience Indicator	Measure	Score Range	Notes
Institutional	Operations/ system management	Degree of dynamic decision-making in maintenance	Poor Good Excellent	Qualitative assessment/ value judgment	This indicator measures the flexibility of maintenance managers to make timely and informed decisions without the need for extensive escalation. For example, can maintenance managers: • Decide to repair groundwater pumping stations under a certain budget threshold without approval from the director of the unit? • Reduce or increase the level of services for maintenance without waiting for approval from the higher authority engineer? • Relocate internal resources to address critical situations?
	Operations/ system management	Level of flexibility in demand management	Low Medium High	Qualitative assessment/ value judgment	Under demand-management options utilities can prioritize supplies to some sectors or locations over others. Options may include: • Pressure management to reduce supply throughout the system or parts of it. • Diverting water to priority locations or to those most in need of water during times of shock and stress If significant changes can be made, the flexibility is higher.
	Regulatory	Ability of the regulatory, policy and legal frameworks to be adjusted or updated	Low Medium High	Qualitative assessment/ value judgment	This indicator is intended to capture the ability of organizations to adjust/modify current regulatory structures when needed.
Biophysical	Technology	Ability to secure, treat and distribute supplies from different sources	Poor Good Excellent	Qualitative assessment/ value judgment	This indicator evaluates a utility's technological ability to secure water from diverse sources, adapt treatment methods, and efficiently distribute water. For example, advanced, on-demand treatment technologies like desalination can offer technological advantages over constant-operation methods like pumping from boreholes. Some technologies provide greater flexibility and potentially reduce costs and should be explored as flexible options to increase resilience.
	Supply	Ability to switch between different components of the systems	Poor Good Excellent	Qualitative assessment/ value judgment	This indicator evaluates the system's ability to isolate, segment or temporarily sever different parts. Different parts of a system should be able to be isolated, segmented or severed (temporarily) so that failures in one part of a system are not transmitted to the rest of the system. Similarly, supplies or services can be augmented by connecting other components in the system. This indicator is closely connected with 'Interconnectedness' of 'Built and/or natural infrastructure'.
	Supply	Ability to switch between different types/sources	Poor Good Excellent	Qualitative assessment/ value judgment	When there is plenty of one type/source of water available, a utility can rely on it e.g. surface water almost exclusively. At the time of reduced supplies, a utility can readily change to other sources/types e.g. if they have access to borehole or desal systems or treated effluent.

RESILIENCE CHARACTERISTIC: INTEGRATION

System Component	System Subcomponent	Tier 2 Resilience Indicator	Measure	Score Range	Notes
Institutional	Governance	Level of integration in water governance mechanisms	Low Medium High	Qualitative assessment/ value judgment	This indicator measures how integrated decision-making and water management options are across different components of the water system? This includes considerations around onsite activities (e.g., decentralized or off-grid systems) and the potential impacts at the system level. This would require integration of multiple system components at different levels e.g., it could be within a single water basin, or basins across different geographies.
	Governance	Presence of policies and mechanisms for integrating grey and green infrastructure	No Somewhat Yes	Qualitative assessment/ value judgment	This indicator measures the level of integration of policies to manage grey and green infrastructures. Do policies exist that allow for, incentivize or promote the use of multiple infrastructure options?
	Operations/system management	Interconnectedness of water-infrastructure planning, operations and management	Low Medium High	Qualitative assessment/ value judgment	This indicator assesses the collaborative efforts of various units and departments in planning, operating and managing infrastructure for seamless connectivity. It examines how effectively these entities work together to ensure optimal functioning and delivery of goods and services. Key aspects include joint planning of future investments for alignment and system-wide benefit, coordinated operation for efficient infrastructure utilization, and collaborative budgeting and pricing for fair and effective service provision.
	Regulatory	Level of integration in water related policy and regulations	Low Medium High	Qualitative assessment/ value judgment	A resilient water system necessitates legal instruments, including policies and regulations, that function in a mutually supportive and reinforcing manner. A resilient water system relies on legal mechanisms that complement and support each other, rather than conflicting or creating gaps. This means evaluating whether the various regulations work together to achieve common goals and avoid unintended consequences.
Biophysical	Operations/system management	Interconnectedness of water infrastructure	Low Medium High	Low (<50%) Medium (50-80%) High (>80%)	This indicator examines how well-connected the water infrastructure is, which allows for more flexible management strategies. The key question is whether these connections are sufficient to support using water in different ways, such as reusing treated wastewater from homes in industrial cooling towers. Additionally, it assesses how well our built water systems integrate with nature-based solutions like wetlands, considering if water treatment plants can leverage them for pre- or post-treatment, ultimately aiming for a more adaptable and sustainable water management approach.

RESILIENCE CHARACTERISTIC: INCLUSIVENESS

System Component	System Subcomponent	Tier 2 Resilience Indicator	Measure	Score Range	Notes
Socio-economic	Access to funds	Economic ability to sufficiently fund regular stakeholder participation in system planning	Poor Good Excellent	Qualitative assessment/ value judgment	This indicator checks if there's dedicated funding for ongoing and unexpected stakeholder engagement. These budgets could cover the operational expenses of stakeholder engagement processes by the utility, as well as a ring-fenced fund to allow stakeholders to travel to these engagements or to hold such engagements where stakeholders are not burdened by travel costs. This indicator should be assessed in conjunction with the indicators 'Ability of stakeholders to participate in decision-making processes' & 'Presence of processes to overcome barriers to participation' under "Governance"
	Knowledge systems	Level of integration of local and Indigenous knowledge into decision-making processes	Low Medium High	Qualitative assessment/ value judgment	Recognizing the value of local and Indigenous knowledge in building system resilience would ensure a more inclusive process. This will generate feeling of ownership by the local stakeholders.
Institutional	Affordability	Economic ability of stakeholders to afford services from the system	Low Medium High	Qualitative assessment/ value judgment	This indicator asks if the system helps people from all backgrounds afford water services. Are there plans to make water more affordable? Does the community have a say in water management? Can low-income families get help paying their water bills or is there a system which provides a basic water allowance without charge? An inclusive organization ensures everyone can afford the services from the system.
	Governance	Ability of stakeholders to participate in decision-making processes	Low Medium High	Qualitative assessment/ value judgment	There are many factors that can influence the stakeholder's ability or capacity to participate in a decision-making process. These include time of day (e.g. they may not be able to find time to attend the process due to their home and work commitments), transportation availability, access to services and information, and priorities (e.g. home and work priorities may take precedence). The engagement/ inclusion process must consider these factors. This indicator should be assessed in conjunction with the indicators 'Economic ability to sufficiently fund regular stakeholder participation in system planning' & 'Presence of processes to overcome barriers to participation' under "Governance"

System Component	System Subcomponent	Tier 2 Resilience Indicator	Measure	Score Range	Notes
Institutional	Governance	Presence of processes to overcome barriers to participation	No Somewhat Yes	Qualitative assessment/ value judgment	Stakeholders may face a number of barriers to participating in decision-making processes, including time constraints, transportation availability, access to services and information, and competing priorities. Engagement processes should be designed to overcome these barriers and ensure that all stakeholders have an opportunity to participate. This indicator should be assessed in conjunction with the indicators 'Economic ability to sufficiently fund regular stakeholder participation in system planning' & ''Ability of stakeholders to participate in decision-making processes' under "Governance".
	Governance	Level of diversity of stakeholders included in decision-making	Low Medium High	Qualitative assessment/ value judgment	Effective decision-making requires input from a diverse range of stakeholders, including representatives from different sectors, demographics and interest groups. A diversity of perspectives can help to ensure that decisions are informed by a wide range of perspectives and worldviews and that they reflect the needs of all stakeholders.
	Governance	Level of trust, engagement and cooperation between stakeholders	Low Medium High	Qualitative assessment/ value judgment	Transparent and accountable decision-making builds trust between stakeholders and planners. Breaches in decisions, implementation failures, and broken promises erode trust. Engaging and collaborating with stakeholders throughout all stages of decision-making and implementation is critical. Is the utility utilizing its stakeholder engagement processes to develop service-level agreements with its stakeholders? Are they utilizing this opportunity to explain how climate change may affect service level delivery and the funding that may be needed to maintain those levels?
	Governance	Level of accountability in implementation	Low Medium High	Qualitative assessment/ value judgment	Effective governance is evaluated during service delivery bottlenecks, like flood response or utility performance. In the case of water utilities, regulations mandate corrective actions for incidents such as pipe bursts. This ensures accountability through measures like providing alternative water, implementing improvement plans and engaging stakeholders. Regular reviews assess incident management and service level delivery, guaranteeing responsible and effective clean water provision.

RESILIENCE CHARACTERISTIC: JUSTICE AND EQUITY

System Component	System Subcomponent	Tier 2 Resilience Indicator	Measure	Score range	Notes
Socio-economic	**Access to services**	Percentage of people from marginalized communities with access to safe and secure water supply	Low Medium High	Low (<50%) Medium (50-90%) High (>90%)	This indicator focuses on equitable access to safe, climate-resilient water, sanitation and hygiene infrastructure within marginalized communities. It tackles questions such as: do all marginalized, vulnerable, or frontline communities have adequate access to water of a suitable quantity and quality, regardless of their socioeconomic status? Do all the users in the system have access to taps in their homes, or do they need to go and use shared facilities if these exist?
	Access to services	Percentage of people from marginalized communities with access to safe and reliable sanitation and hygiene services	Low Medium High	Low (<50%) Medium (50-90%) High (>90%)	This indicator measures the extent to which all people have access to safe and reliable sanitation facilities, regardless of their socioeconomic status or location. Safe and reliable sanitation facilities are those that safely dispose of human waste and protect people from exposure to harmful contaminants.
	Access to services	Percentage of people from marginalized communities with access to water resources for cultural, recreational, spiritual/religious, and other purposes	Low Medium High	Low (<50%) Medium (50-90%) High (>90%)	This indicator measures how well all people can enjoy the benefits of water-related assets, for recreation, relaxation, religious and spiritual practices, and cultural enrichment, regardless of their socioeconomic status or location. Water-related assets include rivers, lakes, beaches and water parks.
	Access to services	Percentage of people from marginalized communities with flood-protection services	Low Medium High	Low (<50%) Medium (50-90%) High (>90%)	This indicator measures the extent to which all people have adequate flood-protection measures (availability and quality of protection), regardless of their socioeconomic status or location. Flood protection measures include things like levees, seawalls, and flood insurance. Are there adequate support systems in place before, during and after flooding events?
Institutional	**Affordability**	Ability of the utility customers to pay for services	Low Medium High	Qualitative assessment/ value judgment	This indicator measures the ability of the utility to support low-income customers by making water services affordable through appropriate financial mechanisms (e.g. free water allocations, subsidized or low rates/fees, etc.). It asks: are there systems in place to cover the cost of water for those who cannot afford to pay?

System Component	System Subcomponent	Tier 2 Resilience Indicator	Measure	Score range	Notes
Institutional	**Regulatory**	Presence of plans and practices to address historic and current inequities	No Somewhat Yes	Qualitative assessment/ value judgment	This indicator assesses the organization's commitment to addressing historical and ongoing inequities, particularly regarding service access for marginalized, vulnerable or frontline communities. It evaluates the existence and adequacy of concrete plans and active practices aimed at remedying these disparities.
	Regulatory	Presence of just and equitable water allocation rules and practices	No Somewhat Yes	Qualitative assessment/ value judgment	Water allocation regulations should ensure equitable distribution during varying water availability. While minimal restrictions may suffice in times of abundance, flat percentage reductions during scarcity can disadvantage certain sectors and communities. Therefore, regulations should mandate tailored percentage reductions based on legislated allocations and specific user/sector needs. This should consider both environmental flow requirements and local wastewater limitations for a holistic approach. The indicator tackles issues such as: are there plans, strategies and/or mechanisms in place to enable equitable allocation of water during different water availability?
	Regulatory	Presence of plans and practices for fairer and equitable compliance measures	No Somewhat Yes	Qualitative assessment/ value judgment	While the indicator itself doesn't directly measure justice and equity, it can offer indirect insights when considered within a broader context: - If fines are the primary tool, they can disproportionately burden low-income households, potentially exacerbating existing inequities in water access and affordability. - Are the compliance measures clearly communicated and enforced consistently across all demographics?
	Regulatory	Degree of regulatory compliance	Low Medium High	Qualitative assessment/ value judgment	This indicator tracks how well water users follow the rules on water use, pollution, development and other environmental impacts. It's not enough to just have laws in place; but households, businesses and communities need to comply for a just and equitable use of resources.

System Component	System Subcomponent	Tier 2 Resilience Indicator	Measure	Score range	Notes
Institutional	**Governance**	Level of effectiveness of water-related policies and practices	Low Medium High	Qualitative assessment/ value judgment	This indicator looks at how water policies support or impact different cohorts/water users, considering both social and environmental aspects, while addressing past inequalities. Effective policies ensure water justice; ensuring everyone has access to clean water, protecting the environment, and righting historical wrongs.
	Governance	Percentage of organizational leadership from diverse groups	Low Medium High	Low (<50%) Medium (50-90%) High (>90%)	This indicator checks if the water utility's leadership team reflects the diversity of its employees and the community it serves. This means having people from different backgrounds, like ethnicity, gender or ability in leadership positions. A diverse team brings different perspectives and experiences to the table, leading to fairer and more equitable decisions for everyone.
	Governance	Level of fairness in workplace governance	Low Medium High	Qualitative assessment/ value judgment	This indicator tracks how fairly a water utility treats its employees. A fair, equitable workplace is one in which all employees, regardless of their background or identity, have an equal opportunity to participate in decision-making and leadership.
	Governance	Level of transparency in fairness practices in the workplace	Low Medium High	Qualitative assessment/ value judgment	This indicator assesses how openly a utility communicates its fairness practices. Does it publicly share clear information about these practices and their application? And if fairness lapses occur, are documented examples readily available? When everyone has easy access to this information, it fosters trust and helps ensure a just and equitable system for all.

APPENDIX C: FINANCING CLIMATE-RESILIENT INFRASTRUCTURE

The tables below are adapted from the 2021 San Francisco Climate Action Plan, and describe tools that can be used to support investment in climate-resilient infrastructure. The tables also list potential challenges and examples of each tool.

FUNDING MATRIX (TAXES, FEES, GRANTS)

Approaches	Descriptions, Challenges and Examples	Notes
Utility Tax/ Users Fee	Description	Cities/states collect impact fees, user fees, regulatory fees, etc. Fees are typically connected to a certain activity or service, i.e., building permit fees help pay the cost of staff who review drawings.
	Potential Challenges	• Increased cost for all utility payers or users which, without strategies to mitigate impacts, may result in a disproportionate burden on low-income communities. It requires, partnership with energy utilities or city's ability to repay debt on a bond issuance.
	Examples	• San Francisco has a utility user tax that was budgeted to generate \$98.7M in FY 2019-20. • California's SB 1383 recovery fees – SB 1383 is a statewide effort to reduce emissions of short-lived climate pollutants.
Property Taxes/ Parcel Tax	Description	Property tax increases can be used to pay for infrastructure projects derived from climate action priorities. Cities would issue general obligation (GO) bonds backed by property tax revenue to access the revenue sooner.
	Potential Challenges	• Increased cost for property owners. • Voter approval e.g. requires 2/3 voter approval. • External risks, such as a major earthquake or similar event, to the city's ability to repay debt on a bond issuance. • Raising equity e.g. levying flat fee per parcel regardless of income.
	Examples	• In Miami, a property tax increase was used to issue a \$198M GO bond for resilience investments. • San Francisco, along with the other Bay Area counties, approved a \$500M parcel tax increase over 20 years to issue \$425M in GO bonds to restore Bay's wetlands.
Sales Tax	Description	Sales tax is a tax that is imposed on sales of certain goods and services. Sales tax can generate a significant amount of funding but requires voters' approval.
	Potential Challenges	• Two-thirds of the voters' approval is required. • May impose a disproportionate economic burden on low-income communities. However, this can be mitigated by excluding 'necessity goods and services.' • Revenue fluctuations may occur in function of the economic cycles.
	Examples	• In 2018, Portland, OR voters approved a Clean Energy Surcharge of 1% on the retail sales within Portland of certain large retailers to support The Portland Clean Energy Community Benefits Fund. Annual revenue expected from the tax is between \$50M and \$70M. The fund allocates resources to job training and green infrastructure, prioritizing communities of color and low-income neighborhoods. • In 2020, Denver voters approved a supplemental sales tax of 0.25%. The tax would raise an estimated \$36M in its first year, which would have to be spent creating jobs in the areas of renewable and clean energy technology and management of natural resources; and on solar power, battery storage and other renewable energy technologies.

Approaches	Descriptions, Challenges and Examples	Notes
Gas Tax	Description	Gas tax is a type of sales tax imposed on the sale of motor gasoline fuels. The United States has a federal gas tax of 18.3 cents per gallon. Local governments can levy gas taxes too.
	Potential Challenges	• Requires 2/3 voter approval. • Can disproportionately affect low-income communities who tend to own less energy-efficient vehicles, unless strategies to mitigate impacts are incorporated into policy design. • As the fleet becomes more fuel efficient the revenue from the gas tax will go down.
	Examples	State Gas Tax already exists in California ($0.50/gallon). A $0.3 gas tax increase was introduced under SB1 in 2020. Generated revenue is mainly used to repair and maintain the state's roads and bridges.
Development Opportunities	Description	Link relevant actions and projects with real estate development projects to generate public-private partnerships that can deliver additional climate mitigation or reliance measures.
	Potential Challenges	Unclear risk allocation between public and private parties.
	Examples	A stormwater project/resiliency park project in Hoboken, NJ includes a deal with a developer, Bijou, to provide the community benefits of a park, public gymnasium, affordable housing and flood resilience measures. The project also includes residential building, retail space and a parking garage.
Community Facility District (CFD)	Description	CFD is a special tax district provided in state law that funds public improvements and on-going services within an identified area. Parks, streets, sewer improvements and public safety services are some of the public improvements and services that may be financed by a CFD.
	Potential Challenges	• Creation of a special district requires formal approval by petition or vote. • Requires 2/3 voter approval within the proposed district boundaries. If there are fewer than 12 registered voters within the proposed boundaries, the vote may pass by the current landowners.
	Examples	San Francisco's 450-acre development on Treasure Island will have buildings and streets elevated 3 feet above current 100-year flood elevations. The city plans to use a CFD to collect taxes to pay for future sea level rise adaptation.
Special Assessment District (SAD)	Description	Property owners pay an additional fee to fund specific improvements or services within the boundaries of the SAD. The special assessment's purpose must be determined prior to the district's creation and the amount that each property owner pays must be directly proportional to the benefit the property will receive from the proposed improvement.
	Potential Challenges	• Requires voters' approval. • Increases the cost of home ownership.
	Examples	The City of San Francisco established a CFD over the entire Transbay Transit Center redevelopment site to pay for core capital projects and other public infrastructure improvements.

Approaches	Descriptions, Challenges and Examples	Notes
Enhanced Infrastructure Financing District (EIFD)	Description	EIFDs are similar to tax increment financing but have more flexibility in what it can fund. Unlike former redevelopment, this tool imposes no geographic limitations on where it can be used. Eligible projects include infrastructure construction and maintenance, housing development, economic development, transportation infrastructure, sewage treatment and climate adaptation projects, among other uses. Assembly Bill 733 (2017) allows for EIFDs to fund climate change adaptation projects, including but not limited to projects that address conditions that impact public health (such as decreased air and water quality, temperatures higher than average, etc.) and extreme weather events (such as sea level rise, heat waves, wildfires, etc.).
	Potential Challenges	• Requires agreement among taxing authorities to consent transferring their share of the property tax increment to the EIFD (school districts are excluded). • No public vote is required to establish an authority, yet a 55% vote is required to issue bonds.
	Examples	Although there are not any currently formed EIFD funding climate adaptation or resilience-specific projects, some EIFDs are funding sustainability and restoration projects. For example, the proposed City of Redondo Beach/County of Los Angeles EIFD includes urban greening and wetland restoration in its proposed projects. The Redondo Beach EIFD aims to revert its now-closed AES Power Plant's 50-acre site into open space and park development, wetland restoration and private development.
Grants	Description	Federal, state, utility, regional and local grant programs as well as philanthropic grant funding are available for specific purposes. Government grants do not require repayment; however they often require either matching funds from the city, staff time to administer the grants (including post-award compliance reporting), or both.
	Potential Challenges	• Identifying and taking advantage of niched funding. • Grants are often for very specific purposes that may not align with needs. • Grants are typically one-time sources and thus are not a reliable source of on-going funding. • Since many grants are competitive, it cannot be assumed to be available as needed.
	Examples	The CalRecycle Food Waste Prevention and Rescue Grants program is designed to lower emissions by establishing new or expanding existing food waste prevention projects in California to reduce the amount of food being disposed of in landfills. This grant is part of California Climate Investments and is funded with cap-and-trade dollars.
Climate Action Plan Tax (Carbon Tax)	Description	Tax dedicated to addressing climate change mitigation. Generated funding can be used to fund policies, programs, direct advising services and rebates to homes and businesses.
	Potential Challenges	• Innovative tax that has not yet been implemented and will require a few years to develop. • Requires voter approval. • If not formulated correctly, this tax can negatively impact disadvantaged communities.
	Examples	Originally passed in 2006 and extended in 2015 to continue through March 31, 2023, the City of Boulder implemented the nation's first voter-approved tax dedicated to addressing climate change. The carbon charge generates $1.8M annually. The tax is levied on residents and businesses based on the amount of electricity consumed. Tax rates are different depending on the sector. Annual average costs: Residential $21, Commercial $94, Industrial $9,600. The tax funds a program that requires rental properties to undergo retrofits, thereby reducing renters' energy burden and improving the quality of rental properties. In November 2020, the City of Albany, California, obtained voter approval to impose a 9.5% blanket utility service tax on all residents except for designated low-income residents. The utility service tax will ultimately fund general city services, including disaster and emergency preparedness, emissions reduction projects, and emergency response and environmental sustainability programs.

<table>
<tr><th>Approaches</th><th>Descriptions, Challenges and Examples</th><th>Notes</th></tr>
<tr><td rowspan="3">Carbon Tax</td><td>Description</td><td>The government sets a price that emitters must pay for each ton of greenhouse gas emissions. Two broad forms:
1) Emissions tax based on the quantity of emissions an entity produces.
2) Tax on goods or services that are greenhouse gas-intensive, such as gasoline.</td></tr>
<tr><td>Potential Challenges</td><td>• An innovative tax that has not yet been implemented in the United States, it will require a few years to develop.
• Requires 2/3 voter approval.
• If not formulated correctly, this tax can negatively impact disadvantaged communities.</td></tr>
<tr><td>Examples</td><td>British Columbia imposed North America's first broad-based carbon tax in 2008. The tax applies to the purchase and use of fossil fuels and covers approximately 70% of provincial greenhouse gas emissions. As implemented, carbon taxes paid by constituents were offset by lower income taxes, corporate taxes or business taxes. Currently, the tax is $45 per ton of CO2.</td></tr>
<tr><td rowspan="3">Food Tax</td><td>Description</td><td>A levy imposed on food producers according to the carbon footprint of their products. This tax would be similar to the sugar tax on soft drinks.</td></tr>
<tr><td>Potential Challenges</td><td>• An innovative tax that has not yet been implemented; it will require a few years to develop.
• Requires 2/3 voter approval.
• If not formulated correctly, this tax can negatively impact disadvantaged communities.</td></tr>
<tr><td>Examples</td><td>No precedents yet. The UK Health Alliance on Climate Change, a powerful coalition of the UK's health professions, has called for a climate tax to be imposed on food with a heavy environmental impact by 2025, unless the industry takes voluntary action on the impact of their products. It is currently unclear how exactly the tax would work and be calculated as the government has not responded to the proposition.</td></tr>
<tr><td rowspan="3">Climate Commitment Act or Cap-and-Invest Bill</td><td>Description</td><td>Caps emissions from large polluters, and then lowers that cap every year to force them to continually reduce their fossil fuel output. The program and its revenues will fund net-zero emissions initiatives.</td></tr>
<tr><td>Potential Challenges</td><td>• An innovative tax that has not yet been implemented and might require several years to develop.
• Requires political will.</td></tr>
<tr><td>Examples</td><td>The Climate Commitment Act was passed in the State of Washington in 2021. The bill aims to adopt a comprehensive program that caps and reduces emissions from large emitters. Any company that wants to go over the limit must buy allowances to pollute.</td></tr>
<tr><td rowspan="3">Downtown Congestion Pricing</td><td>Description</td><td>Congestion pricing involves charging a fee to drive into downtown during weekday rush hours to reduce vehicle delays, increase safety, clean the local air and address climate change, and advance equity for historically underinvested communities.</td></tr>
<tr><td>Potential Challenges</td><td>• Congestion pricing policy must be designed in an equitable manner so as not to negatively impact equity-priority communities.
• Congestion pricing will require authorization from the state, as well as environmental and other approvals. Anticipate needing at least five years to implement.</td></tr>
<tr><td>Examples</td><td>The San Francisco County Transportation Authority is currently studying how a fee to drive downtown during busy hours could help alleviate congestion when the economy recovers.

The study is using public feedback and technical analysis to shape a fair and effective congestion pricing recommendation for San Francisco. It will combine the congestion fee with discounts and incentives to make the system fair and encourage the use of sustainable transportation modes like transit, walking and biking. Substantial public outreach has been completed, and a new round of outreach is planned in 2022.</td></tr>
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FINANCING MATRIX (BONDS, CERTIFICATES OF PARTICIPATION, LOANS)

Approaches	Descriptions, Challenges and Examples	Notes
General Obligation (GO) Bonds	Description	GO bonds are secured by voter-approved ad valorem property taxes. They are used to pay for projects that provide taxpayer benefits—in some cases, projects that are unable to raise their own revenue (libraries, parks), and in other cases projects that can (hospitals, affordable housing).
	Potential Challenges	• Requires 2/3 voter approval. • The city charter imposes a limit on the amount of general obligation bonds the city can have outstanding at any given time, which is 3% of the assessed value of all taxable property in the city.
	Examples	In June 2016, voters in a 9-county area, including San Francisco, approved Measure AA, a region-wide local tax to fund nature-based flood protection through wetlands, habitat restoration and pollution-removal projects. A $425M general obligation bond was issued to restore wetlands and a $500M parcel tax is being used to repay it.
Revenue Bonds	Description	Revenue bonds are used to pay for projects such as major improvements to an airport, water system, garage or other large facilities which generate revenue. They are generally repaid from revenues generated by the bond-financed projects (transportation fees, water rates, etc.). There are different types of revenue bonds: lease revenue bonds, special tax revenue bonds and general airport revenue bonds.
	Potential Challenges	• Once bonding authority is granted, individual bond issuances can be approved by the Board of Supervisors. • Repayment of the bond is from the revenue generated by the project or issuer.
	Examples	Proposition A, approved by San Francisco voters In 2018, granted the San Francisco Public Utilities Commission authority to issue revenue bonds to pay for new power facilities with a two-thirds vote of the board of supervisors and the support of the mayor.
Certificates of Participation (COPs)	Description	Similar to lease revenue bonds, though the COP contrasts with a bond, in which the investor loans the government or municipality money secured by lease revenues in order to make capital improvements.
	Potential Challenges	• No voter approval is needed while complying with California debt limitation laws such as Proposition 13. • The San Francisco 10-Year Capital Plan has a policy of limiting COPs to not more than 3% of discretionary General Fund revenue.
	Examples	Can be used to support energy projects, water and wastewater projects, public buildings and solid waste facilities
Energy Loans	Description	Similar to bonds, loans fund projects by borrowing money from lenders and paying it off over time. However, the borrower is typically an individual or company.
	Potential Challenges	• Applicable to specific types of energy efficiency projects. • Borrowers are required to be a utility customer and, more typically, the designated property owner at the service premise (i.e., there is still limited availability of these types of loans for renters).
	Examples	On Bill Financing (OBF) programs currently being offered within investor-owned utility services areas.

ABOUT THE CEO WATER MANDATE

The CEO Water Mandate is a partnership between the UN Global Compact and the Pacific Institute that mobilizes business leaders on water, sanitation, and the Sustainable Development Goals for corporate water stewardship. Mandate endorsers commit to continuous progress against six core elements (direct operations, supply chain and watershed management, collective action, public policy, community engagement, and transparency) and in so doing understand and manage their own water risks. Established in 2007, the CEO Water Mandate was created out of the acknowledgement that global water challenges create risk for a wide range of industry sectors, the public sector, local communities, and ecosystems alike.

ABOUT THE PACIFIC INSTITUTE

Founded in 1987, the Pacific Institute is a global water think tank that combines science-based thought leadership with active outreach to influence local, national, and international efforts in developing sustainable water policies. From working with Fortune 500 companies to frontline communities, our mission is to create and advance solutions to the world's most pressing water challenges. Since 2009, the Pacific Institute has also acted as co-secretariat for the CEO Water Mandate, a global commitment platform that mobilizes a critical mass of business leaders to address global water challenges through corporate water stewardship. For more information, visit pacinst.org.

ABOUT AGWA

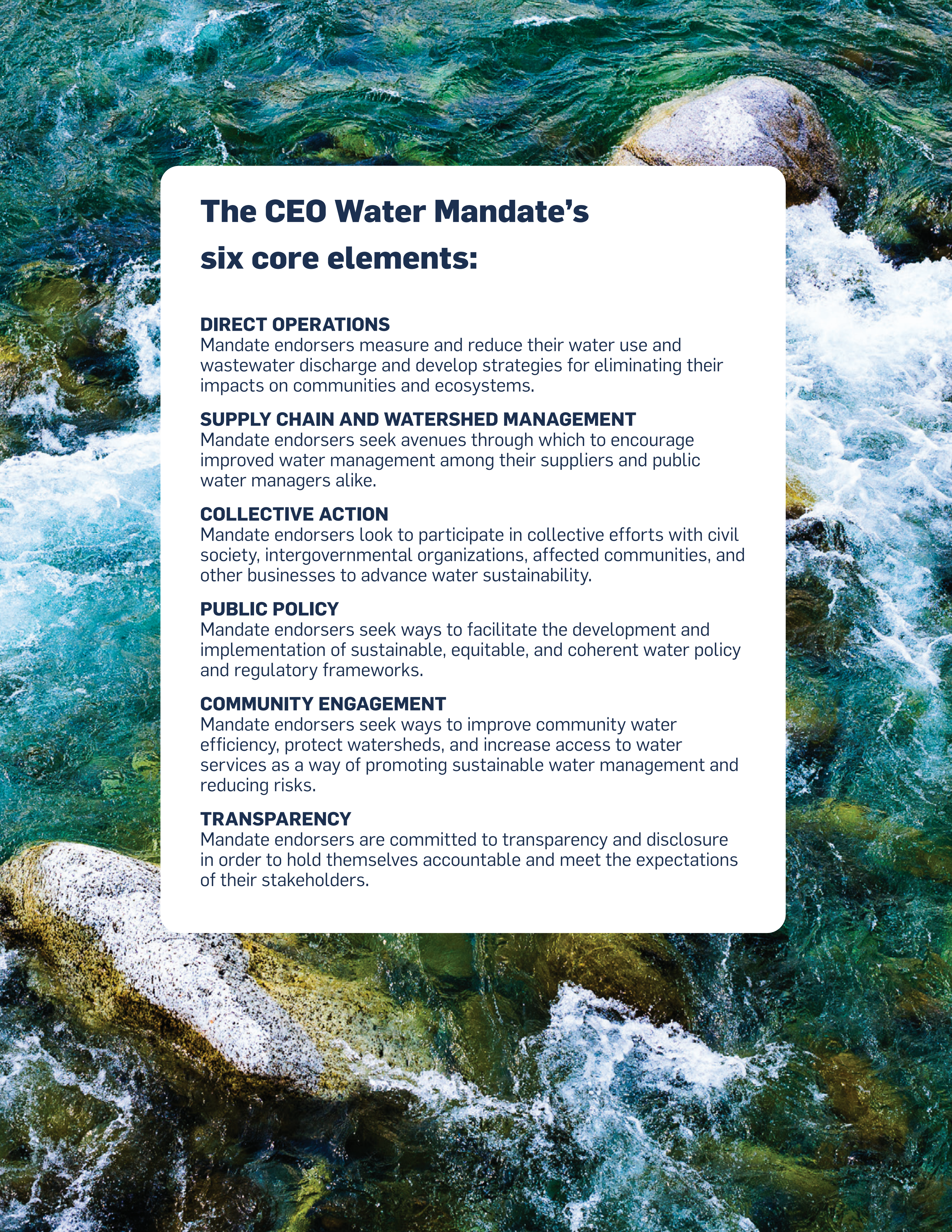
AGWA is an international NGO working across technical and policy programs to mainstream resilient water resources management, focusing on the connections between water resources and climate adaptation and mitigation. AGWA works with and through its member network to develop and crowdsource solutions across disciplines, institutions, and sectors. For more information, visit www.alliance4water.org.

ABOUT IWMI

The International Water Management Institute (IWMI) is an international, research-for-development organization that works with governments, civil society, and the private sector to solve water problems in developing countries and scale up solutions. Through partnership, IWMI combines research on the sustainable use of water and land resources, knowledge services, and products with capacity strengthening, dialogue, and policy analysis to support implementation of water management solutions for agriculture, ecosystems, climate change, and inclusive economic growth. Headquartered in Colombo, Sri Lanka, IWMI is a CGIAR Research Center with offices in 15 countries and a global network of scientists operating in more than 55 countries. Find out more at www.iwmi.org.

ABOUT THE UNITED NATIONS GLOBAL COMPACT

As a special initiative of the United Nations Secretary-General, the UN Global Compact is a call to companies worldwide to align their operations and strategies with Ten Principles in the areas of human rights, labour, environment and anti-corruption. Our ambition is to accelerate and scale the global collective impact of business by upholding the Ten Principles and delivering the Sustainable Development Goals through accountable companies and ecosystems that enable change. With more than 20,000 participating companies, 5 Regional Hubs, 62 Local Networks covering 67 countries and 15 Country Managers establishing Networks in 34 other countries, the UN Global Compact is the world's largest corporate sustainability initiative — one Global Compact uniting business for a better world.



The CEO Water Mandate's six core elements:

DIRECT OPERATIONS
Mandate endorsers measure and reduce their water use and wastewater discharge and develop strategies for eliminating their impacts on communities and ecosystems.

SUPPLY CHAIN AND WATERSHED MANAGEMENT
Mandate endorsers seek avenues through which to encourage improved water management among their suppliers and public water managers alike.

COLLECTIVE ACTION
Mandate endorsers look to participate in collective efforts with civil society, intergovernmental organizations, affected communities, and other businesses to advance water sustainability.

PUBLIC POLICY
Mandate endorsers seek ways to facilitate the development and implementation of sustainable, equitable, and coherent water policy and regulatory frameworks.

COMMUNITY ENGAGEMENT
Mandate endorsers seek ways to improve community water efficiency, protect watersheds, and increase access to water services as a way of promoting sustainable water management and reducing risks.

TRANSPARENCY
Mandate endorsers are committed to transparency and disclosure in order to hold themselves accountable and meet the expectations of their stakeholders.