RESILIENCE PRIMER

Potable water

An industry guide to enhancing resilience

THE RESILIENCE SHIFT

Resilient ORGANISATIONS
A collaboration between research & industry

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Published by The Resilience Shift in collaboration with Resilient Organisations

March 2019

CITATION REFERENCE

Hatton, T., Kay, E., Naderpajouh, N., and Aldrich, D. (March 2019) Potable water: An industry guide to enhancing resilience. Resilience Primer. Resilient Organisations and Resilience Shift, UK.

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ABOUT THE RESILIENCE SHIFT

The Resilience Shift exists to inspire and empower a global community to make the world safer through resilient infrastructure. More people than ever depend on the critical infrastructure systems that provide essential energy, water, transport and communications services, and underpin food, healthcare and education. When this infrastructure fails the consequences can be catastrophic.

Supported by Lloyd's Register Foundation and Arup, the Resilience Shift provides knowledge and tools for those responsible for planning, financing, designing, delivering, operating and maintaining critical infrastructure systems. Our aim is to ensure infrastructure systems are able to withstand, adapt to, and recover quickly from anticipated or unexpected shocks and stresses - now and in the future.

DEFINING RESILIENCE

Resilience is the ability to withstand, adapt to changing conditions, and recover positively from shocks and stresses. Resilient infrastructure will therefore be able to continue to provide essential services, due to its ability to withstand, adapt and recover positively from whatever shocks and stresses it may face now and in the future.

ACKNOWLEDGEMENTS

We are very grateful to the respondents who gave generously of their time to inform this primer. We extend our thanks to the multiple representatives of Wellington Water, Watercare, Selwyn District Council, Aon Insurance Brokers, Professional Engineer (New Zealand), Sydney Water, Yarra Valley Water, City West Water, Melbourne Water, New South Wales Office of Emergency Management, Victoria, Department of Land Environment Water and Planning (Australia), and the Los Angeles Department of Water and Power (USA). Thank you also to Justin Abbott, Arup. Any errors or omissions are solely the responsibility of the authors, not the contributors.

Foreword

Building resilience of critical infrastructure requires decision-makers working in different industry sectors to understand what can be done, why it should be done, and how to put it into practice. Our work to date has told us that key stakeholders are often either unaware of the value that resilience can bring or are constrained by a lack of resources or support in terms of how to embed and enhance resilience.

This primer is a brief document introducing the elementary principles of resilience governing the Potable Water industry and is part of a body of knowledge, tools and approaches that the Resilience Shift is producing, funding, and curating, intended to help those responsible for the financing, planning, design, delivery, operation and maintenance of critical infrastructure systems to shift practice. Our vision is to contribute to a common understanding across critical infrastructure sectors of what improves resilience and how it can be achieved in practice.

Building resilience into your infrastructure systems, across your value chains, will allow you to prevent or mitigate against shocks and stresses that you identify, and to respond better to those events that you can't predict or avoid.

We're delighted to have supported the team at Resilient Organisations in producing this primer.

The Resilience Shift team

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Executive summary

Are you working in, or responsible for a water network? What legacy would you like to leave? A strong robust water network able to serve the needs of current and future generations, or a series of near-misses or incidents that leave communities and economies weaker? Achieving a resilient water network is not easy. But it is vital that we all look to the multitude of small acts that together can improve resilience, persisting even when significant barriers may appear. Water is an integral part of our lives, both in its requirement for life, but also in its ability to create healthy communities. Building a resilient water network helps to enable current and future generations not only to recover from shocks and stressors but also to thrive. Building a resilient water network needs to be balanced with the needs for a resilient eco-system that also supports communities to thrive. There is a need for a holistic approach to resilience to satisfy, and sometimes compromise, conflicting needs.

For the water industry, a resilient network is one that can continuously supply the quantity of water desired (or accepted) by customers, at a quality that meets health standards. The value chain, from source to our pouring a glass of drinkable water from a tap, is a large and complex system. To truly build resilient systems, attention needs to be paid to all parts of the system – from source to tap, and beyond, in our interdependent ecological systems.

Consideration of resilience in water networks is nothing new, but as described by one urban water operator, “the floodgates have opened for resilience efforts as society more broadly embraces the concept”. There is no one solution to the barriers that reduce resilience improvement efforts. This primer presents 17 recommendations to give resilience adoption a boost. These suggestions were inspired by 19 interviews with water sector operators and stakeholders and consideration of policy frameworks, advocacy bodies and academic reports. Some suggestions will be applicable to many contexts, others not. **We hope that these suggestions inspire you to begin, or continue, your resilience journey so that we can ensure that our potable water networks continue to assist communities to thrive.**

Our recommendations

- Understand your risks
- Engage communities in resilience
- Create public resilience metrics
- Find your burning platform
- Motivate change through stories
- Choose appropriate messaging
- Learn from other countries
- Create effective organisational structures
- Develop resilience advocates
- Review professional education
- Provide the legislative mandate to act
- Build organisational resilience capabilities
- Ensure water is valued
- Embed resilience thinking at project inception
- Explore alternative funding mechanisms
- Apply system not territorial boundaries
- Build and utilise co-operative networks

Details of these recommendations are provided in Chapter 6.

Water tower in Deogad, India (Atharva Tulsi - Unsplash.com)

1 Introduction

Access to safe drinking water is a fundamental human need, and one which is often taken for granted in the developed context. In the developing world over 2.1 billion people are estimated to lack access to safe water (UNICEF, 2017). In the developed world where this primer is focused, sufficient quality and quantity of potable water is regarded as an essential function for a thriving community. Potable water is used for many functions other than drinking, including sanitation, hygiene, health care, food production, and economic activity.

> ***Water, in excess or in absence, will be the greatest challenge our world faces in the next century.***
>
> **http://www.globalwaterchallenge.org/**

Water crises, defined as "a significant decline in the available quality and quantity of fresh water, resulting in harmful effects on human health and/or economic activity" (World Economic Forum, 2019), are identified as a top 10 risk facing the world in 2019. Climate change impacts are only expected to exacerbate water issues.

> ***"Much of the impact of climate change will be felt through changing patterns of water availability, with shrinking glaciers and changing patterns of precipitation increasing the likelihood of drought and flood. If climate change is the shark, then water is its teeth and it is an issue on which businesses need far greater levels of awareness and understanding"***
>
> **(Paul Dickinson, Carbon Disclosure Project launch, 2019)**

The vision of the Resilience Shift is to contribute to a common understanding across the value-chain of what contributes to resilience and how it can be achieved in practice. This approach aims to break down silos that may exist within and between the planners, developers, operators and users of critical infrastructure. A key aspect of the value-chain view of critical infrastructure is recognising that everyone has a role to play in delivering resilience value, through the decisions they make in their jobs.

This primer was informed by 19 interviews with representatives of water operators and key stakeholders, together with reviews of strategy documents, reports by government agencies, interest groups and academic literature. Our interviewees were based in Australia, New Zealand and the United States of America. Our aims were to explore attitudes of individuals and organisations about resilience including both the current and desired state, examine resilience building initiatives, understand perceived barriers that impede resilience improvement and identify incentives that assist resilience efforts.

VALUE CHAIN OF CRITICAL INFRASTRUCTURE

DIAGNOSE & CONCEIVE			DESIGN & DELIVER			OPERATE & MAINTAIN		
DIAGNOSE	OPTIONS	PROCURE	DESIGN/ PLAN	FINANCE	IMPLEMENT	OPERATE	MAINTAIN	DISPOSE/ REUSE

Arup optimised the initial design in order to provide the most economic pipe route, whilst reducing reinstatement costs, achieving less environmental impact and avoiding lengthy planning issues. (Photo by Arup)

2 Defining resilience in the potable water industry

Essential functions

For the water industry, the expectation is for the continuous supply of the quantity of water desired by customers, at a quality that meets health standards.

There are many parts to the system that provides this:

POTENTIAL SUPPLY AVAILABILITY
Inflows to natural sources

CAPTURED SUPPLY
Adequate storage, aquifers, reservoirs

TREATMENT AND DISTRIBUTION
Wells, pipes, plumbing, treatment

DEMAND MANAGEMENT
Water value, meters, restrictions

Getting the used water away from customers through effective and hygienic wastewater systems is also a critical aspect of a resilient potable water system.

Defining resilience

The term resilience is used across different fields including psychology (Werner, 1971; Fletcher and Sarkar, 2013), ecological sciences social-ecological systems management (Holling, 1973; Walker et al., 2002; Gao et al., 2016), engineering (Hollnagel et al., 2006), supply chain management (Christopher and Peck, 2004) and organisational studies (Naderpajouh et al., 2018). For the water system the ability to provide continuous quality supply under varying conditions is the ultimate goal of resilience.

Resilience for the potable water network encompasses concepts associated with resilience in the context of infrastructure systems specified by Bruneau et al. (2003), including:

> *The overarching goal of resilience in potable water is the continuation of an acceptable level of quality supply, regardless of any crisis – in order to ensure the function and wellbeing of the community.*

ROBUSTNESS OR RESISTANCE	**The ability to withstand shocks/stressors and continue to function; e.g. changing the pipe types to withstand a new normal level of soil moisture because of drought to avoid increasing pipe breaks.**
REDUNDANCY	**A property of the overall system to substitute its failed components and continue to function when individual components are compromised; e.g. addition of desalination plants. In short, "Don't put all your eggs in one basket" Stockholm Resilience Centre (2015).**
RESOURCEFULNESS	**Proactive identification and management of potential resources to respond to potential threats to function, and to provide the foundational capability to respond promptly to shocks and stresses, e.g. generators, desalination plants.**
RAPIDITY	**The ability to respond, recover, and thrive rapidly from unavoidable disruption; e.g. emergency response planning, climate change adaptation strategies.**

These resilience characteristics apply at the many different parts of the potable water supply system. Also of importance is considering the impact and spillover of improving these characteristics on the broader ecosystem.

Underpinning the physical resilience of the key infrastructure is the ability of the individuals and organisations to enable the achievement of those resilience characteristics (NSW Critical Infrastructure Strategy, 2018). This includes being able to rapidly adapt to changes impacting the system, as well as actively seeking to shape their context through practices and actions such as advocacy, demand management and water use efficiency.

There is also a growing sophistication in the way that communities are viewed as active contributors to, and instigators for, rather than recipients of, resilience efforts. This includes changing water use behaviours and preparing individually for supply outages. As an example of this approach, the current New South Wales infrastructure strategy places community resilience as a key outcome but also a contributor to infrastructure and organisational resilience.

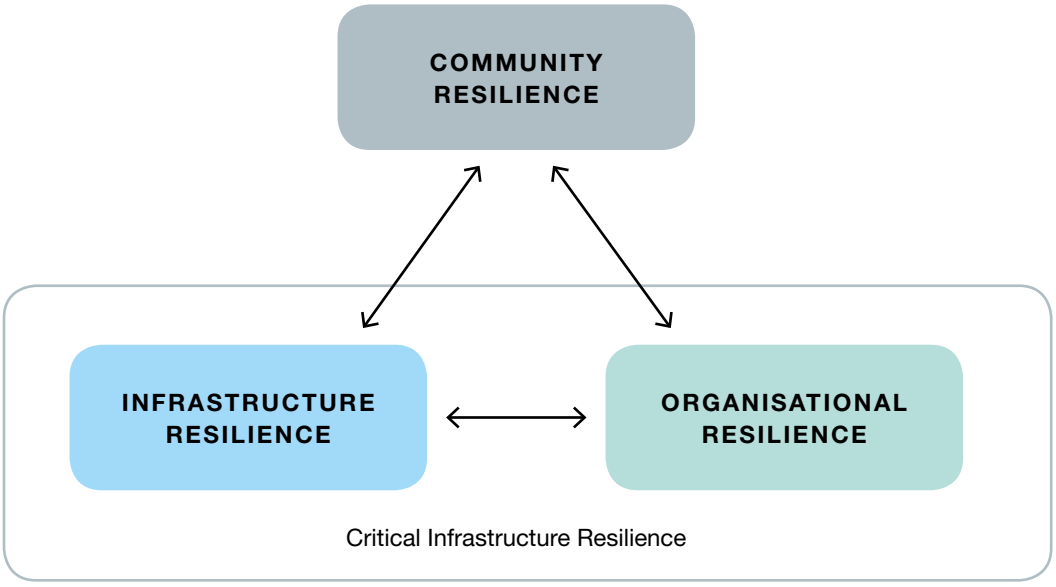


Figure 1

NSW (Australia) Critical Infrastructure Resilience Strategy (Creative Commons Attribution 4.0 license)

Collaboratively building city water resilience

OurWater is an online tool to improve water governance through coordination and knowledge-sharing between all those working with the water system. Part of the City Water Resilience Approach, a five-step approach and suite of resources launched in 2019, this multi-partner collaborative project was developed with the support of the Resilience Shift and the Rockefeller Foundation. It aims to collaboratively build resilience to local water challenges into how we plan, design, implement and maintain water infrastructure, helping cities to improve outcomes for urban populations who rely safe water systems for their health and wellbeing.

In order to move beyond the basic assurance of the water supply and to consider management of demand and the broader impact of resilience related actions on ecosystems, there is a need for **metrics**. At an operational level, organisations may use particular measures to gauge their resilience outcomes. These might take a customer perspective, for example by:

- including the number of customer days without water;
- the number of leaks and main breaks;
- or the level and length of water restrictions imposed (if applicable).

Other performance metric frameworks exist, focusing on the efficiency or effectiveness of networks. These may include:

- maintenance costs per unit of the length of pipe;
- operating costs per unit of the length of pipe;
- per capita consumption and distribution;
- as well as system water loss (Ganjidoost et al., 2018).

Ideally, water resilience needs to be examined holistically considering customer, efficiency and holistic system perspectives including interdependencies. Work by the Australian Attorney General's Department in conjunction with Resilient Organisations suggest the following holistic model (see next page) as a means to unpack how resilience of a critical infrastructure sector might be achieved (Hatton et al, 2018). This model attempts to address the question:

...how do [critical infrastructure] industries, consisting of networks of organizations, many with competing goals and interests, provide reliable services in the absence of conventional forms of command and control?

(DeBruijne & VanEeten, 2007, p. 19)

This work emphasises a need to consider resilience at a system level. For example, where a large urban centre has multiple organisations involved in water supply, the collective responses of the organisations is as important as the individual components. The involved organisations need to collaborate within and across industries to ensure resilience of the system (Opdyke et al., 2017), while the collaboration should also include the community and government agencies (Naderpajouh et al., 2018). Such collaborations are established for provision of the services in the stable state, however, the variations associated with shocks and stresses result in the need for shaping new networks or modifying existing networks for efficacy of the response and to ensure resilience of the potable water system.

Figure 2

Critical Infrastructure Sector Level Resilience (Australian Government Attorney General's Department)

Over 5000 tourists a day had a destructive impact on local ecosystem and caused a drinking water shortage. Phi Phi Inslads, Thailand

3 Historical vulnerabilities of the potable water industry

Quality failures can kill people. Quantity failures cause significant negative consequences impacting human, social and economic wellbeing. Unfortunately, there are many occurrences of these events internationally.

Figure 3

Examples of water quality and supply risks as reported by media.

For detailed case studies of water failures, presented as learning opportunities see Hrudey and Hrudey (2014). Ensuring safe drinking water: learning from frontline experience with contamination, American Water Works Association.

The Lady Grattan Fountain - restored by Dublin City Council, bringing drinking water back to the fountain (photo by William Murphy - Flickr.com)

4 The resilience value chain in the potable water industry

The value chain, from source precipitation to our happily pouring a glass of drinkable water from a tap, is a large and complex system. The desirability of improving robustness, redundancy, resourcefulness, and rapidity apply at all points in the supply chain to increase the likelihood of continuous quality supply of safe drinking water.

Figure 5 illustrates a simplified view of the water supply system and the key risks that could impact each node. Resilience can be enhanced or eroded at any point in that system.

	SYSTEM	KEY RISKS
	Potential availability Inflows to natural sources	• Over utilisation (competition with other uses) • Environmental change • Quality • Land use changes • Ownership issues
	Captured supply Adequate storage e.g. aquifers, reservoirs	• Damage • Contamination (including deliberate and accidental) • Over-use, under replenishment
	Treatment and distribution Wells, pipes, plumbing, treatment	• Continuity of function (damage e.g. disaster or terrorism, ageing mechanical failure) • Interdependencies with other services • Quality/contamination
	Demand management Water value, meters, restrictions	• Demographic changes • Changing industry usage • Land use change

Figure 4

Water supply system and key risks

POTENTIAL SUPPLY

Attention to source water's health, replenishment and future capacity, as well as quantity and quality, are all essential for resilience. This applies to whichever source is relevant to a community – and includes the management of catchment areas, where other uses may impact the water supply. For example, potential supply might include desalination or recycled water. Climate change is a key area of concern for potential supply in many locations as the frequency and intensity of droughts escalates, and changes in snowmelt alter inflow patterns to rivers, or have an impact on water quality. Internationally, control over source water is proposed as a potential cause of severe conflict in the future (The Future of Water, 2017; National Geographic, 2016). Changes to catchment area management have the potential to erode resilience.

CAPTURED SUPPLY

This refers to the amount of water 'captured' via reservoirs, dams, tanks, aquifers or other storage mechanisms. Redundancy and reliability are key issues in this area. Inadequate storage alongside increased demand has created severe issues historically in many countries. Capture mechanisms also need to preserve other eco system functions required by thriving communities. The reliability of the supply infrastructure is relevant for both quantity (actual failure) and quality (contamination).

TREATMENT AND DISTRIBUTION INFRASTRUCTURE

Millions of kilometres of pipes, along with pumping stations, treatment stations, and wells create multiple sources of failure, which drives up risk. Networks have often been incrementally added to and, in some cases, the full system picture is not clear, even to the asset owners. The age of much of this infrastructure creates many vulnerabilities, and simply maintaining a reasonable replacement rate of these assets is costly and time consuming. Water treatment is an evolving science and many instances of contamination and harm have occurred, as treatment processes, including quality control systems, have failed to manage new or previously unencountered forms of contamination, such as in the case of Flint, Michigan[1].

DEMAND MANAGEMENT

Influencing how we use water is a key part to ensuring resilient systems. Efficient use of water can reduce the level of investment needed in all parts of the water system.

To summarise, the water industry has the responsibility to manage physical infrastructure utilised to store, treat, and distribute water. To truly achieve resilience outcomes, it is imperative that the industry (1) advocate and shape the environment that affects source water supply, and (2) work with water users to manage and influence demand changes over time. Furthermore, the maintenance, repair and rehabilitation process need to be revisited over time as new challenges and solutions emerge (Naderpajouh et al., 2017).

Eroding resilience

Common issues that may erode resilience enhancements include:

SHORT TERM THINKING

Short term thinking can lead to a lack of investment in resilience. Resilience dividends often occur over the long term, whilst costs incurred tend to be in the short term.

"If they (senior management) choose to invest in resilience, there's no upside. But there's also no downside. If they invest in growth, there's huge upside. No one gets patted on the back for spending money on resilience. By definition you're stopping risk from happening".

(Urban water operator)

Short term political cycles can also lead to a lack of emphasis from higher level policies. Encouraging decision makers to think more about 'whole of life', as well as multi-capital costs and benefits increases the opportunity to capture resilience benefits. Governance models and decision-making methodologies[2] that help users to navigate complex, highly uncertain future decisions may also assist in responding to challenges associated with resilience. This will include making choices that are robust across a range of future options, and/or allow decision-makers to adapt their decisions as our understanding of the future evolves, or community values change.

EFFICIENCY AND ECONOMY DRIVERS

There is often a natural tension between efficiency (creating more output for less input) and the need for redundancy and responsiveness. Together with an emphasis on short term thinking, these mindsets may compromise the long-term effectiveness of the system for the short-term return.

SINGLE DRIVER UPGRADES

Funding and legislative changes can lead to single driver resilience efforts that can ignore other threats. For example, in Australia, an enormous investment is being made into security of supply, driven by climate change concerns (and legislation). However there are other threats that may be overlooked as a result, for example earthquakes and cyclones.

"What if the unexpected were to happen? It will happen. We know an earthquake will hit one of the Australian cities. The only questions that remain are: when and how severe?"

(MunichRe)

AGEING INFRASTRUCTURE

Many urban locations are currently trying to maintain adequate maintenance and replacement schedules for infrastructure systems built long ago. These assets have often been designed for performance standards and expectations that are substantially lower than those required today – not only are they old, and hard to access, maintain and replace, but they can't perform like we'd now like them to. For example, water infrastructure in the US is rated D by American Society of Civil Engineers, with estimated $1 trillion to maintain the service for the required demand by 2042.

"Essentially, the majority of our water system was built in the 1890's and 1950's and that was when we had not very many people. Yet the stuff that I'm planning for now, we're talking about 8 million plus people living off the same infrastructure that was built in 1950 or earlier. We decided, we only need a reservoir this big, because it saves us money. For every customer that we add on, the risk is growing. At the moment it's growing so rapidly in terms of that risk profile."

(Urban water operator)

Simply keeping up with the required maintenance of these systems requires an enormous investment of cost and effort. The American Water Works Association's state of the water industry report (2017) states that renewing ageing water infrastructure is the number one concern of water utility workers. While replacing a 100-year-old pipe with a modern equivalent is likely to improve resilience, these replacements also compete with funding to address areas now identified as key vulnerabilities. In effect, even a prioritized list of areas requiring investment to build resilience will take decades to achieve, given the organisational and financial constraints on this activity.

COMPETING CHALLENGES

There are many issues that compete with improvements to potable water resilience and in many instances, this is associated to funding. For many potable water operators this is the waste and sewage activities that they also manage. For some organisations, water competes with all other municipal services including parks, libraries, waste, and community facilities and there is only one funding pot to cover all services. Other water users and environmental groups can also hinder resilience solutions. For example, the siting of new facilities to provide redundancy can be opposed on environmental grounds.

DECISION BIASES

Decisions over resilience enhancing investments suffer from many biases that impact societies' overall lack of preparation for adverse events. No matter how skilled we are at decision making we are all human, operating in busy and often pressured environments, and we may unconsciously bring many biases to our decisions.

- **Conformation bias** – the status quo way of doing things, and the herd aspect (staying within group norms) can exert a powerful and sometimes unseen influence over our decisions.
- **Short term focus** – our short-term political cycles and increasingly high turnover of senior executives mean that short term returns hold more sway than they should. Some countries' national cultures are also more likely to think in the short term (Hofstede).
- **Availability bias** - we tend to react based on recent issues or events but fail to act upon lessons learned from longer ago.
- **Anchoring bias** – we can rely too heavily on one piece of information (often the information presented first).
- **Optimism bias** – "it won't happen here or in my lifetime". Maybe it won't – but what if it does? Or even "it has already happened here, so it won't happen again."

Awareness of these potential biases is the first step to reducing their impact.

Water mains next to the KCRC East Rail Extensions, Hong Kong (Photo by Arup)

5 Benchmarking current resilience practices in the potable water industry

General overview of resilience penetration

Consideration of resilience in water networks is nothing new, but as described by one urban water operator,

> ***The floodgates have opened for resilience efforts, as society more broadly embraces the concept.***
>
> **Urban water operator**

Resilience penetration varies across geographies reflecting the influence of the local hazard environment, politics, culture and economics on attitudes towards resilience. This section focuses primarily on current resilience practices in Australia and New Zealand and should be taken as examples of practices rather than generalisable findings applicable to the water industry globally.

In New Zealand, natural hazard exposure[3] creates a significant interest in building resilience at multiple levels. Significant earthquakes occurring in 2010, 2011, 2013, and 2016 have given both private and public sector organisations real events as references to create what one respondent described as a 'step-change' in prioritisation of resilience improvements.

In Australia, recognition of climate change impacts and the legislative mandate to address these is a key driver of resilience recognition, with network operators developing climate resilience strategies. Four New Zealand and Australian cities are part of the Rockefeller Foundation 100 Resilient Cities network, with Chief Resilience Officers driving the development and implementation of city resilience strategies. Both New Zealand[4] and Australia have national level disaster resilience strategies. Significant research funding and effort in both countries is assisting both with knowledge and publicity of potential hazard impacts, and with the development of expertise in resilience solutions. Both countries also have networks in place for critical infrastructure owners and operators to share knowledge and practice, although further opportunity exists to deepen the sharing of solution provision where significant interdependencies exist – for example, between water and power.

"I think we're all realising it's important"

(Urban water operator)

"There's lots going on in this space"

(Government interview)

The findings from these interviews indicated that, in general, water utilities in Australia and New Zealand understand the importance and urgency of improving resilience across the sector, and many champions of resilience are present within organisations, regulatory authorities, and potential incentivisers. However, significant work is needed to convert those understandings and aspirations into completed collaborative actions across these organisations and communities:

"I always look at the differences between the energy sector and the water sector. The energy sector has resilience at a local and a global scale, whereas water has basically no resilience at a global scale. It has the ability to respond and recover, that aspect of resilience, but it doesn't actually prepare around big failure. So, all of our systems are all one source, one treatment plant, kind of one network. When you talk about the big scale resilience stuff, we're not really doing anything about that at all. We're thinking about it but we're not actually doing anything about it at this stage."

(Large urban water operator)

2nd Field Engineers from Linton repairing water mains at Burwood Hospital. Image from Royal New Zealand Air Force P-3K Orion that conducted aerial surveillance of areas affected in Christchurch earthquake on 22 February 2011 (Photo by New Zealand Defence Force)

One key enabler for making real resilience change is support from Chief Executive Officers or board level. Those resilience champions with higher level support are able to make significantly more progress than those without and can create higher social capital to support initiatives associated with resilience (Aldrich, 2012).

"So where I've been fortunate is that the chief executive is extremely supportive, but if you didn't have it you're in a world of pain because you won't be able to get the investment on one side and you won't be able to get the buy in for the staff for the soft support on the other"

(urban water operator)

Common operational measures

INVESTING IN (SOFT) RESPONSE AND RECOVERY CAPABILITY

Organisations are investing in resilience through continuity champions who run scenarios and exercises to test responses to potential failures and learn lessons to reduce occurrences of crises. The best of these are including wider and wider networks of employees, and potentially other organisations to build capacity. Specialised incident management systems have been developed and used to help manage efficient responses to incidents. Organisations with high resilience maturity are investing significantly in considering succession planning, knowledge sharing mechanisms, and the training and certification of staff. The champions within these organisations need to be supported by organisational leaders to ensure that employees are best prepared for crisis, and systems are well tested.

COLLABORATING AND GROWING NETWORKS

Collaboration is a vital part of resilience in the water sector. Positively, all urban water operators across the multiple countries our interviews spanned, are involved with a network of their peers. This allows for the sharing of ideas and initiatives to benefit the sector as a whole.

WATER SERVICES ASSOCIATION OF AUSTRALIA (WSAA)

The Water Services Association of Australia (WSAA)[5] is the representative group for the urban water industry. WSAA facilitates knowledge sharing and collaboration, promoting networking and cooperation across the sector. The association influences national and state policy, advocates for environmentally sustainable development, and provides best practice documentation for the industry. They also focus on research, education, and training in the water, wastewater, and treatment space.

TRUSTED INFRASTRUCTURE SHARING NETWORK (TISN)

The TISN[6], established in 2003, was developed specifically to generate information sharing across Australian critical infrastructure providers. It offers a space to develop resilience building initiatives and address challenges to business continuity and security, and includes representatives from essential services such as healthcare, electricity, water, food, electricity, communications, banking, and transportation. Although interviewees mentioned that further work could be done to improve the sharing of lessons learned across different utilities ("everyone's happy to just keep it within their little sector silos and you know, why are we all sitting at this table then?" – urban water operator), the existence of the platform provides a place for collective conversations and solutions to develop and grow.

WATER AND WASTEWATER AGENCY RESPONSE NETWORKS (WARNS)

In the United States, WARNs[7] bring utilities within states together. These are comprised of "utilities helping utilities" within a state, who respond to and recover from emergencies by sharing resources with one another. WARNs are governed by a common mutual aid agreement that allows utilities to share resources in a more expedited way, compared to other mechanisms that require a formal disaster declaration. The agreement even spells out how liability, workers' compensation, insurance, and reimbursement will work. Other benefits include increased emergency preparedness and coordination, and enhanced access to specialised resources. This allows for fast mobilisations of utility responders who, once notified of an event, are typically on the ground within 24 hours.

LIFELINES

In New Zealand, Lifelines groups[8] are established in most regions to provide a forum for regionally based collaborations between utilities, emergency services, scientists, and other relevant professionals. These groups have coordinated major projects including The Wellington Resilience Project, which combined 16 utility providers together with local government to identify, evaluate and present a justified and coordinated programme of

infrastructure investments for Wellington (Smith, 2018). Water New Zealand[9] also acts as a non-profit voice for the New Zealand water sector.

UK WATER INDUSTRY RESEARCH (UKWIR)

In the United Kingdom, UKWIR[10] enables the sharing of research and learning. Consisting of 19 water and wastewater utilities across the UK, this research programme aims to address 'big questions' (such as eliminating leakage and interruptions, and achieving 100% compliance by 2050), many of which help to build resilience.

Although there may be ways in which these various networks could improve, it is promising and positive that such networks exist in countries across the globe. These networks and associations provide the perfect platform for information and solution sharing and co-development.

CROSS UTILITY COOPERATION

One large urban operator is part of a voluntary demand reduction program run by the electricity network ("Instead of building more power stations they (power companies) want us to shed.") This is achieved by turning power off at a key site and switching over to own generator usage, with 10 to 30 minutes notice given to the water operator. In some instances, this is voluntary and in others the water operator is paid a sum greater than the cost of generator use. This enables the electricity company to fully utilise all capacity in the network (e.g., generators) and potentially avoid outages to those without their own generation. There is a side benefit for the water operator emergency capability as this helps to ensure generators are regularly maintained and operational.

ATTEMPTING TO BUILD REDUNDANCY

Resilience champions are pursuing efforts to build what they refer to as hard response and recovery capability (e.g., infrastructure that can allow a switch of supply to key areas). One example is ensuring a key area for employment or critical facilities has multiple connections to the water system. One operator is promoting standardised design solutions to allow for interchangeability of parts of the system.

MANAGING CONTRACTORS

Contractors responsible for day to day operations of the water supply network need to have responsibility for the continued safety of the water supply, rather than a simple, transactional contract. This lesson was learned by one water provider following a contamination outbreak. They subsequently changed contracting arrangements into 'management' contracts – ensuring a culture of ownership and responsibility for end results.

ASSESSING ORGANISATIONAL RESILIENCE

In 2012, five Australian water utilities took part in a joint project to examine their organisational resilience[11] – illustrating that organisational resilience capability building is firmly on the agenda. It found strengths in their abilities to survive and manage crisis events, but they were less confident in their abilities to adapt and continue to thrive in an uncertain world. This suggests a strong emergency readiness and response focus but a lesser organisational focus on being positioned for long term resilience efforts.

CROSSING GEOGRAPHIC BOUNDARIES

Building resilience requires an approach spanning geographic or organisational boundaries. The formation of Wellington Water, amalgamating water operations previously undertaken by three separate bodies, and the creation of the Murray Darling Basin Water Management Plan are two examples. The formation of these recognises water system boundaries, rather than territorial ones.

Drivers for operational resilience

INSURANCE

Risk assessments carried out by insurance providers have already started to factor in resilience measures and may impact the availability and, in the long term, the cost of premiums. However, these are weak mechanisms that are often dealt with quite separately from big strategic direction and investment decisions. Organisational silos may be contributing to a lack of knowledge about insurance incentives. For example, when asked about insurance, an Australian respondent mentioned that they weren't aware of insurance reporting until they explicitly went looking for the information. "We have group insurance cover in our state, called the 'State' Water Utility Program, and I learnt that we are actually the most competitive program in Australia. We provide information on our liabilities and risk maturity and the proactive approach we are taking to minimise interruptions and handle incidents etc. Insurers then tender for our program, and apparently due to the proactive work we are taking to be more resilient we have the most competition (and therefore lowest prices) for our programme". Reducing these silos, increasing the awareness of existing capabilities, and highlighting the fiscal benefits of resilience building efforts may help to improve executive and employee buy-in to improvement initiatives. This example also shows that international research collaborations such as the Resilience Shift, can instigate awareness and knowledge sharing across organisations to further explore the level of existing capability to address resilience.

CUSTOMER CHARTERS

Performance metrics such as outages or breaks are a key driver noted by Australian operators. Customer charters in some cases define the expected performance of the water system – or how resilient it needs to be. When considering risk management, one urban water operator links their asset management and renewal plans to their customer charter, ensuring that levels of service are strictly maintained.

POLITICS

Issues with water quality or quantity tend to be highly publicised with the public and government highly critical of any service outage. This creates a very real pressure (but not necessarily funding) to maintain supply. As one urban water operator noted, "customers' tolerance and community tolerance to these outages is degrading… people want things now and they expect everything to be working and as soon as it's not they're onto social media, telling you what for".

STRATEGY

Resilience is operationalised as a key goal in some water operators' strategies and is implicit in the goals of others. For example, the Three Waters Strategy introduced by Wellington Water specifically outlines the resilience of networks to support the economy of the area (see Figure 5).

At an implementation level, many operators have specific targeted actions to improve resilience, largely driven by climate change. In Australia, WSAA have published guidance documentation[12] to aid in adapting to climate change, which contains easy to use steps for organisations commencing the process of climate adaptation.

REGULATORS

In the UK, Ofwat, as the economic regulator of the water sector, has reviewed the business plans of water companies to assess their plans for efficiency gains, customer service and resilience improvements. Fourteen companies have been asked to do further work to improve their plans (Ofwat, 2019). Therefore, regulations can instigate operational resilience within the sector.

Improving infrastructure resilience	
Infrastructure planning	• Integrated planning and investment • Good data enabling good decision making • Locating infrastructure in less risk-prone locations • Risk avoidance in the planning stage • Hazard mitigation
Infrastructure design	• Resilience by design • Security by design
Infrastructure operations and infrastructure	• Maintenance resilience - Maintenance planning - Remote sensors • Operations resilience - Faster service restoration • Reconstruction resilience - Infrastructure betterment in restoration or reconstruction

Figure 5

NSW Critical Infrastructure Strategy, 2018 (Creative Commons Attribution 4.0 licence)

Safe and healthy water	Respectful of the environment	Resilient networks support our economy
We provide safe and healthy drinking water	We manage the use of resources in a sustainable way	We minimalise the impact of flooding on people's lives and proactively plan for the impacts of climate change
We operate and manage assets that are safe for our suppliers, people and customers	We will enhance the health of our waterways and the ocean	We provide three water networks that are that are resilient to shocks and stresses
We provide an appropriate region-wide fire-fighting water supply to maintain public safety	We influence people's behaviour so they are respectful of the environment	We plan to meet future growth and manage demand
We minimalise public health risk associated with wastewater and stormwater	We ensure the impact of water services is for the good of natural and built environment	We provide reliable services to customers

Figure 6

Wellington Water, New Zealand: Three Waters Strategy, 2018

Existing asset management

Operators with a high level of resilience maturity build resilience thinking into ALL decisions regarding asset management and long-term planning, in line with a value chain approach. They understand that meeting their mission of continuous supply of the desired quality and quantity of water requires resilience to be considered at every point in the system – from physical assets to the people and systems used to maintain these assets.

CLIMATE CHANGE RETREAT

As an example of this approach, the gradual retreat of key assets from areas likely to be impacted by climate change is being managed proactively by one operator, through asset management planning processes to ensure efficient spending, whilst retaining service quality.

ADAPTIVE PLANNING

Some Australian operators are trying to ensure that long term plans are adaptive, using a Dynamic Adaptive Policy Pathways approach.

"What we're now talking about is let's have multiple options that can evolve over time and then monitoring our trigger points like population, climate change etc, that's going to be the real big day, how you switch from one option to another based on some potentially weak signals in those trigger points. That's a real clear focus of this plan, putting scenarios into our modelling and then just trialled a few projects, doing adaptive pathways planning and coming up with train-line diagrams".

In Australia, water utilities are drawing on their shared networks to plan and refine their adaptive pathways strategies. This is another example of how shared networking platforms allow these organisations to work proactively with each other to the benefit of resilience across the sector.

"WSAA is just doing an adaptive pathways planning joint project where there are probably about 8 of us signed up. We've stated where we're at, what we're trialling, committed to building some joint toolkits together, how we might use these things and also how we might figure out sign posting together."

(Urban water operator)

PRIORITISATION

Most operators recognise that the scale of work needed to build resilience is greater than the available resources and funding. As assets are renewed, more resilient solutions are incorporated – for example replacing old pipes with modern seismic resistant constructions[13]. However, with thousands of miles of pipes, this process is a decades long programme. Prioritisation is being used to ensure that in more vulnerable areas infrastructure and assets are upgraded first. However, prioritisation is not a straightforward process with significant understanding needed of interdependencies, community needs, as well as political and social incentives.

AdaptWater TM[14]

Originally developed to help address climate change adaptation, the ADAPT tool helps users to identify the risks across the many assets of the water sector, to understand which risks should be prioritised for resilience improvements. The online tool is a user-friendly software programme which helps users quantify the risks to assets and provide modelling for investment decisions. Although initially developed for the water sector, ADAPT can be adjusted for use by other utilities.

Figure 7

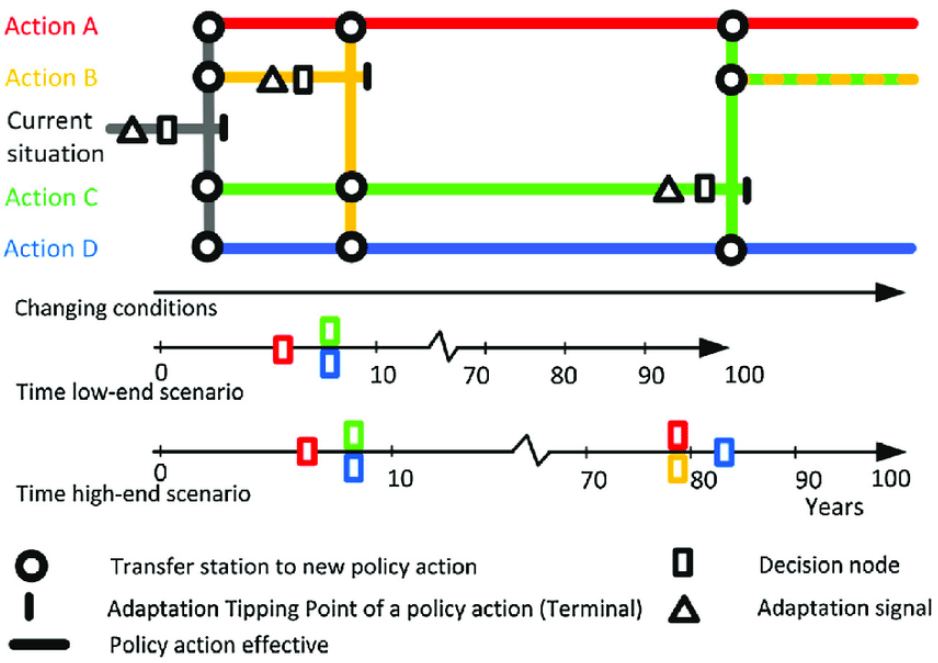
Example Adaptation Pathways Map (Source: https://www.deltares.nl/en/adaptive-pathways/).

Dynamic Adaptive Policy Pathways (DAPP) is an approach that was developed to aid in the development of an adaptive plan that is capable of dealing with deep uncertainty.

Users set specific targets or objectives, and DAPP allows decision makers to respond to changeable conditions and perceptions in the system. The focus is on thresholds rather than time and mixes long-term and short-term options and actions to provide increased flexibility to achieving the user's objectives. Additionally, DAPP allows for timely adaptation through the monitoring of early signals and trigger points.

Users complete a cost-benefit matrix for each pathway (and possible combinations) which aids in decision making.

For a full explanation of the DAPP, including an example, this short video is useful: https://www.youtube.com/watch?v=yLS4PubQVgc.



STANDARDS

Although the ISO international standard in Asset Management does not directly address resilience, projects to obtain certification may produce many resilience benefits. For example, Thames Water (UK) undertook an asset management improvement journey between 2011-2014 and they report that this has helped with:

- Developing outcomes that are informed by customers (potentially helping to meet resilience standards desired by customers).
- Balancing long term health of assets with short term drives for cost efficiency.
- Delivering organisational resilience improvements.
  (Sutton & Chadwick, 2014)

DEMAND MANAGEMENT

Programmes to ensure appropriate utilisation of the existing assets are already in place. For example, Victoria, Australia has a water conservation strategy, Target 155, illustrated below. This strategy, first introduced during the Millennium Drought, aims at reducing each citizen's water usage to 155 litres per day. In order to achieve this, permanent water saving rules have been in place in Victoria since 2011. These help to prevent the need for water restrictions (although restrictions are still possible during times of drought) and help encourage the efficient use and valuing of water. One urban water operator did note that there is a limit to efficiency gains.

"a lot of the appliances now, where you had 12l flush toilets, you've got 4.5 and 3l flush toilets. It's not too much further that can go down in water use without putting in a vacuum. Then that adds energy. There is a basic level of water consumption required at a household level… and we're starting to hit that… we're getting very close to the efficiency point in appliances".

This operator noted that in the future,

"there's going to be a challenge for us in terms of keep promoting water efficiency but also there's a base level that's required as well".

This suggests that management of water demand can only go so far.

The Stockholm International Water Institute[15] has produced a pilot catalogue of initiatives aimed at improving the efficiency or productive use of water, through water savings or yield increases across agricultural, urban and industrial uses.

Management of demand has also consequences that need to be addressed down-stream, such as increasing the ration of solid to liquid waste which in turn creates complexities and needs for modifications in sewage systems.

OPTIMAL UTILISATION OF EXISTING ASSETS

"Mexico City actually wastes as much water as some of the world's largest cities use"
(Waterworld, 2013)

Reducing leaks is a challenging, but vital endeavour in some cities. For example, in Christchurch New Zealand a program of water loss reduction commenced in 1996[16]. Extensive guidelines exist[17] to assist water operators with tools to assess and reduce loss through leakage. Ageing infrastructure and local capability are key inhibitors to reducing wastage.

Figure 8

Example of marketing for the Target 155 campaign.

The Water Efficiency Labelling Scheme (WELS) is the national program for encouraging more efficient domestic water use. The scheme labels domestic water products with their consumption information, influencing purchasing decisions and driving both reductions in demand for water and competition amongst suppliers. After a decade of implementation, the WELS scheme is estimated to be saving at least 100 gigalitres of water each year in our major cities and towns, along with achieving major energy savings.

Australian National Climate Resilience and Adaptation Strategy, 2015

New assets

Examples of new asset decisions that address climate change that adresses resilience and natural hazard risk are presented in this section.

AUSTRALIA'S DESALINATION PLANTS

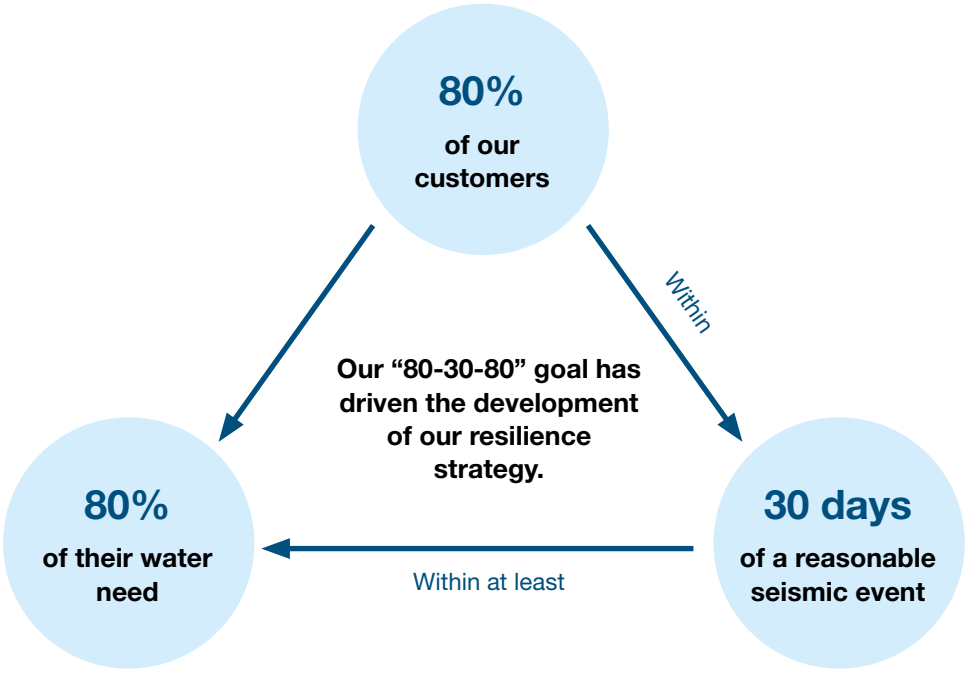
Demand management can only do so much to improve the resilience of the water networks. Utilities must also look at supply resilience to ensure water continues to remain available for consumption. Understanding this, and in response to the Millennium Drought, both the Victoria and New South Wales governments in Australia invested in the building of desalination plants to increase their water supply. These plants were completed in 2012 and 2010 respectively. Although these plants will not supply all of the urban water needs, it provides a buffer in water provision, improving the resilience of these cities.

COMMUNITY WATER FACILITIES

Building resilience in high seismic hazard areas is complex. Wellington Water has created an innovative new network of 21 community water stations. These community water stations are designed to be able to supply water to residents by Day 8 following a major earthquake. There is a well-publicised expectation that communities need to be self sufficient until Day 8 following a major earthquake. The creation of these stations acknowledges the current vulnerabilities of the network, the long timeframes for improvement of that network, and the need to think differently to ensure basic human needs are met in the event of an expected major earthquake.

Figure 9

Wellington Water's "80-30-80" goal



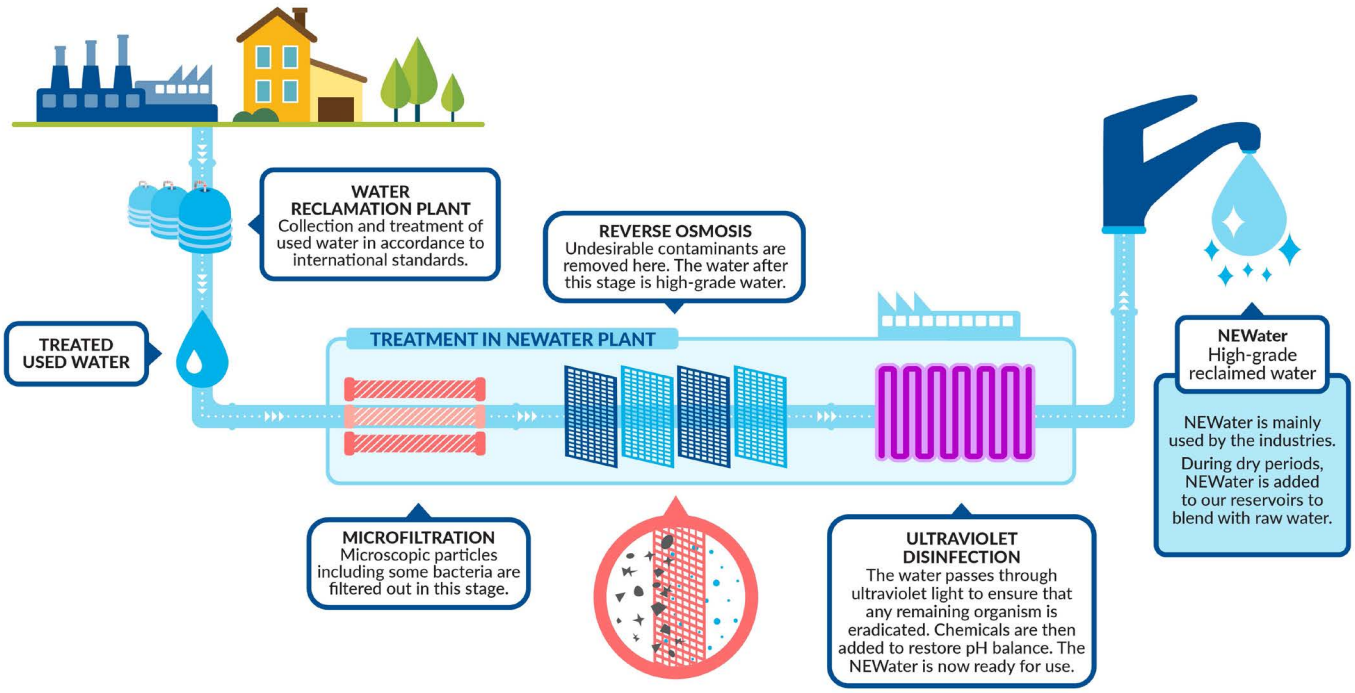
Best estimates are that it could take 100 days to restore the water network to many residents after such an event. The building of these community water stations is helping Wellington Water to meet their “80-30-80” goal, shown in Figure 9.[18] There are separate contingency plans to meet fire-fighting needs including deployment of a temporary water main, mobile pumps, tankers and utilisation of sea water

NEW WATER TECHNOLOGIES

Singapore is pioneering the use of new technologies to transform wastewater into potable water[19]. In an effort to build water security, new technology is providing up to 30% of daily needs. While a number of operators have commented that they believe this is the way of the future, there are significant public perception issues to overcome general acceptance of these methods.

Figure 10

Singapore NEWater process (reproduced with permission from "PUB, Singapore's national water agency"



Water tower, Norris City, Illinois, US (Photo by Rachel Nickerson Unsplash.com)

6 Opportunities for achieving critical mass

In our interviews with water operators, we found many potential ideas for ways to enhance resilience building. Our overall conclusion was that resilience building is enhanced by considering three specific areas – the organisation, its customers, and the legislative environment it operates within. As Naderpajouh et al. (2018) suggested, actions associated with building resilience need to be formed across the decoupled domains of community, corporate, and public governance.

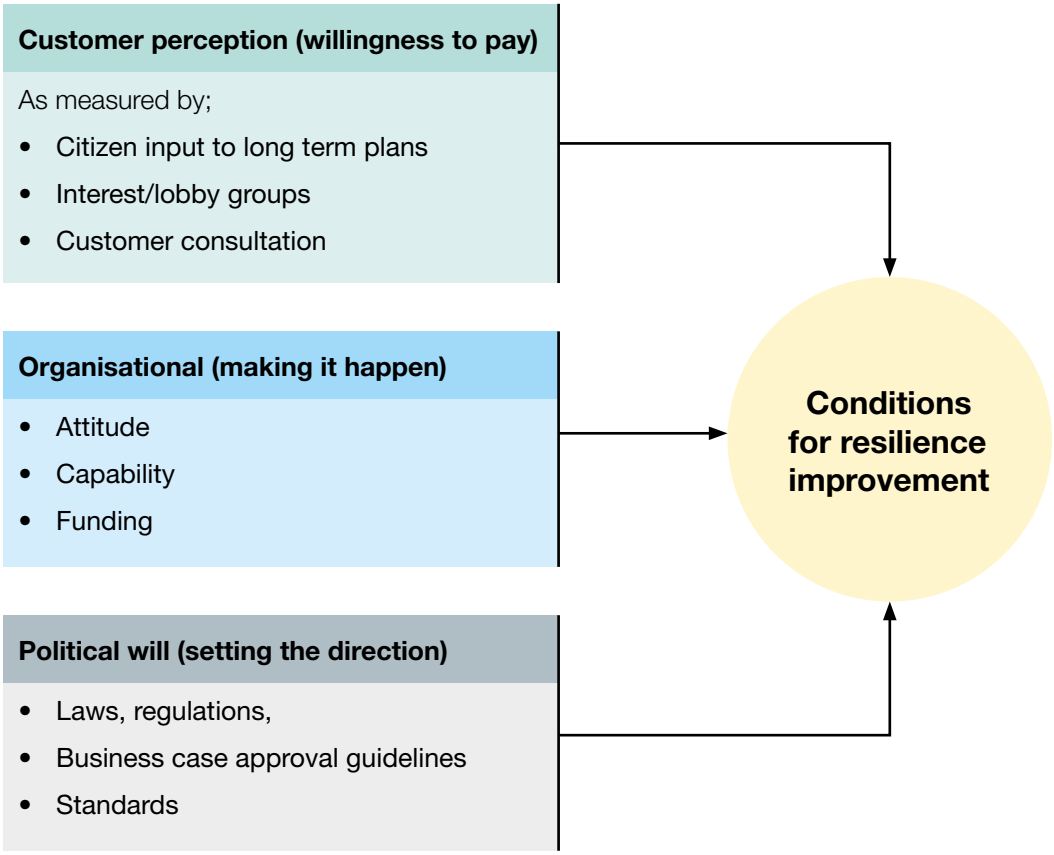


Figure 11
Framing water resilience enhancement.

A lack of impetus from any one of these three actors may constrain any resilience agenda. If actions across these three actors are aligned, greater progress will be made. Organisational will alone is likely to be hampered by customer opposition, and/or by political barriers. Customers are a crucial, and often a missing link, as the ultimate funders of any resilience investments.

"In an ideal world the community is all on board with your actions and they want you to spend money on upgrading your assets and they want you to take action on climate change".

(Urban water operator)

A clear shared vision and unity of purpose across these three areas, will greatly enhance resilience prioritisation and efficacy.

Recommendations

There is no one solution to the barriers that inhibit resilience improvement efforts. This primer presents **17 suggestions** to give resilience development a boost. Some will be applicable to many contexts, others will need to be tailored for specific application. We hope that these suggestions may inspire you to begin, or continue, your resilience journey so that we can ensure that our potable water networks continue to assist communities in thriving. We can categorise them based on their role in enhancing resilience (Hollnagel and Woods 2006).

ANTICIPATION MONITORING LEARNING RESPONSE

ANTICIPATION	1	Understanding your risks
ANTICIPATION	2	Engage citizens in better understanding of the risks and vulnerabilities
MONITORING	3	Create public resilience metrics
LEARNING	4	Find your burning platform
LEARNING	5	Tell good stories
LEARNING	6	Consider what message is appropriate
LEARNING	7	Learn from other countries and cultures
RESPONSE	8	Create effective organisational structures
ANTICIPATION	9	Continue building an adequate number of advocates and voices for resilience
LEARNING	10	Engineering education and professional bodies
RESPONSE	11	Provide the legislative mandate to act
RESPONSE	12	Build organisational resilience capabilities
LEARNING	13	Ensure water is valued
LEARNING	14	Embed resilience thinking at inception
RESPONSE	15	Consider alternative funding options
RESPONSE	16	Reflect system boundaries in governance arrangements
RESPONSE	17	Build and continue to best utilise co-operative networks

1 UNDERSTANDING YOUR RISKS

Projects that help organisations gain a good understanding of the likelihood and consequence of their risks are helpful for prioritising investment and engaging with customers on how those risks can be responded to. As one operator notes, while we might want our water supply to continue to perform in any crisis, this is likely unachievable. Contextually appropriate risk information enables informed conversations with all stakeholders; including discussions around risk appetite and alternative risk treatment options.

2 ENGAGE CITIZENS IN BETTER UNDERSTANDING OF THE RISKS AND VULNERABILITIES

As ultimate funders of the water supply network, communities need to actively engage in decisions about water system resilience. This requires an assessment of information gaps regarding supply risks, along with consideration of multiple different communication pathways. Some citizens will listen to councils, some to government, some to science, and some to media. Risk discussions need to be more sophisticated than the current headline grabbing state. Trade-offs between resilience and cost need to be better understood by customers who ultimately are the funders of any resilience improvement projects. Educating consumers on potential restoration times in the event of incidents could also aid the building of community level resilience through alternative water supplies. Strategies and nudges such as sharing resilience information through bills may instigate increasing engagement of communities. Some of these lessons have been explored in actions associated with sustainability and bushfire risk[20] and can be further extended to the resilience discourse.

3 CREATE PUBLIC RESILIENCE METRICS

Measures of utility resilience can produce accountability and sector level competitive pressure.

"It's interesting because I do look around and I do see other organisations that are incredibly more resilient than we are but publicity about the relative resilience of organisations isn't there. So as a result, we don't feel like we're performing poorly on it, because no one's calling us out on it."

(Urban water operator)

Work in this area could also help to address the divergence of views on the question of "how resilient is the water network", providing tangible measures to assist operators in clarifying the gap between the current and desired state. An agreed set of metrics could also assist operators in looking holistically, at what one respondent called "the three legs of the stool"; physical systems, organisational systems, and community resilience. Metrics can take an all hazards approach, while consultation with stakeholders would be needed to achieve acceptable compromises between ease and accuracy of measurement. These metrics could also act as a feedback to keep the systems in a desirable regime (Biggs et al., 2015). There are a growing number of resilience measurement frameworks. However, there would appear to be significant work still needed to create easy to use, acceptable measures tested by a number of water operators.

4 FIND YOUR BURNING PLATFORM[21]

In Australia, recognition of climate change, and the associated risks has provided the driver for much of the resilience action. In much of New Zealand, natural hazard risk has provided a key driver, along with recent contamination issues. Finding the key driver or realistic threat (as per understanding your risks and talking openly with all stakeholders about those threats) to your region provides a necessary impetus to decision making.

- If climate change is your burning platform, the guidelines by WSSA, developed in consultation with all of Australia's water utilities, may be a very handy resource[22].

Build resilient infrastructure, promote sustainable industrialization and foster innovation

- If sustainable UN Sustainable Development Goals are a big issue in your country, seek out the resilience aspects of these to make your case[23]. For example, Goal 9 specifically relates to resilient infrastructure.
- If your organisation is risk averse, consider whether the legal, economic or other implications of any potential failures may convince decision makers. For example, the Hutley opinion in Australia stated that

"it is conceivable that directors who fail to consider climate change risks now could be found liable for breaching their duty of care and diligence in the future"

(Hutley & Hartford-Davies, 2016)

5 TELL GOOD STORIES

Keep prior events alive in people's minds to overcome recency biases in decision making. For example, prominent markers of prior flood events help people to understand real threats.

"It's that telling people stories about examples of where things have happened, outside of the realm of what we considered possible, to make them aware that you should be planning for things that perhaps don't seem likely at this point"

(Government interview).

Respondents note that for many operators, re-arrangement of who owns and operates the water networks mean that institutional memories of incidents or near misses are quite short. Resilience champions within the organisations need help to illustrate these events, written in a way that overcomes the arguments of "it's never happened, it won't happen here," or "it has already happened to me, it will not happen again." There are numerous examples where operators are learning from other well publicised events, rather than waiting for their own experiences of incidents. One respondent noted that visuals or videos may be a more effective way to help people really "get it". For example, this could be a short video showing what happens when 500,000 people are without water for two days. Managing communication facilitates broadening the participation as a major principle of building resilience (Biggs et al., 2015).

Another respondent suggested using the 'how many for how long' consideration. If a key vulnerable asset breaks, it provides a powerful message to start engaging senior management about the needs for resilience investment.

6 CONSIDER WHAT MESSAGE IS APPROPRIATE

In some contexts, the word resilience may not be the best way to obtain support for proposals. "Maintaining service levels" may be easier for a wider group of stakeholders to accept in some organisations. Resilience champions need to pause and consider the audiences' context. In some cases, "security" may be a more appropriate description. In others, health and safety regulatory frameworks may provide a compelling case for necessary improvements. Choosing the right way to effectively shape and convey the message across different communities and organisations is crucial.

7 LEARN FROM OTHER COUNTRIES AND CULTURES

Resilience thinking is more natural in some nations and cultures than others. The world could learn many lessons from Japan, where one engineer suggests that building resilient infrastructure is simply the norm. Clearly, their high hazard environment is influential, but there is potentially an element of national culture with regards to a collectivist view of society and a long-term orientation that influence their decision making. Consideration of how national level culture may impact our resilience attitudes may be helpful in any consideration of appropriate messaging and the 'sales-pitch' most appropriate in any context. For example, if there is a tendency for short term thinking to be the dominant view, messaging that sells why long-term thinking is needed might need to precede specific resiliency messages.

If community engagement is not the normal or expected way for local or national authorities to conduct their work, messaging will need to differ from that used in communities where high levels of consultation are expected.

8 CREATE EFFECTIVE ORGANISATIONAL STRUCTURES

Span of control: Multiple conflicting priorities, in many organisations responsible for operating water networks, make a focus on resilience more difficult than in those solely tasked with any one or more of the three water infrastructures. In our research, operators tasked solely with water provision had more advanced resilience programmes, than those responsible for overall city functions. Getting this right is difficult. From a holistic systems perspective, there may be benefits from a broader span of control which leads to a greater overview of the many areas needing investment to build resilience.

Efficiencies of scale: Whilst there are many clear advantages to local control of water, there are also significant impediments to achieving best practice when the community served is not large enough to fund the expertise necessary. If larger organisations are politically unpalatable, then some mechanism for better pooling the use of expertise across utility operators would be beneficial. An OECD survey (2016) of 48 countries found that 65% identified staff and managerial competency as a barrier to water infrastructure improvements.

9 CONTINUE BUILDING AN ADEQUATE NUMBER OF ADVOCATES AND VOICES FOR RESILIENCE

We interviewed many passionate resilience champions for this project but overall, they are still fewer than the numbers needed to instigate and respond to the magnitude of the change needed to improve resilience. Initiatives such as the 100 Resilient Cities network that continue to build resilience champions, ideally at the highest possible levels within organisations, are useful endeavours to elevate the resilience conversation. Forums that assist these champions to 'sell resilience' provide an important mechanism for shared learning and moral support. There may also be a place for consideration of professional development options for those with a passion and interest for resilience, but who have little formal background. Organisations appointing resilience champions need to ensure sufficient investment is made in connecting those champions with others and providing opportunities to them to learn, grown and share their resilience knowledge.

10 ENGINEERING EDUCATION AND PROFESSIONAL BODIES

Engineers (and other professionals) are often in an influential position to advocate resilience thinking, especially as the very early design phases of a project are often where resilience gains may be obtained most cost effectively. However, informed commentators suggest that engineers may deliver only to the given brief and tend not to engage in debate about the brief or its limitations. That is, an engineering solution is often developed and presented in a siloed approach, rather than more time being spent in an iterative process where a number of solutions and their pros and cons are exhibited and formed across multiple stakeholders. Consideration and influence over engineering and other professional bodies to increase their understanding of the other actors and their coverage of systems thinking and resilience may be one small piece of the jigsaw to consider. Advocacy skills may also assist professionals in understanding when and how to debate project briefs.

REBUILDING AFTER DISASTER

A silver lining to the impact of any disaster on a community is the opportunity to enhance resilience in the repair and rebuild efforts. Unfortunately, this is also a time when funding is a major constraint. Following the Canterbury, New Zealand earthquakes in 2010/11, the goal of the organisation tasked with repairing and rebuilding the cities horizontal infrastructure (water, wastewater, storm water, and road networks) was to "create resilient infrastructure that gives people security and confidence in the future of Christchurch". However, a number of barriers constrained the realisation of resilience improvement (MacAskill, 2016). It is important for rebuild authorities to consider how funding mechanisms, organisational arrangements and community engagement might be managed to maximise opportunities to enhance resilience as part of rebuild efforts. For more information on the rebuild of Christchurch's infrastructure, see *https://scirtlearninglegacy.org.nz.*

11 PROVIDE THE LEGISLATIVE MANDATE TO ACT

Major utility operators are compliance focused. While the incentive approach (carrots) may be favoured by some, many of the resilience champions within these organisations are very happy with compliance (the stick) (e.g., regulation and standards, licensing frameworks, legislative acts, guidelines) as this enables them to get investments approved more readily.

"If I'm going to get the kind of investment that we need to build resilience into our water network it needs to come through government policy, it won't come through any, there's no way I'm going to get it through a business case to the organisation."

(Water operator resilience champion)

In October, 2018, US Congress signed into law the American Water Infrastructure Act (AWIA) which now requires water utilities to conduct a risk and resilience assessment (RRA) of their community water systems and to develop a corresponding emergency response plan (ERP). The US Environmental Protection Agency (EPA) is tasked with certifying compliance with this federal mandate.[24]

ENSURE CONSISTENCY WITHIN AND ACROSS POLICY FRAMEWORKS

A key issue is to ensure consistency within political and legal frameworks. For example, authorities responsible for price regulation need to make their decisions in accordance with other policy objectives. This is achieved in Victoria, Australia by having customer outcomes as a key driver for regulatory authorities (Essential Services Commission 2016). In effect, this means that investments that will require water price changes must be strongly linked to ensuring the delivery of key customer outcomes such as continuity and quality of supply.

Another consistency issue exists in cost sharing arrangements that may be counter-productive by disincentivising resilience investments. For example, the cost sharing arrangements in place for major disasters in Australia and New Zealand can disincentivise assets owners (local councils) to focus on building resilience. These arrangements commonly provide a set percentage of central government funding to reinstate critical assets, but do not provide for any improvement of those assets. Essentially, these policies prohibit the "build back better" ethos of resilience-minded, disaster recovery advocates (see rebuilding after a disaster). As a result, these policies may instigate reactive rather than proactive measures, which are at odds with national resilience policies.

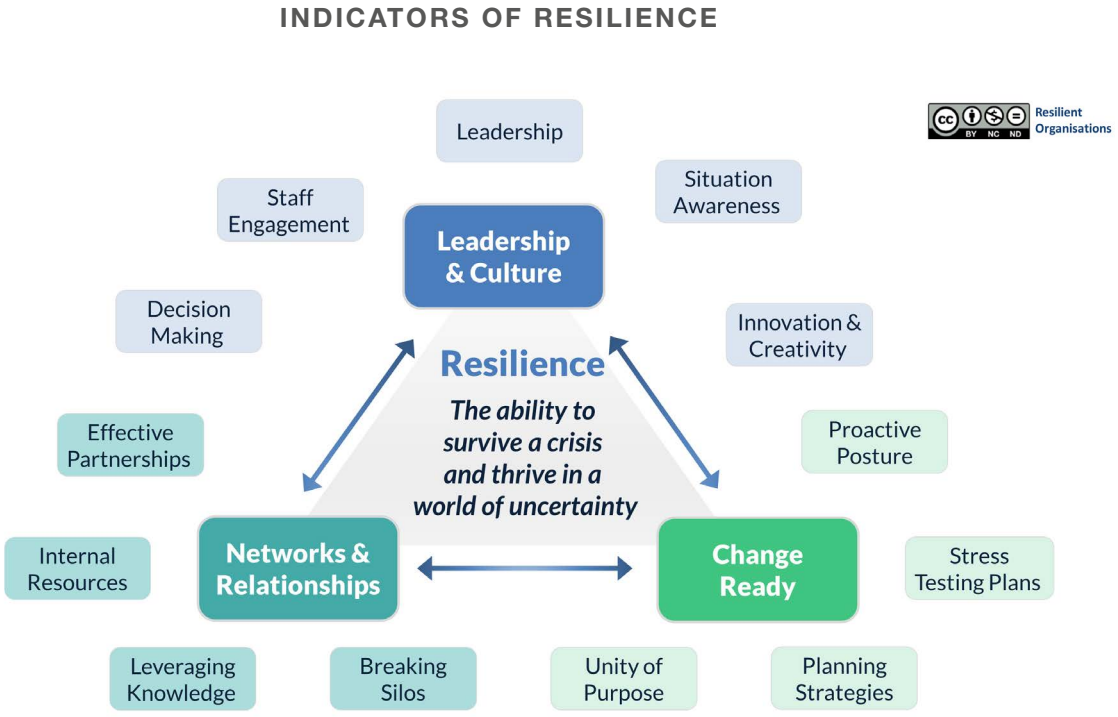


Figure 12
The 13 indicators of organisational resilience (resorgs.org.nz)

Another example is where one regulatory authority (environmental protection for example) mandates standards but these are not supported by pricing regulators. The regulation needs to be placed well within the existing regulations and joined up with common goals and intra-government collaboration to ensure that impacts from changes are well understood.

PROACTIVELY REVIEW STANDARDS AND POLICIES

In general, standards reviews are reactive. An event happens where failure occurs, reviews follow, and an improvement is made to increase required standards. Becoming more proactive when standards reviews occur would be beneficial with more future thinking about what we might be expected to face (particularly in regard to climate change). Pairing this with proactive phasing in of improved standards would improve resilience.

MAKE REPORTING ON STANDARDS PERFORMANCE MANDATORY

Issues that companies are required to publicly disclose (e.g. financial risks relating to climate change) are likely to focus board attention on mitigation efforts. The Task Force on Cimate-Related Financial Disclosures[25] is currently developing guidelines for voluntary consistent climate-related financial risk disclosures for use by companies.

The Co-operative Research Centre for Water Sensitive Cities has some interesting work on influencing government and policy – see for example the Ten Commandments of Influencing Government at https://watersensitivecities.org.au/solutions/science-to-policy-strategies/ten-commandments-of-influencing-government/.

12 BUILD ORGANISATIONAL RESILIENCE CAPABILITIES

"You can't design everything out and just have the system completely foolproof, things do break, things do fail, people do make mistakes. You need people to be equally resilient to be able to respond to that."
(Urban water operator)

"People are our single biggest vulnerability."
(Urban water operator)

Respondents identified not only the resilience of physical assets as key, but also the organisations' managing water networks.

Organisational resilience is a strategic capability. A resilient organisation has the foresight and situational awareness to prevent many potential crises from emerging, the ability to recover quickly from those that cannot be avoided, and an ability to turn crises into a source of strategic opportunity. Organisational resilience models and measurement tools exist that can assist organisations to move from conceptual to actionable improvements. The Resilient Organisations 13 indicator model and associated measurement tool has been used by critical infrastructure organisations across Australia and New Zealand to assess organisational resilience (See Figure 12).

13 ENSURE WATER IS VALUED

"People take it for granted and don't even really value it."

(Urban water operator).

Valuing water assists in demand management and in allocation across uses. However, there are still many locations where water metering is not used and unlimited supply is provided. Where unlimited water is provided and funded via a general rating mechanism, the value concept is lost.

At a regional level, allocation systems can potentially drive better use of limited resources, where scarcity is an issue. This is particularly an issue where allocation crosses organisational and territorial boundaries.

14 EMBED RESILIENCE THINKING AT PROJECT INCEPTION

Ensure resilience concepts are included in internal processes involved in project inception. Lessons from examining damage and reconstruction following the Canterbury earthquakes point to resilience (specifically seismic resilience in this instance) being easier to achieve for little investment if included in the earliest of planning stages (e.g., design briefs, business case criteria).

"At the early planning stages, improvement in resilience can be achieved for little or no cost. As the design process progresses, the opportunities reduce and the cost increases; to the point that at detailed design the ability to improve resilience is limited and can increase the cost of the project substantially"

(Hunt & Hutchison, 2014)"

Many initiatives are under way to develop tools that assist organisations in incorporating resilience thinking at the inception of their projects. For example, Colorado have developed a resilient design performance standard for municipal infrastructure[26]. The Resilience Shift has a stream of work investigating tools and approaches to help make resilience tangible and practical[27].

15 CONSIDER ALTERNATIVE FUNDING OPTIONS

More needs to be done than we can afford. Looking at innovative new ways to fund projects may be necessary to make the improvements needed. Australian governments including the NSW Government have recently issued green bonds.This is a model that could potentially incorporate resilience either through separate bonds, or through lobbying to illustrate the close links between resilience and sustainability. Stanford University have created a living map which illustrates case studies of successful alternative means of funding infrastructure improvements[28]. For example, the PACE program in the US enables homeowners to make water efficiency upgrades with payments deducted via their property rates bills, overcoming the barrier of high upfront costs. In Pajaro Valley, California landowners are incentivised to increase stormwater infiltration by a rebate on groundwater pumping fees. Also in the US, their EPA have created a program of low interest loans to support water upgrades[29].

16 REFLECT SYSTEM BOUNDARIES IN GOVERNANCE ARRANGEMENTS

Water crosses territorial boundaries – let organisations do so as well. For example, the security of supply of water for Los Angeles is closely linked to the wider California region, and collaborative efforts (which are underway) are needed to ensure a whole of system approach to designing solutions.

"The mismatch between hydrological and administrative boundaries calls for a functional approach to water resources management, which should consider the scale of integrated basins systems rather than municipal jurisdictions."

OECD, 2016

17 BUILD AND CONTINUE TO BEST UTILISE CO-OPERATIVE NETWORKS

Potable water is only one element of building resilient communities and is often dependent upon other utilities for operation. Water operators need to continue to build and best utilise the co-operative networks that exist both within and across critical infrastructure sectors to explore interdependencies and design solutions that build overall community resilience. Where these already exist, for example the Trusted Information Sharing Network (TISN) in Australia and Lifelines Groups in New Zealand, high level approval must be given to ensure that information is freely shared to allow mutual learning. At a more local level, local emergency management committees or their equivalents are noted as a valuable place for cross-sector discussions that go beyond 'lights and sirens'.

Perlan, Reykjavik - the hot water storage tanks were used to meet fluctuations in demand (Photo by Greg Poulos - Flickr.com)

7 Call to action

The resilience of potable water is in everybody's interest and is everybody's responsibility. To achieve genuine and effective action, resilience needs to be driven by champions and a shared imperative.

> ***There's no set responsibility either. It's everyone's responsibility so it's no-one's responsibility.***
>
> **(Local government representative)**

There are parallels with Health and Safety issues, which in many countries have undergone a journey from being one person's key responsibility to an all of organisation priority and underlying, pervasive culture. However, this takes time and is a journey that requires champions to drive. Assigning specific responsibility for resilience enhancement at a high level within operators can help organisations both embed and operationalise resilience thinking, addressing the issue identified by one urban water operator:

> ***When we did our interviews (internally), our number one finding was we'd all do it but we don't know what to do and no one's telling us how to do it.***
>
> **(Urban water operator)**

Achieving a resilient water network is not easy. But it is vital that we all look at the multitude of small actions that together can bring us closer to this goal and persist with our efforts even when significant barriers may appear. Water is an integral part of our lives, both in its requirement for life, but also in its ability to create healthy communities, providing innumerable social benefits to our communities. Building a resilient water network into the future helps enable current and future generations not only to survive but also to thrive.

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