

Resilience



THE CHALLENGE

Safe drinking water and effectively treated wastewater are cornerstones of every community. However, many factors regularly challenge the water sector's ability to provide these critical services. Deteriorating infrastructure, shifting water demands, extreme weather, contamination, technology failure—these are just some of the issues utilities must be prepared to address. By some measures, risk management has become a utility's central role.

The water sector must anticipate and manage risks from a variety of disruptive events, both natural and manmade, as well as quickly bounce back—restoring, and in some cases rebuilding, to continue to perform core duties. And because these risks are often unpredictable, and regulations, technology, and science are all evolving at a record rate, this can be a hard-won task.

THE RESEARCH

WRF has a long history of equipping the water sector with the guidance it needs to stay agile. With more than 400 research projects in the areas of technology and security threats, emergency response, extreme weather and climate change, and infrastructure, WRF helps utilities identify vulnerabilities and proactively plan for impacts.

Because the success of the water sector is dependent on many factors and services, including energy, regulations, and funding, WRF has built strategic relationships with cross-sector partners, including state and federal agencies,

universities, and private entities. In 2015, WRF expanded its partnership outreach, becoming one of 20 institutions that make up the Urban Water Innovation Network (<https://erams.com/UWIN/>). The group is a result of a \$12M grant from the National Science Foundation, formed to address threats to urban water systems and create solutions to help communities bolster water system resilience. With 21 projects underway, the network is applying state-of-the-art science to everything from water demand patterns to the effects of climate change on hydrologic processes.

Enterprise Resilience

The first step in building a resilient organization is promoting an environment that values foresight. Enterprise resilience requires a structure where leadership and staff work together—within an organization's walls and with outside partners—to plan for, respond to, and prevent potential problems. WRF has been at the forefront of scientifically based solutions that help utilities build strategies to manage a full range of business risks. A significant component of this is balancing the tradeoff between the time, money, and staffing it takes to prepare for potential impacts and the consequences of ignoring vulnerabilities until being forced to react.

Beginning in the mid-1990s, WRF introduced the water sector to concepts widely used in other industries, but not yet a regular part of water utility operations, like risk governance and organizational change. From 2007 through 2021, WRF published four projects ([2939](#), [4363](#), [4573](#), and [4734](#)) offering a comprehensive look at best practices for water utility, concrete strategies for how risk management can be integrated into everyday utility operations, case studies, and more.



Recognizing that a resilient organization cannot exist without a robust workforce, WRF also provides science to support a thriving industry, such as helping to fill the looming workforce gap brought on by aging employees. Collectively, the water workforce fills more than 200 different occupations—from electricians and technicians to financial and management positions. The 2018 guide, *Renewing the Water Workforce* ([4751](#)), highlights the range of jobs and identifies pools to fill these positions, exploring new strategies to equip workers with the skills they need.

Security

Because the water sector is on the frontline of protecting public health, utilities must be acutely aware of potential threats, monitoring and putting measures in place to safeguard resources. Whether an intentional act of terror or an equally devastating natural disaster, these events have far-reaching impacts. WRF explores the tools, concepts, and guidance to help facilities prevent physical threats like chemical, biological, and radioactive contamination, as well as disruptive technologies and cyber attacks.

In the wake of 9/11, WRF received a multi-million-dollar EPA grant to develop a series of security products to protect the nation's water and wastewater infrastructure from natural and manmade disasters. The resulting 12 projects address a range of risks faced by the water sector, offering resources like *Emergency Response Plan Guidance for Wastewater Systems* ([03CTS4S/1116](#)), which serves as a starting point for developing response plans. Because these threats—and the upsets they cause to water systems—are so prevalent, sensors to detect and prevent disruptions are a top priority. *Feasibility Testing of Support Systems to Prevent Upsets* ([03CTS7S/1119](#)) looks at technologies used by other industries to detect anomalies and incorporates that information into a decision-support prototype to predict contamination at water treatment facilities.

And because threats are constantly evolving, WRF also leads efforts to investigate emerging contaminants—such as those that make their way into systems after catastrophic events. This was the case after a 2011 earthquake off the coast of Japan raised international concern over radiation levels. WRF partnered with Philadelphia Water, the Pennsylvania Department of Environmental Protection, and AWWA to sponsor a workshop on Iodine-131, the radioactive material in question. The event proposed research to improve the management of this material in drinking water and wastewater going forward.

As the water sector continues to evolve, more sophisticated technology systems and data are playing an increased

role—and ensuring this data is protected is instrumental in a utility's security. *Considerations for Security and Communications for Intelligent Water Systems* ([4670](#)), makes a key move in this direction, exploring the sources of information water utilities rely on, assessing security risks, and determining whether current cyber security measures provide adequate protection. The report also identifies technologies to help optimize communications and strengthen future cybersecurity measures.

Emergency Planning and Response

Even with the best preventive measures in place, the risk of system disruptions can never be eliminated—and increased pressure from climate change and extreme weather are elevating these risks. Because utilities must be ready to respond and get operations back up and running as quickly as possible, WRF created some of the water sector's first guidance on emergency response and strategic action plans.

Since the early 2000s, WRF research has provided a basis for comprehensive disaster action plans based on best practices. More recently, WRF took this a step further with the release of *Preparedness and Response Practices to Support Water System Resilience* ([4601](#)). The study looks at out-of-the-box approaches to improve resilience and build on emergency management practices, and includes a scorecard to track practices currently in use at utilities and to target future practices.

As extreme weather threatens the water sector, WRF is also helping utilities prepare for and adapt to these events. An ongoing project, *Enhancement of Resilience to Extreme Weather and Climate Events: Proactive Flood Management* ([SIWM-17-15/4842](#)), is working to develop a pocket guide to improve resilience to wet weather, focusing on risk assessment. Another project, *Holistic and Innovative Approaches for Flood Mitigation Planning and Modeling under Extreme Wet Weather Events and Climate Impacts* ([5084](#)) will synthesize modeling tools and develop a guidance document based on state-of-the-practice planning and mitigation approaches for climate change impacts. Utilities of all sizes will be able to apply the project results to incorporate climate variability and uncertainty into their flood management approaches.

WRF has also leveraged partnerships to bring the latest information on extreme weather to a wider audience. As part of the project, *Using Climate Information in Water Utility Planning* ([5054](#)), WRF and NOAA convened a series of workshops, all designed to improve the delivery of resources for small- to medium-size water utilities to help them build their resilience to climate change. Workshop participants asked for more information on precipitation, resulting in a



five-part joint webinar series, *Our Changing Precipitation: A Conversation on the Science of Precipitation and Planning for the Future* (<https://www.waterrf.org/resource/our-changing-precipitation-webinar-series>).

Because even the best-laid response plans can be muddled by confusing or inaccurate communication, WRF has released important work on incorporating clear lines of communication into emergency planning. Efforts like the 2008 guide *Emergency Communications with Local Government and Communities* (03-CTS-5SCO/3046) shed light on the importance of effective communication between a variety of stakeholders. The handbook includes decision-making guidance and sample messages for some of the most likely emergency scenarios.

Water Supply Planning and Source Protection

In addition to the more overt security and disaster-related threats utilities face, they must also deal with threats to their water supply. As demand changes and climate and weather-related events affect the availability and quality of sources, many utilities struggle with how to continue to deliver critical services while keeping rates at publicly acceptable levels. WRF is helping utilities find the right

balance, providing solutions to protect current supplies and exploring ways to integrate alternative sources.

WRF has a body of research on safeguarding water sources, helping utilities prioritize and manage watershed risks like wildfires, insect infestations, and nuisance organisms. Cyanobacteria, which continues to be one of the most problematic organisms in our water systems, remains a top research focus. Since 1994, WRF has completed more than 30 projects to help detect, monitor, and manage these microorganisms. WRF is also exploring ways to incorporate risk-based planning into source water protection—a key need at a time when watersheds face growing threats. Using the AWWA G300 Source Water Protection Standard and World Health Organization Water Safety Plans as underlying frameworks, *Evaluation of Risk Management Frameworks and Tools and Their Application for Managing Source Water Risks in the United States* (4748) developed a practical approach for assessing and managing risks from watershed hazards.

WRF is also helping utilities create more robust water portfolios by balancing traditional and alternative supplies. Because the least expensive way to increase water supply

SOLUTIONS IN THE FIELD: Philadelphia Water Department

In 2012, Gary Burlingame, Director of Philadelphia Water Department's (PWD) Bureau of Laboratory Services, participated in an UKWIR workshop to discuss risk management in the water sector. By the meeting's end, he and several other participants recognized the need for a guide to walk water utilities through identifying and managing business risk and signed on to contribute to a primer being funded by WRF and other water organizations. The result, *Risk Governance: An Implementation Guide for Water Utilities* (4363), was released in 2013. The handbook details risks that threaten organizational objectives of water utilities and offers steps to offset and manage these risks, including tools like risk frameworks and matrices.

Burlingame then championed the risk governance concept at PWD. The idea gained traction, and others at PWD came on board, piloting risk governance at their Bureau of Laboratory Services. They put the guidance and tools in the handbook into action, developing a risk profile to identify threats, forming a risk committee,



and adopting a risk governance framework that took team culture into account. To encourage the use of these resources at other water utilities, WRF and PWD co-hosted a 2018 workshop. The event brought together experts from the United States and abroad, as well as utilities and consulting firms, providing an opportunity to share experiences in applying risk governance to address issues like resilience, extreme weather, asset management, and source water protection.



is to decrease demand, WRF has been working to improve demand forecasting and management—raising the understanding of water use trends as well as the potential for conservation, see the Water Use and Efficiency synthesis. In 2018, WRF released findings from *Framework for Evaluating Alternative Water Supplies* (4615), helping utilities weigh the costs of a variety of sources against ultimate payoffs from reliability, sustainability, and resilience. Along the same lines, *Alternative Water Source Requirements for Conventional Drinking Water Treatment* (4665) examines the suitability of nontraditional water sources, like stormwater, by identifying potential contaminants and establishing the requirements needed to bring these sources up to specific water quality standards. WRF took these findings further with the 2019 study, *Anticipating Tradeoffs of Using Alternative Water Supplies* (4715), which assessed corresponding costs and benefits to public health, the environment, infrastructure, and the community for the most common alternative water supplies.

More utilities are also turning to direct potable reuse (DPR), or highly treated wastewater, to diversify their water supplies. While operational resilience is a key concern for all water systems, it is especially critical in DPR systems, and WRF is helping ensure these systems are safe. Driven by a California state mandate to study the feasibility of developing uniform criteria for DPR, WRF launched the DPR Initiative in 2011. The four-year effort, valued at \$24M, produced 34 research projects—exploring everything from regulatory concerns to economic feasibility to public perception. In 2021, WRF published results of DPR research funded by a \$1.4 million grant from the California State Water Resources Control Board (SWB), along with additional funding from Metropolitan Water District of Southern California. SWB is relying on this research to aid in the development of uniform water recycling criteria for DPR that are protective of public health. Because safety is a top concern, research focused on better methods and guidance for pathogen risk assessment and monitoring.

Infrastructure Resilience

While all water utilities recognize the importance of risk management, when it comes to infrastructure, applying this concept can be difficult, especially when many assets are buried. With decades of research on managing infrastructure, WRF helps assess risks posed by asset failure and provides tools and techniques to optimize asset life.

Although utilities must constantly manage infrastructure risk from everyday depreciation, this threat is heightened

OTHER RESOURCES

Resilience requires the identification and management of a variety of risks, both manmade and natural. For more information, see WRF's research syntheses on climate change, asset management, stormwater, reuse, cyanobacteria, and water use and efficiency.

during catastrophic events, and understanding the full scope of potential impacts is key to utility vitality. Findings from a 2018 project, *Seismic Fragility and Restoration of Pump Stations for Potable Water Supply* (4709), capture a more complete picture of the impacts of severe events on water utilities, considering factors such as how the lack of electricity can delay repairs. The study uses data from a 2014 California earthquake to validate a model to hindcast water supply pipeline damage. Utilities can use the model to prepare more realistic emergency response plans, as well as to help disaster response agencies understand the real impacts of these events.

»» WHAT'S NEXT?

Because extreme weather continues to threaten utility resilience, WRF launched a new project in 2022, *Holistic Wet Weather Management through Adaptive Volume and Pollutant Source Control at a Community Scale: Finding the Sweet Spot* (5131). The project will develop holistic modeling guidance that positions utilities to respond optimally to future wet weather events, all while taking affordability and equity into account. A companion project, *Advancing Adaptive Wet Weather Management Approaches to Meet Emerging Challenges for Extreme Snowstorm Events and Cold Climate Impacts* (5128) will adapt rainstorm-based management approaches for extreme snowstorms and cold climate events as part of long-term holistic wet weather management, resulting in more proactive and coordinated decision making between municipal departments. In addition, the project will develop guidance on the state-of-the-practice for addressing snowstorm and cold climate water quality and quantity issues, infrastructure planning, and community resilience.