# Centralization

Kenneth L. Mercer | Editor-In-Chief

A fundamental component of industrialization is centralization. Economies of scale are achieved by consolidating smaller, individual activities into larger, collective efforts managed by a specialist group or community with pooled resources. The benefits of centralization are well demonstrated in the water industry—larger communities typically have more customers to share costs and more resources available to manage their water systems. In fact, small water systems that struggle to attract qualified staff and maintain older infrastructure may be encouraged to consolidate with a nearby system to share their burdens.

These days, decentralization is a popular notion, but its application deserves scrutiny in the face of the obvious benefits of consolidation. For water systems, decentralization generally takes the form of on-site capture of rainwater or wastewater reuse. Scale matters, and the issues that face a large campus differ from those of a homeowner. But regardless of size, every decentralized system must determine how its recovered water will be reused.

A note of caution is needed here as any potable applications must be viewed through the lens of public health. Decentralized nonpotable reuse is great where it's feasible and financially viable, but the public health risks of decentralized drinking water give me pause. Here I don't mean private wells or point-of-use devices with high-quality sources where treatment is used only as a finishing step. Instead, I mean decentralized potable reuse—collecting wastewater or rainwater and treating it to drinking water standards.

While the spirit of recycling is admirable, the costs are often high. First, a regular connection to the drinking water supply will still likely be required in case something happens, so secondary recovery systems in an urban environment are ultimately redundant. In addition, because of the technology and complexity involved, they can be relatively expensive.

Beyond these challenges, though, it strikes me that the biggest issue is daily operation. Water systems need capable operators because, even on a small scale, there are requirements for proper collection, treatment, pumping, monitoring, and maintenance. Everything needs to be replaced eventually—filters need to be changed, ultraviolet lights burn out, pumps fail. Someone needs to maintain the system, and that person needs to be reliable.

With a centralized system, the water operator is trained and certified. With a decentralized system, who is ultimately responsible? Water system operators are the first and best line of defense for protecting water supplies, and they are the strongest part of a multibarrier approach to delivering safe water. We need to ensure that all drinking water systems are operated by qualified experts, and they need to be at the forefront of any discussion of decentralized potable reuse.

This month's *Journal AWWA* features an interview with A.P. Black Award recipient Melinda Friedman, as well as articles on customer notifications, sanitary surveys, affordability, and more. If you are interested in submitting an article on challenges and solutions for the water industry, contact me at journaleditor@awwa.org.

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## Report Lists 10 Most Endangered American Rivers

The nonprofit organization American Rivers recently released its annual list of America's Most Endangered Rivers®, featuring 10 rivers where climate change and racial injustice are putting the water supplies and well-being of tens of millions of people at risk. America's Most Endangered Rivers of 2022 calls for specific solutions, amplifying the leadership of Tribal Nations and frontline advocates.

The following list ranks the 10 most endangered American rivers from most to least endangered:

1. Colorado River—Ariz., Calif., Colo., Nev., N.M., Utah, Wyo., Mexico
2. Snake River—Idaho, Ore., Wash.
3. Mobile River—Ala.
4. Atlantic salmon rivers—Maine
5. Coosa River—Ala., Ga.
6. Mississippi River—Ark., Ill., Iowa, La., Minn., Miss., Mo., Tenn., Wis.
7. Lower Kern River—Calif.
8. San Pedro River—Ariz.
9. Los Angeles River—Calif.
10. Tar Creek—Okla.

The Colorado River topped a list in 2022 as one of America's most endangered rivers.

The Colorado River (ranking no. 1 as the most endangered) is ground zero for the climate crisis as water levels plummet, threatening an essential resource for 30 federally recognized Tribal Nations and seven states. On the Pacific Northwest's Snake River (no. 2), dams and rising water temperatures have driven salmon to the brink of extinction and are violating treaties with Tribal Nations. Pollution along Alabama's Mobile (no. 3) and Coosa (no. 5) Rivers will be exacerbated by increasingly severe flooding, disproportionately affecting Black communities.

The latest report from the Intergovernmental Panel on Climate Change, released in February 2022, warned that climate change is bringing severe consequences—from increasing floods and failing dams that endanger entire communities to droughts and tapped-out water supplies that put industries, economies, and ecosystems at risk. Black, Indigenous, Latino, and other communities of color feel these impacts most acutely as a result of historical and contemporary policies, practices, and norms that maintain inequities.

The Colorado River is so overtapped that it dries up before reaching the sea. Rising temperatures and drought driven by climate change, combined with outdated river management and overallocation of limited water supplies, threaten the region. The Colorado River system is already operating at a deficit, and climate change is expected to further reduce the river's flow by 10% to 30% by 2050. For the first time ever, mandatory cutbacks triggered by water shortages will cause Arizona

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to lose more than 500,000 acre-feet in Pinal County alone.

The Colorado River supports some of the country's largest cities, including Denver; Las Vegas; Los Angeles; Phoenix; Salt Lake City; San Diego; and Santa Fe, N.M. It provides drinking water for 40 million people, irrigates 5 million acres of farm and ranch land, and supports a $1.4 trillion economy.

With the campaign in its 37th year, American Rivers reviews nominations for America's Most Endangered Rivers from local groups and individuals across the country, selecting rivers on the basis of three criteria: (1) the river's significance to people and wildlife; (2) the magnitude of the threat to the river and communities, especially in light of climate change and environmental justice; and (3) a decision in the next 12 months that the public can influence.

## EPA Approves Southern Ute Indian Tribe's Water Quality Standards

The US Environmental Protection Agency (EPA) Region 8 announced its approval of the Southern Ute Indian Tribe's water quality standards under the federal Clean Water Act (CWA). With EPA's action, the Southern Ute Indian Tribe becomes the 47th federally recognized tribe, out of 574 nationally, to have tribal water quality standards approved by EPA under the CWA. The approval allows the tribe to protect the water quality of the lakes and rivers it uses for swimming, boating, and fishing.

The Southern Ute Indian Tribe's water quality standards apply to many waters within the Southern Ute Indian Reservation, including portions of the La Plata, Animas, Florida, Los Pinos (or Pine), Piedra, San Juan, and Navajo Rivers and portions of the Navajo Reservoir. With the approval of the Southern Ute Indian Tribe's water quality standards, combined with the prior and separate EPA approval of the Ute Mountain Ute Tribe's water quality standards, all federally recognized Indian tribes with reservation lands in Colorado now have EPA-approved water quality standards.

The CWA has a two-step process to establish tribal water quality standards: (1) tribes acquire CWA water quality standards program authority from EPA, and (2) tribes submit specific water quality standards to EPA for CWA review and approval. In 2018, the Southern Ute Indian Tribe received CWA water quality standards program authority from EPA for waters on the Southern Ute Indian Reservation, located on tribal trust lands (as well as one parcel of tribal trust land contiguous to the reservation).

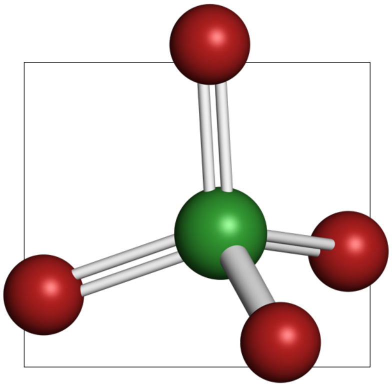
In developing its water quality standards, the tribe collaborated with the state of Colorado and surrounding county and municipal governments, as well as other interested parties, to gather input. A public comment period from Aug. 23 to Oct. 22, 2021, included a public hearing. On the basis of comments received, the Southern Ute Indian Tribe revised its water quality standards, adopted them on Feb. 8, 2022, and submitted them to EPA on Feb. 15. EPA approved the tribe's standards after determining they were consistent with the requirements of the CWA and EPA's Water Quality Standards Regulation.

Water quality standards developed by the Southern Ute Indian Tribe have been given the go-ahead by the US Environmental Protection Agency. Pictured here is the San Juan River, part of which falls under the jurisdiction of the recently approved standards.

## EPA's Plan to Address Perchlorate in Drinking Water

The US Environmental Protection Agency (EPA) has completed review of a July 2020 determination to not regulate perchlorate in drinking water and concludes that the 2020 decision is supported by the best available peer-reviewed science. In addition, EPA has announced integrated actions to protect public health from perchlorate in drinking water.

"EPA is taking action and applying the right tools to support public health protections," said EPA assistant administrator for water Radhika Fox. "Funding through the Bipartisan Infrastructure Law, a new monitoring study, financial and technical tools, and cleanup of contaminated sites will enhance protections and help ensure that communities can rely on clean and safe drinking water."



The US Environmental Protection Agency is approaching perchlorate contamination of drinking water from multiple angles.

Through the Bipartisan Infrastructure Law, EPA is providing $11.7 billion through the Drinking Water State Revolving Fund, and $4 billion in dedicated funding to address emerging contaminants. This funding can be used to address perchlorate and other drinking water needs.

EPA will support research to better understand perchlorate as it relates to firework displays

*Continued on page 94*

and also plans to create a web-based toolkit that will provide updated technical information to assist drinking water systems and communities that have concerns about perchlorate contamination of their source water.

Cleaning up existing contamination and protecting drinking water sources from future contamination are central to EPA's approach to addressing perchlorate in drinking water. EPA is working with states to address perchlorate contamination under the Comprehensive Environmental Response, Compensation, and Liability Act, also known as the Superfund program. These cleanups have already reduced perchlorate levels at some sites. The agency will also consider proposed revisions to Resource Conservation and Recovery Act standards for the open burning and open detonation of waste explosives and bulk propellants to reduce effects of perchlorate on human health and the environment.

While EPA is not pursuing a drinking water regulation at this time, the agency will continue to consider new information on the health effects and occurrence of perchlorate. EPA's decision does not affect any state standards for perchlorate. The agency will continue to consider if perchlorate should be added to future Contaminant Candidate Lists for possible regulation under the Safe Drinking Water Act.

## BUSINESS BRIEFS

In September 2021, water industry professionals convened for the **Global Water Intelligence Network's** online symposium, The New Future of Water: How NEOM Can Change the Water Industry. The event was hosted in partnership with **NEOM** to discuss a more sustainable future for water that focuses on resource recovery and eradicating waste. Ideas addressed in the symposium are further explored in a recently published white paper outlining NEOM's solutions to water scarcity challenges: zero-cost water production; a smart, connected water infrastructure; a blueprint for sustainable water generation that could be replicated around the world; green solutions through desalination and brine processing; and how full wastewater processing will be used at NEOM to achieve 100% recycling of wastewater, generate energy, and produce viable solid end products to enhance the environment.

**Aquasend** is participating in the **Xylem** Innovation Incubator Program, a one-year initiative designed to evaluate technology cohesiveness and develop a sustainable relationship between the two organizations, which are working together on water solutions for the aquaculture market and advancing these technologies in the market. Aquasend has set a company goal to help transform the global aqua-farming industry within the next five years.

**The Water Council's** Business, Research and Entrepreneurship in Water (BREW) Accelerator 2.0 will be held June 23, where companies from around the world will present their innovations at a virtual pitch event for water industry professionals and investors. The conference focuses on late-stage water technology startups ready to enter the market or with early sales. BREW 2.0 includes virtual training throughout the year to help young companies build connections and grow capacity. The program is sponsored by **Beckhoff Automation** and **Thales Water Advisors**.

**Sloan,** a global manufacturer of commercial plumbing systems based in Franklin Park, Ill., has signed onto **The Water Council's** WAVE (Water Stewardship Verified) program. WAVE will help Sloan improve its water stewardship performance and public reporting, concluding with independent verification of its progress. The Water Council created the WAVE program to help businesses throughout the world develop strategies, goals, and actions.

Stockholm-based **Bluewater** and Denver-based **FloWater** recently announced their merger. Bluewater was founded in 2013 by Swedish environmental entrepreneur Bengt Rittri. FloWater was co-founded by Rich Razgaitis in 2013 and has been led by him since then. Rittri will formally lead the new combined entity as its chief executive officer, although the two companies will continue to operate under their existing brand names. Razgaitis will continue to lead FloWater's US and international operations.

**Great Lakes Dredge & Dock Corp.** has signed an agreement with the College of Engineering at **Texas A&M University** (College Station, Texas) to provide funding and technical support for what will become the Great Lakes Dredge & Dock Laboratory of Dredging and Coastal Studies. The longstanding relationship between Great Lakes and the university has included research, participation in short courses on dredging, and advocacy for the ocean and coastal engineering profession.

## BUSINESS BRIEFS

**Global Water Resources Inc.** has signed a definitive agreement to acquire **Farmers Water Co.,** a subsidiary of **Farmers Investment Co.** The acquisition, if completed, would add approximately 3,300 active water service connections and an approximate 21.5 square miles of Certificate of Convenience and Necessity service area in Sahuarita and surrounding unincorporated Pima County, Ariz. Global Water Resources plans to retain all Farmers Water employees and maintain a local customer service center.

**Stantec** is helping the **South County Regional Wastewater Authority** (SCRWA) expand its existing wastewater treatment plant near Gilroy, Calif., with the design of a new membrane bioreactor facility. The new facility will add additional capacity of 2.5 mgd to the existing plant's 8.5-mgd wastewater treatment. The SCRWA facility receives and treats wastewater from domestic, commercial, and industrial users, and has a successful water recycling program.

The **City of Sandy Springs, Ga.,** was recognized as a 2021 Tree City of the World by the Arbor Day Foundation and Food and Agriculture Organization of the United Nations. To earn the designation, the city met five program standards: establish responsibility for the care of trees, set rules to govern the management of forests and trees, maintain an updated inventory or assessment of local tree resources, allocate resources for a tree management plan, and hold an annual celebration of trees to educate residents.

The **City of Vancouver, B.C.,** is working with **Brown and Caldwell** in partnership with **Kerr Wood Leidal** to develop the Healthy Waters Plan: Adapting and Integrating Sewage & Rainwater Management in Vancouver. The two-part plan aims to guide policy, regulation, advocacy, and long-range investments in Vancouver's sewer and stormwater management while supporting equity for all residents and reconciliation with Indigenous communities. It will use Vancouver's Rain City Strategy to integrate rainwater and sewer infrastructure policies, projects, and programs.

**Pennsylvania American Water** will provide funding for 13 watershed-related projects through the company's annual Environmental Grant Program. The grant funds, totaling nearly $75,000, will be used for community-based projects that improve, restore, or protect watersheds. Pennsylvania American Water initiated the grant program in 2005. Since then, American Water has expanded the annual program to many of its state subsidiaries across the nation.

In other company news, Pennsylvania American Water has added a new customer advisory map to its website. The map allows Pennsylvania American Water customers to view any active water service disruptions, planned service outages, hydrant flushing notices, or boil-water advisories in their area. Customers can search by address to determine whether they are located in an alert area and can view additional information, such as estimated time of restoration and steps to take when under an advisory.

**Rogerson Water District** (Boise) was recognized as Idaho's best-tasting drinking water during the Idaho Rural Water Association's (IRWA) Spring Conference. IRWA will send a representative of Rogerson Water District to Washington D.C., with the utility system's drinking water to compete against other states' rural water association winners in a nationwide contest, which will take place in February 2023.

**Atlas Copco** has completed its acquisition of **Pumpenfabrik Wangen GmbH.** Pumpenfabrik Wangen is a German manufacturer of progressive cavity pumps used for transferring fluids mainly in the biogas and wastewater sectors. The company also manufactures twin-screw pumps used in sectors such as food and beverage and cosmetics. It will become part of the Power and Flow Division within Atlas Copco's Power Technique Business Area.

**Aclarity** has closed a $3.3 million seed financing round to deploy on-site technology to destroy per- and polyfluoroalkyl substances (PFAS). Aclarity's proprietary electrochemical process permanently destroys PFAS and other harmful chemicals instead of returning them into the environment. Aclarity plans to use the funds on new installations and system operations.

**Trillium Flow Technologies** has completed its acquisition of **Termomeccanica Pompe.** Operating for more than 110 years from its headquarters in La Spezia, Liguria, Italy, Termomeccanica Pompe offers vertical turbine and split case pumps used in water transmission, desalination, power generation, and oil and gas markets.

**PC Construction** recently accepted a Build America Award from the Associated General Contractors, its third consecutive win in the past five years. This latest recognition is for the company's work on the Richland Creek Water Supply Program in Paulding County, Ga. PC's $93 million portion of the program, which began in 2016 and was completed in 2020, eliminates Paulding County's dependence on outside water sources and is designed to meet the water needs of its 168,000 residents for the next 40 years. The new water and wastewater facilities are also designed for significant expansion, with the ability to add three pumps to the reservoir station and the double the treatment plant's processing capacity from 18 to 36 mgd.

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# Water 2050: Time Flows Quickly

David B. LaFrance, Chief Executive Officer

Way back in 1981, the rock band Alan Parsons Project intoned that "Time keeps flowing like a river." That was the same year IBM introduced its very first personal computer (PC), yours truly graduated from high school, and my buddies started calling me Vive (as in Vive la France).

Alan Parsons was right. How time flows! To wit: IBM sold its last PC more than a decade ago; I am now 35 years into my career; and while my buddies still occasionally call me Vive, there's also a two-year-old girl who calls me Grandpa.

It seems the older we get, the more we understand that the future comes much faster than we expect, whether we're ready for it or not. So I am pleased that, thanks to our volunteer leaders—particularly President Chi Ho Sham and President-Elect Joe Jacangelo—AWWA is acting with great intention to visualize the future of water and chart a course for the water community's success and sustainability. The initiative is called Water 2050, and I hope you'll accept this invitation to be part of it.

Let me explain a little more about Water 2050. Over the next two years, AWWA will be pondering the future of water through the prism of five core drivers: sustainability, technology, economics, governance, and social/demographics. We'll engage in this exploration on many paths. There will be council discussions, surveys, think-tank events, association and section conference activities, media campaigns, and even artistic expressions depicting the future of water.

Although time keeps flowing like a river, we're putting our oars in the water and rowing toward a future the water community chooses. Good rowers understand that if you don't think ahead and act with purpose, you'll simply end up wherever the current takes you. But by understanding the currents—or the drivers, in our case—and recognizing the distant obstacles, you can gather the necessary speed and maneuver to the desired end point.

As with any good adventure, we will gain a great deal from the journey itself. We will develop new relationships with people and entities from outside the traditional water community. We will collaborate in new ways with colleagues and other associations from within the water community. We will hear from some new voices who challenge our way of thinking, and from others who confirm what we know to be true.

Maybe most important, we will listen closely to the wisdom of the young and emerging water professionals—those who will row this boat, so to speak, by implementing and adjusting the strategies the water community pursues through Water 2050.

For Water 2050 to reach its potential, it needs your voice. Each and every AWWA member has a unique perspective to offer. Beginning at ACE22 and continuing through ACE23—and likely longer—we will be asking for your engagement. For some of us, that may mean participating in a discussion at an AWWA section or at an AWWA event. For others, it may mean participating in a survey. Still others may pen articles for AWWA publications, observing how water may be affected by a particular driver. There will be many other ways to help formulate and refine this vision.

Water 2050 officially launches at ACE22 in San Antonio, Texas. AWWA president Chi Ho Sham will introduce the initiative during the June 13 Opening General Session, and we'll share insights from young professionals in a video titled "The Future We Create." I'll have the opportunity to chat with members of the Water 2050 Project Advisory Team during the Last Drop session on June 15. All attendees are invited to engage directly in the project through some exciting activities at the AWWA Pavilion on the exposition floor.

I hope you'll be at ACE22 in San Antonio to participate. Because without your input, the Water 2050 vision will have blind spots. Time is flowing like a river, and we're on the clock!

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## STANDARDS OFFICIAL NOTICE

This shall constitute official notice of the availability of the following new or revised AWWA standard. The effective date of this standard shall be the first day of the month following notification of the availability in *Journal AWWA.* To obtain copies of this or any AWWA standards, contact the AWWA Customer Service Group at (800) 926-7337, email service@awwa.org, or visit www.awwa.org/standards. This standard has been designated American National Standards by the American National Standards Institute. The date of ANSI approval is shown in parentheses.

**ANSI/AWWA B200-22**
Standard for Sodium Chloride
(Apr. 14, 2022)

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## Recognitions

Farmer

The Henry County Water Authority (HCWA; McDonough, Ga.) paid tribute to the 40-year legacy of former general manager **Lindy D. Farmer Jr.** at a recent event in his honor, following his retirement at the end of 2021. Farmer joined the HCWA as its first formally designated general manager in 1982.

Wheeler

Toho Water Authority (Kissimmee, Fla.) has dedicated its administration building to honor **Brian L. Wheeler,** founding executive director. Wheeler retired in 2018 after leading Toho for 15 years. Before that, Wheeler had served as the City of Kissimmee director of water resources since 1985.

San Diego County Water Authority (SDCWA) finance director **Lisa Marie Harris** has been named 2022 CFO [Chief Financial Officer] of the Year in the Public Sector category by the *San Diego Business Journal*. Harris has served as director of finance and treasurer for the SDCWA since May 2014, capping 30 years of experience in public and private finance.

## Transitions

Burlingame

**Gary A. Burlingame** retired as laboratory director for the Philadelphia Water Department (PWD) in March of this year, after more than 40 years of service. At PWD, Burlingame was promoted from biologist to director for the Bureau of Laboratory Services. He has served on AWWA and US Environmental Protection Agency committees and has been involved in many Water Research Foundation projects and committees. Burlingame will continue volunteering for AWWA and The Water Research Foundation while working part-time as a senior scientist for the Environmental Science, Policy and Research Institute.

**Josh Blount** has been promoted to the position of regional director for the Western Region of the Ductile Iron Pipe Research Association (DIPRA). During his time at DIPRA, Blount has helped utility managers, engineers, operators, and field crew personnel with system planning and design, installations, and asset management related to iron pipe. In this new role, he provides training and presentations and assists with relevant references and guides.

Cisic

**Suad Cisic** has joined Brown and Caldwell as managing director of client services. With more than 30 years of engineering and construction consulting experience, Cisic has led the growth of new geographies, markets, and client relationships domestically and overseas.

McElroy Manufacturing has hired **Barry Johnson** as the company's new quality director. He will replace **Steve Burgess,** who has announced his retirement after 35 years of service to McElroy.

Johnson

ASTERRA has hired **Pazit Malchi Bodesky** as vice president of marketing. The company also has promoted two senior leaders, **Yuval Lorig** and **James Perry.** In her new role, Bodesky will use her experience leading marketing in other global tech spaces to boost growth for ASTERRA. Based in ASTERRA's headquarters in Tel Aviv, Israel, Bodesky has 15 years of experience with firms that include VMWare, Samsung, and SanDisk. Lorig was promoted to vice president of research and development. He will continue his work in Tel Aviv, developing new SAR (synthetic aperture radar) Earth observation and remote sensing technologies. In the North American office, Perry has been promoted to executive vice president, bringing his extensive sales experience to ASTERRA nearly six years ago, spearheading growth with water-saving projects in 60 countries.

## Obituaries

**John C. Fimognari,** Youngstown, Ohio; Silver Water Drop Award 2019

**Timothy J. McCandless,** Wheat Ridge, Colo.

**L.D. Palmer,** Newton, Iowa; Life Member Award 2006

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**Information in the People in the News section is published about and for AWWA members.**

# The World Needs Environmental and Water Resource Engineers

Xuyen Mai

*Layout imagery by APChanel/Shutterstock.com*

One could write a whole doctoral dissertation on whether graduate school is the right path for college graduates. If that topic interests you, here are four questions to consider:

- Do you love learning about the mechanisms by which water, air, and earth regulate the planet and support its inhabitants?
- Do you enjoy using your knowledge of the inner workings of our natural environment to solve environmental resource and sanitation problems?
- Is service learning your passion?
- Is making positive contributions to the ever-changing sociopolitical climate of our world your vibe?

If you answered yes to even just two of these questions and feel that your undergraduate education did not prepare you enough to pursue your interests, please consider attending graduate school for environmental and water resource engineering (EWRE). Seriously, we need you! Ensuring access and sustainable management of water and sanitation for all has long been among the United Nations' Sustainable Development Goals, and these problems will be further complicated by climate change. So, yeah, we need help!

## What Graduate Program Is Right for You?

You might have noticed that I mentioned EWRE, and that's because my graduate program at the University of Massachusetts Amherst (UMass) is named EWRE. But graduate programs related to environmental engineering have many different aliases and focuses. Although they are typically housed in civil engineering departments, EWRE programs might be in different departments at different schools (e.g., Chemical Engineering at Yale).

Your first step to finding the right school is to read about different programs that in recent years have produced research and/or courses in which you're interested. For example, the UMass EWRE program focuses on water problems, and that is why I selected it. After you have done your research, reach out to faculty members in programs that interest you and ask them questions that will help confirm your choices. You might ask whether resources are available for you to explore the topics you're passionate about. Determine whether there are faculty members in the department who share your interests. The timing, content, and tone of their replies should serve as good metrics to gauge whether a program is a good fit for you.

I will refrain from writing the following sentence in all caps, but am I yelling excitedly at you through the computer? You bet! When a graduate program offers you admittance, please visit the campus! If you are unable to attend in person, please use remote video conferences to visit the department's study and lab spaces. Ask graduate students in the program to show you recreational facilities on and off campus. Try to imagine yourself there beyond the academic setting, as resources for self-care and enrichment are just as important as ones for academic growth. Try to find out whether the students in the program are happy and whether they keep a healthy work–life balance.

At this stage, you should be able to have a straightforward conversation with your potential advisor about where your funding will come from for your time in graduate school. Understand that your funding resources may not necessarily be the same every year. It is great if your potential advisor has the same research funding for you for the next few years, but it should not be a deal breaker if they do not. Ultimately, you want to find out if your advisor will support you and advocate for your funding throughout your academic career. These preliminary discussions will help familiarize you with the various opportunities and help you decide which program is the best fit for you. No matter how competitive a program might feel, remember that graduate school is a two-way street: you will contribute to your institution with your brilliance as much as it will provide a place for you to learn and grow.

## Water Your Plans Now

In my experience, the first few semesters of graduate school were academically rigorous. There are typically more classes and a PhD-qualifying exam to ensure you nailed those classes. As you march your way through these semesters, try to continue conversations with your advisor about your research interests. It is important to keep your eyes on the prize—your degree—as you continue to explore your interests through your research. Establishing a good rapport with your advisor will help you understand what you need to do to graduate as quickly as you can and with as many career options as possible.

A good way to think more deeply about your research is to submit grant and scholarship applications—and your efforts may help pay the bills. If you're like me and need to motivate yourself to write, understand that submitting a grant or scholarship application fills two needs with one deed: you are setting your future self up for success because you are planning your research, and you could potentially be awarded money to support yourself.

## What About Self-Care?

If you have made it this far, congratulations! You're well on your way to at least thinking about attending graduate school. I want to close with a few comments about favorite extracurricular activities that have helped me survive the experience. There's no doubt that graduate school is stressful, but the following self-care tips may provide some guidance on preventing a severe case of graduate school burnout.

- **Make friends.** Graduate school is one of the only experiences you'll have where you will be around people as excited as you are about course schedules. Assert yourself in study groups. Better yet, start study groups. Before you know it, you will have a ride-or-die squad that will go on vacations with you to celebrate a New Water Year together.
- **Get free food.** There are so many free-food events on campus that you may need to consider building optimization programs to help you pick. Also, free food connects people. Try making new friends by inviting them to get food with you and/or make new friends at these places.
- **Map your campus resources.** I truly believe you will benefit from knowing where to go to find support groups or even the best burrito on (or off) campus. Think of planning ahead as a way for your current self to support your future self. Whether your semester gets busy and knowing where good food is will save time, or you need to talk with someone at the graduate school about graduation credits before panic sets in, you will be covered because you planned ahead.
- **Go to conferences.** Whether you are an extrovert or an introvert, going to a conference will greatly enrich your learning journey. You can extend your network by meeting like-minded, inspiring, or potentially hiring (wink) people. In my experience, everyone I have talked to or asked questions of was happy to help and connect. You can attend presentation sessions, go to networking events, or get some freebies at exposition halls. Conferences are the ultimate work-hard/play-hard experience, so be proactive about abstract submission deadlines and don't miss out!
- **Advocate for yourself.** There are a variety of opportunities—student organizations, teaching jobs, seminars, etc.—in graduate school that can help you learn myriad skills, from service learning to negotiating salary. Give these opportunities a try and see if they might benefit you. There are also organizations focused on supporting those with marginalized identities if you need support; for example, I have been involved with the UMass Graduate Women in STEM group since the summer I started my studies as a graduate student. I have met some of my closest friends and mentors through this group.
- **Rest!** Unfortunately, being a graduate student is often synonymous with overwork. Ignoring your need to take breaks can potentially backfire and cause severe burnout. Be the "greatest of all time" in the way star athlete Simone Biles has been; she knew that not participating in the Olympics finals for her event was the best thing she could have done for her mental health and future self. Similarly, you should trust your body and mind when they tell you it is time to take a break.

Graduate school is challenging, but remember your passion for learning and making positive changes in the world. Plus, if you do it right, you will make lifelong friends and learn valuable skills outside of the lab and the classroom. I hope you can use those challenges to become your own number one fan and advocate.

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# Effective Collaboration in Water and Wastewater Construction Projects: A Case Study

Elie G. Andary and Juan Mata

## Key Takeaways

Delivering water and wastewater construction projects involves complex processes that focus on minimizing environmental impacts and public expense.

Water utilities could realize benefits by establishing a collaborative working environment throughout the life cycle of a construction project.

Collaboration practices from an integrated project delivery approach could improve the efficiency and success of design–bid–build projects and still honor traditional contract limitations.

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Collaboration is the principle of integrating a highly diverse membership into a productive project that has mutual benefits for all. Collaborating to address complex problems involves sharing strategic thinking and practical insights that can lead to innovations and better targeted interventions (Keast & Mandell 2012).

Water and wastewater projects sometimes involve high levels of uncertainty during design and construction. The complex nature of large projects requires specialized skills in planning, cost estimation, design, and construction to complete them on time, within budget, and with minimal environmental impact. Hence, complex projects require continuously coordinating the collaborative work of a project team (Sebastian 2011). The contract delivery method adopted for such projects greatly influences their progress and affects their cost and schedule. Competitive design–bid–build (DBB) has been the commonly used method for water/wastewater projects (Abi Shdid et al. 2019).

Multiparty contracts have been offered as a solution to coordinate construction parties' collaborative work in complex construction projects (Lahdenperä 2012). The construction industry has seen an increase in the use of integrated project delivery (IPD) for privately owned residential and commercial construction projects. IPD can enhance collaboration by aligning the interests and practices of all parties in a multiparty agreement (Thomsen et al. 2009). In this article, we identify collaboration practices from IPD that could be applied to the DBB approach without compromising competitive bidding requirements.

## Collaboration Research

A collaborative work environment for construction projects gives stakeholders access to information with a complete overview of the project status, also allowing management to track progress (Andersen et al. 2003). While some research has focused on the use of technology to help stakeholders collaborate and exchange information on projects, most studies related to collaboration are limited to technology-based practices and don't emphasize the human aspect.

A survey by Shelbourn et al. (2007) showed that it's necessary to focus on the people involved in a project to implement effective collaboration, followed by business processes and procedures and technology aspects. Collaborative relationships are established between all project parties, their supply chain processes, and the technology they use (Shelbourn et al. 2007), and contractual and procedural coordination is needed. A comparative case study of collaborative work in two hospital construction projects showed that collaboration practices, such as co-located working, joint decision-making, a liaison role, and shared project goals, were needed throughout the projects (Lavikka et al. 2015).

Coordination of collaborative work in the construction industry is demanding because of cultural and organizational barriers (Barlow 2000). IPD integrates project parties, systems, and business structures and practices into one multiparty agreement that runs from early design until project handover (AIA 2014). Traditional project organization is structured in a way that operational silos exist between design, procurement, construction, and ownership, where each participant works for their own interest rather than that of the overall project; as a result, project information does not effectively cross boundaries (CURT 2004). However, if owners collaborate and share information early in a project, it can promote better decision-making at the earliest stages of the design phase and minimize potential risks for all project stakeholders (AIA 2010).

An owner could choose a traditional delivery approach, contracting with designers and builders independently, yet still use some aspects of IPD (Thomsen et al. 2009). The following sections describe collaboration practices from IPD and strategies to effectively integrate them into DBB water and wastewater projects.

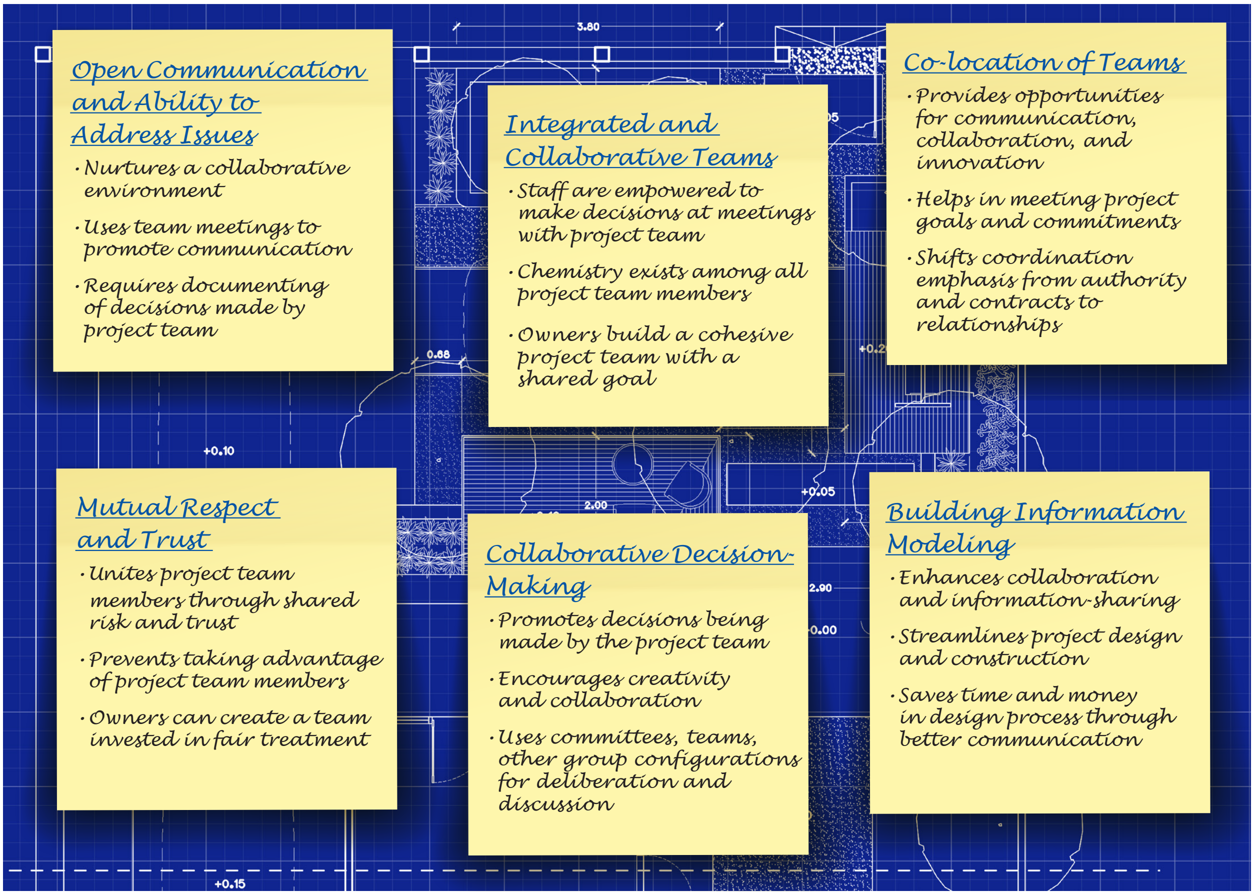
## Collaboration Practices

The American Institute of Architects publishes a set of IPD practices that are commonly used in the industry. In addition, several researchers have identified other principles that distinguish IPD from other delivery methods (Andary et al. 2020). For example, building information modeling (BIM), which is described later in this article, could be considered an IPD principle, or it could be viewed as a practice that facilitates the IPD process by recording and sharing project information and helping the IPD team optimize both product and process (NASFA et al. 2010, Thomsen et al. 2009).

DBB provides the market advantage of open competition through a design phase, followed by separate bid and construction phases. However, the competitive nature of DBB results in processes that could be improved through collaboration. Traditional DBB contracts limit collaboration and coordination among the involved parties (Matthews & Howell 2005). This means that for owners using DBB to take advantage of collaboration practices like those found in IPD-type delivery, contract provisions and project procedures must be modified. Still, collaboration practices can be successfully integrated into DBB projects; Figure 1 provides a summary.

Fundamentally, improving collaboration will involve better communication among project participants.

## Applying Collaboration Practices to DBB Project Delivery




DBB—design-bid-build

**Figure 1**

Owners must provide open channels of communication within the project team, especially around essential team meetings in which decisions are made and documented. Applying collaboration elements to DBB will require more staff time than the traditional DBB process does, and staff need to be empowered to make decisions at meetings with project participants. Integrated teams promote collaboration, and owners should recommend any necessary personnel changes if they see a lack of cohesion or chemistry among team members or uncertainty over shared goals.

Co-location of teams increases opportunities for collaboration and innovation and helps in meeting project goals and commitments. In DBB, co-location can involve the design and construction project participants, including trade contractors and suppliers, and it can start after the contract is awarded. The owner and engineer can have direct relationships with subcontractors during construction and during final design, and for large projects, owners can provide space on their construction sites for all parties to work on site. Co-locating teams shifts the coordination emphasis from authority and contracts toward relationships, and it provides a more open environment for communication (Lavikka et al. 2015).

A team culture based on risk-sharing and trust is required to tie the parties together for a project involving contractual relationships to be successful, with a level of trust that prevents project participants from being taken advantage of. Owners play a big role in this, encouraging respect and trust by aligning goals appropriately. In traditional DBB, owners do not have the ability to select a team that will necessarily treat the owners fairly. This can be sought in a DBB project but cannot be guaranteed.

Also known as group decision-making, collaborative decision-making promotes the decisions made by groups and is effective in encouraging creativity and collaboration. Collaborative decision-making is beneficial when there is time for proper deliberation, discussion, and dialogue. It can be achieved in configurations such as committees and teams.

BIM can enhance collaboration and information-sharing as well as streamline project design and construction. For construction of water or wastewater facilities, owners need to save important project information that staff can use for long-term facility management after construction. Many owners depend on consultants to collect, organize, manage, and store this information. BIM can save time and money by allowing project participants to communicate better during this process. During design, building information models assist in creating two- or three-dimensional drawings for fabrication and for review by the architect and engineering team. BIM helps make the shop-drawing process concurrent with design, which eliminates waste and saves time and duplicate efforts.

**Seminole Tribe Wastewater Treatment Plant Parameters Summary**

| Project Parameter | Value |
|---|---|
| Project award price | $54,237,000 |
| Project total actual cost | $56,052,377 |
| Total cost of change orders | $1,815,377 |
| Notice to proceed date | 3/28/2018 |
| Scheduled substantial completion | 3/27/2020 |
| Actual substantial completion | 7/31/2020 |
| Scheduled project duration | 730 days |
| Project actual duration | 856 days |
| Change order percentage | 3.34% |
| Total cost of claims | $0.00 |
| Cost of field rework | $0.00 |
| Average RFI response time | 3 days |

RFI—request for information

**Table 1**

## Case Study

The project examined in this article is the construction of a 3-mgd wastewater treatment facility—the Seminole Tribe Wastewater Treatment Plant (WWTP), located in Hollywood, Fla. A notice to proceed was issued in March 2018, with a final acceptance date in June 2020. The contract cost at bid time for this project was $54,237,000.

The new facility featured a headworks structure that is 40 feet tall, with rotary bar screens, grit removal equipment, and an odor control system. The treatment process consists of a four-basin sequencing batch reactor tank, with each basin having a treatment capacity of 750,000 gallons. After the sequencing batch reactor decant is complete, the water travels to an effluent pump station that houses five submersible pumps, which pump the water through a 24-inch pipe to an injection well pump station. The 24-inch pipe was installed by directional drilling to a depth of 40 feet underneath the Florida Turnpike. Water is pumped into two deep injection wells. Critical project parameterswere collected to characterize the project, which are summarized in Table 1.

### Collaboration at Full Scale

Construction of the Seminole Tribe WWTP was already underway when the collaboration principles were applied, so this limited the inclusion of some efforts during the design, bidding, and preconstruction phases. The collaboration principles described previously were all included in this project, as described next.

### Establishing Regular Conversation

Essential team meetings and initial efforts at collaboration among project participants opened avenues for more communication. A progress meeting was held each week with the contractor, consultants, and owner involved in the planning, coordination, and work performance. Discussions included current progress of work, schedule revisions, milestone dates, and total contract time, and participants were empowered to make formal decisions at these meetings.

In addition to weekly meetings, the construction manager met daily with the general contractor, whether there were issues or not. Informal daily meetings were held in the engineer's or contractor's office or in the field, and construction issues and conflicts were addressed immediately rather than waiting for weekly meetings or issuing a request for information.

Phone communication between the engineer and general contractor was constant. For example, the contractor would call to notify the engineer of any engineering documents requested by the building department officials. The engineer would also call the contractor, requesting clarification or supplemental information during the shop-drawing review process to expedite its approval. Open communication ensured information was spread widely and helped address issues faster by conveying messages right on the spot. Whether issues were related to design or water utility operations, a timely phone call often expedited resolution.

### Promoting Good Chemistry

Project participants were encouraged to work as team members rather than adversaries, and this was established by maintaining good relationships between the owner, engineer, and contractor. It helped that the construction management firm had used the same project manager for several projects. Successful shared experiences on previous construction projects for the owner, engineer, construction manager, and contractor helped promote further chemistry between the key project participants in the design and construction of the Seminole Tribe WWTP, and those who were new to the team learned and adjusted to the group's dynamic. Several social activities were held outside the workplace, such as Thanksgiving and Christmas lunches or dinners; these events brought people together and promoted camaraderie.

### Co-location of Teams

During construction of the Seminole Tribe WWTP, the owner and engineer co-located project parties in a shared facility. The owner provided approximately half an acre of physical space on the construction site that included parking, a trailer city for contractors, and subcontractors' trailers. Moreover, the offices of the owner, engineer, and construction manager were all located within five miles of the construction site.

> **Collaborative decision-making promotes the decisions made by groups and is effective in encouraging creativity and collaboration.**

### Establishing Trust

As mentioned earlier, for successful collaboration, trust should be strong enough among members of a project team that they are not concerned about being taken advantage of during the project. Ghassemi and Becerik-Gerber (2011) demonstrated that trust comes in two ways: preexisting trust and forced trust. If trust does not already exist, tools and activities can be used to help project team members develop mutual trust.

In the case of the Seminole Tribe WWTP, the owner, consultant, and contractors had worked together previously, so they had a head start in promoting an environment of mutual respect and trust among the key project participants. An indicator that trust has been built is when changes or extra work is needed, and the contractors proceed with solutions before even receiving change orders or documentation assuring the contractors they will be compensated for the extra work.

### Collaborating Through Teamwork and Tools

The construction manager for the Seminole Tribe WWTP project formed a leadership team for decision-making purposes that included the contractor, consultant, owner, and other stakeholders. The team held monthly meetings and provided recommendations on decision-making priorities and activities.

Communication tools and strategies were considered and developed to enhance project efficiencies. Project management software (BIM) was used throughout the project to improve information flow between parties. The easy access to information helped with collaboration.

## Overcoming Unprecedented Challenges

The commissioning phase of the Seminole Tribe WWTP project was scheduled to start in the first quarter of 2020, when the coronavirus (COVID-19) pandemic was beginning to surge. COVID-19 had a profound impact on the completion phase of the project, which required additional collaboration to overcome these unprecedented challenges.

The influent wastewater needed for plant commissioning had been primarily generated by the new Guitar Hotel, recently constructed in Hollywood. Because of COVID-19, the hotel was shut down and thus the anticipated influent flow rates to the new WWTP were not met. Furthermore, many airline flights were canceled during the COVID-19 outbreak, which meant manufacturers could not be physically on site for equipment startup, plant commissioning, and owner training.

Collaboration principles led to resourceful thinking in coming up with new means to overcome these challenges and complete the project. Influent flows were provided from different sources, equipment startup was coordinated between the general contractor (on site) and manufacturers (out of state), and plant commissioning was coordinated among the owner, engineer, and contractor, who were present on site. Amid all the COVID-19 delays, the project was successfully completed, only four months past the original substantial completion date. Collective experiences during the pandemic proved that through collaboration and shared sense of purpose, great solutions can be delivered online.

## A Worthwhile Investment

Utilities have many options to consider that will promote collaboration and improve working relationships between the owners, engineers, and contractors throughout the life cycle of a construction project. Construction of the Seminole Tribe WWTP provided a case study of collaboration, and our study provides insights on how to best implement collaboration practices in DBB water and wastewater construction projects.

It is important to emphasize that the implementation of collaboration practices is demanding in terms of time and resources. However, these initial investments result in quicker problem-solving and decision-making over the course of the project. The Seminole Tribe WWTP construction project was delivered with minimum delays and within budget, and the owner was satisfied with project execution and quality control. Hence, the case study project was considered successful (Andary 2020).

When using the concepts of collaboration, it is recommended to measure key performance indicators, then compare them with those of traditional DBB projects. Develop a process checklist for facility owners to use in managing how they implement any collaboration practices. Standardize the process to ensure they receive the attention they need to be successful. Further research is needed to confirm the successful implementation of collaboration practices in other types of delivery methods, including multiparty contract types.

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- **The Design–Build Story of a University's New Water Treatment Plant. Lanza R. 2021. *Journal AWWA.* 113:5:80. https://doi.org/10.1002/awwa.1730**
- **Consider Alternative Capital Project Delivery Methods. Reichenberger JC. 2020. *Journal AWWA.* 112:10:76. https://doi.org/10.1002/awwa.1599**
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VIEW IN
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# Meter Advances Drive Water Efficiency and Management Success

Peter Mayer

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Over the past 25 years, per capita water use and total water withdrawals for public supply in the United States have declined, saving billions of dollars in avoided supply and infrastructure. Improvements in fixture and appliance efficiency, an ongoing transformation in landscape choices and preferences, and increasing water costs have reduced indoor and outdoor demand in many regions of the country, enabling population growth without corresponding increases in water demand. Although changes in water use have been well documented, an overlooked aspect of this story is the fundamental role of water meters, accurate measurement, and the increasing importance of high-resolution meter data.

## Meter Advances

AWWA and its dedicated volunteers work vigilantly to ensure that the water meters deployed throughout the water industry are accurate and reliable—regardless of the make, model, or type—and the data collected from those meters are used to understand and improve water management and service. The fact that water is accurately measured in a timely fashion by a water utility engenders consumer confidence and enables more reliable revenue collection—a win–win situation. Meter accuracy and reliability have enabled water utilities to implement more effective water rate structures in which the price of water increases as usage increases, thus incentivizing efficiency. This economic incentive, coupled with national codes and standards that have increased the efficiency of fixtures and appliances, have reduced per capita water use across North America.

Water has been managed and measured for thousands of years with approaches and devices of varying complexity and accuracy. The Romans carefully managed aqueduct supplies just as modern water utilities carefully manage surface water and groundwater resources. Civilizations around the world have managed water as a limited resource to be carefully and equitably apportioned and paid for since the beginning of public supply. Precise water apportionment and measurement procedures remain central to water management, particularly as prices increase.

Today, the information water providers collect from water meters is critical to understanding water usage and demand trends. When you get down to it, water meter data are the basis for all utility water planning. Effective utility planning and management can't be done without this information, so it's difficult to overstate the fundamental importance of such data to a water utility.

From the customer's perspective, until recently, the water meter has been an underused tool that seldom provided useful information. Water meters are necessarily "out of sight and out of mind," located in a meter box or pit near the street, or in building basements or crawl spaces. Customers seldom, if ever, see their own water meter, and few may even know (or care) where it's located. For customers, the meter delivers information monthly, bimonthly, or quarterly in the form of a water bill that usually provides little context or explanation for charges and fees. However, new meter systems and technologies are rapidly changing the customer experience, and water users today have better access to their own water use information in real time than ever before.

## New Capabilities

Recent years have seen a revolution in meter communications and meter reading technology. Manual meter reading and drive-by systems are gradually being replaced with some form of wireless transmission of meter reading data. Customers can purchase their own devices that attach directly to the meter and provide nearly instantaneous flow data. Instead of once a month, modern water meters and technology enable meters to be read once per hour or more. Although utilities still use monthly consumption for billing purposes, hourly and high-frequency flow data can reveal leaks and unexpected usage patterns, reducing water waste and/or alerting customers before property damage occurs.

Ongoing advances in utility metering communications allow customers to take advantage of volumetric data to more effectively manage irrigation, eliminate waste, identify abnormal usage, and lower bills by reducing consumption. The potential is significant, but the utility investment is substantial, so it will likely take 10 to 20 years to complete this transition as water utilities of all sizes modernize their metering systems.

The value of these systems is enhanced by pairing water consumption with information detailing the number of residents or customers, the size and description of the landscape, water-use fixtures, and best practices. Such data allow water utilities to evaluate water use efficiency and develop more accurate water budgets—information that becomes particularly important when supplies and demands must be managed carefully, such as during a drought. Today's exciting and much needed water data revolution is increasing our understanding of current and future water demands as well as improving water efficiency and the customer experience.

Hourly data provide useful insights, but high-resolution data have proved to be the gold standard for understanding water use at the customer level. Since the 1990s, high-resolution flow data collected every 5 or 10 seconds at the meter level has helped document changes in customer water demand as fixtures and appliances have become more efficient. The Water Research Foundation's Residential End Uses of Water studies in 1999 and 2016 (https://bit.ly/WRF4309) were based on 10-second interval flow traces collected using portable flow recorders strapped to magnetic drive water meters. These studies showed that toilet, shower, and clothes washer efficiency have combined to reduce per capita water use across the United States.

High-resolution data also have been essential in gaining insight about instantaneous water demands in large buildings and the sizing requirements for water meters and service lines. Ensuring that all water meters are sized correctly represents an ongoing challenge in the water industry. Properly sized water meters allow for full and accurate revenue recovery for a utility through its chosen rate structure. An accurately sized meter also delivers satisfactory water service and pressure to end users as well as ensures customers only pay for the water they use. Inaccurately sized water meters—either too big or too small—can create financial and maintenance problems as well as contribute to apparent water losses.

## Ongoing Development

Modern, water-efficient fixtures have changed water usage patterns in buildings, reducing overall flows as well as the frequency and magnitude of peak flows. Working from data collected from a series of Water Research Foundation studies, the fourth edition of AWWA's Manual of Water Supply Practices M22, *Sizing Water Service Lines and Meters*, which will be released in the next year, will include further information on water demands in modern buildings as well as reevaluated meter sizing curves and approaches for residential and nonresidential buildings. Much work remains to be done to better understand the demand patterns and instantaneous demands of larger nonresidential and mixed-use buildings.

With grim optimism, every water professional I've ever met understands that tremendous water supply and management challenges await us in our careers. As we confront these challenges, the trusty water meter and the remarkable advancements in water meter data collection and analysis will help customers and water utilities manage this increasingly valuable resource.

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# Demystifying Digital Twins: Definitions, Applications, and Benefits

James P. Cooper, Stephen Jackson, Sri Kamojjala,
Garrett Owens, Kedric Szana, and Saša Tomic

## Key Takeaways

For utilities, digital twins are the next step in their digital transformation.

Digital twins have various functional purposes and levels of maturity.

Digital twins can be used to transfer knowledge from a retiring workforce, support increased customer trust and satisfaction, and optimize operations.

*Layout imagery by metamorworks/Shutterstock.com*

Innovation is thriving across the water sector in part as a result of ongoing research that has defined a clear value, structure, and purpose by which to achieve more, compete in the workforce marketplace, and improve public service. This is evidenced by a definition of *innovation* as the application of new ideas resulting in increased value to our customers and/or increased productivity (Carter et al. 2017).

The water sector has experienced a digital transformation over the past several decades, but the current era is different, and one innovation that is rapidly gaining traction is the digital twin. To dispel any confusion around the purpose, value, and even a basic definition of a digital twin, AWWA created a Digital Twins Committee to develop, educate, and promote digital twins across the complete water cycle (Photo 1). The committee does this by developing educational guidance and case studies, building consensus on standard terminology, and collaborating across organizations toward a common understanding (Cooper 2021).

The committee organized a pre-conference workshop at the 2021 Water Infrastructure Conference, which was held in Phoenix, to facilitate a structured conversation on digital twins by bringing together perspectives from utilities, technology providers, consultants, and academics. The full-day workshop consisted of presentations and small group exercises focused on discussing various challenges. Workshop participants brought diverse experiences with digital transformation—from individuals who had never heard the term *digital twins* to global specialists in them. The following sections capture the major items presented and discussed during the 2021 Demystifying Digital Twins workshop.

## Digital Transformation and Modeling

Digital transformation is the process of integrating digital technology into daily operations, and it largely involves translating the physical characteristics of water systems into data. Analyzing this data creates knowledge that provides a solid foundation for making current decisions and future plans. The process of digital transformation from collecting data to taking action is shown in Figure 1.

System data are collected from many sources, and examples include sensor signals and survey results. Data are a foundational component of a digital transformation, although typically useless without context. Once data are organized and context is provided through metadata, the result is useful information that can be analyzed to create system knowledge.

Using computer applications and tools to analyze information is another way to view system modeling. Hydraulic models and building information models are

> **AWWA created a Digital Twins Committee to develop, educate, and promote digital twins across the complete water cycle.**

The first in-person meeting of the Digital Twins Committee convened at the 2021 Water Infrastructure Conference. *© 2021 Satish Tripathi, City of Houston*

**Photo 1**

examples of this. Models provide knowledge based on the original data, and their predictive nature can come from deterministic analysis, stochastic tools, artificial intelligence and machine learning, and other means. Model results will change only when the input data change.

To support a decision, a model needs to adequately represent the current system and update automatically when the system changes. Model updates can be in real time or near-real time, but they can also represent other timelines. For example, project planning models can be automatically adjusted on the basis of changes in task durations or supply-side limitations. Regardless, correct decisions should lead to optimal actions that result in better system planning, operation, and management.

A platform that automatically adjusts the system model to support decision-making can be considered a digital twin. A digital twin can be defined as a data-driven decision support tool that manages predictive models to make sound decisions and take reasonable actions.

The process of digital transformation enables utility operators and managers to view and optimize their systems through computers. Digital twins are the next step for utilities on their digital transformation paths. Digital twins combine different utility data models with powerful analytic and predictive tools to create decision support platforms that enable human and machine intelligence to collaborate.

**Digital Water Transformation**

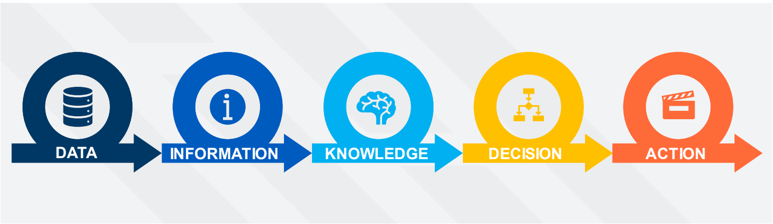





**Figure 1**

## Digital Twin Types and Levels

A digital twin is a "suitcase" term that represents various services and functions, but we can better understand what a digital twin is by unpacking the various digital twin components and their functions. A basic definition of a digital twin is provided in the *Gemini Principles* as a realistic digital representation of something physical (Bolton et al. 2018). In more detail, a digital twin is a way of working using interoperative services in an enabling environment to understand, monitor, inform, optimize, or simulate an asset, system, process, or organization from planning to inception and throughout its full life cycle, with the purpose of creating better insights and better definitions.

Digital twins already exist in a basic form at many utilities today. The digital transformation that has been occurring for decades has developed many digital systems that measure, monitor, and simulate portions of our water system and associated infrastructure. The difference between advanced applications of geographic information systems (GIS), supervisory control and data acquisition (SCADA), or other models, and a digital twin is based on the maturity of the utility's integration. As shown in Figure 2, a Level 0 (Digital Twin Ready) twin might be an existing model or system that could be doing more than its originally intended functions. A Level 1 (Informational Twin) brings together multiple systems and data sources into an environment that enables interaction. Higher-level digital twins enable additional functions through the twin's relationship with the physical system or its components.

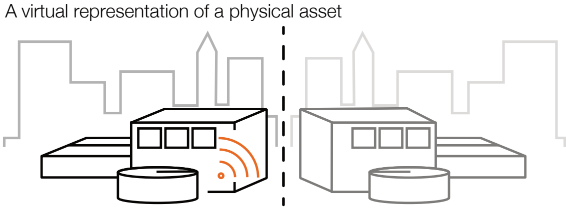
> **Digital twins combine different utility data models with powerful analytic and predictive tools to create decision support platforms that enable human and machine intelligence to collaborate.**

Digital twins may be best defined by their type or purpose. For example, an asset health twin is one that is informed by real-time data streams, Internet of Things, and sensors providing live readings on the physical and

## Digital Twin Maturity Levels

**Level 0: Digital Twin Ready**

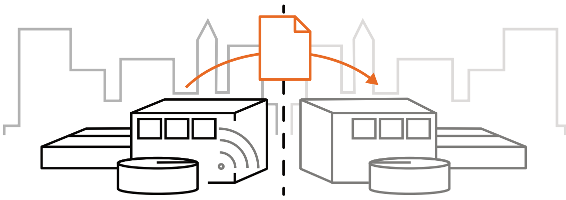
A virtual representation of a physical asset



Digital-twin-ready twins can enhance operations modeling, design support, and traditional planning capabilities for areas such as pipe sizing or nonrevenue water evaluation.

**Level 1: Informational Twin**

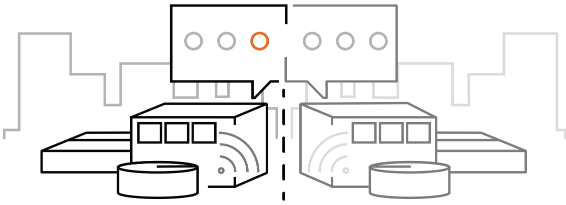
A virtual representation of an asset that uses historical data to enhance a utility function



Informational twins use historical data to support vertical and horizontal asset management, run what-if scenarios to optimize operations, and help staff safely train on assets in a digital environment.

**Level 2: Operational Twin**

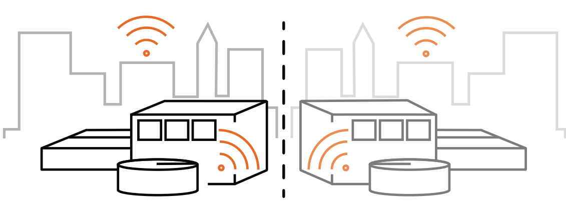
A virtual representation of an asset that uses real-time data analytics to enhance a utility function



Operational twins leverage live data streams and real-time analytics to optimize power and chemical usage, asset health, compliance management, and field deployments.

**Level 3: Connected Twin**

A virtual representation of connected assets that uses real-time data analytics to coordinate functions across domains



Connected twins leverage live data streams and real-time analytics to optimize interdepartmental coordination across a community network, such as alignment between repaving and pipe replacement schedules.



**Figure 2**

operational conditions of an asset. Another type is a training twin that brings together a simulation environment, asset reference materials such as an operations manual, and a multidimensional physical representation of the asset. A digital twin could connect individual analyses from hydraulic modeling, asset risk modeling, and optimization modeling for greater system intelligence than when users have to make those connections manually.

## Digital Twin Applications and Benefits

The applications and benefits of a digital twin are unique to each organization, but the approach is universally applicable to systems of any size. A digital twin approach can be adapted to suit any style of system management, and the basic principles of a digital twin provide guidance regardless of an organization's specific needs and circumstances.

As described in the following case study, a good approach to integrating a digital twin is as follows:

- Focus on value
- Start where you are
- Progress iteratively through feedback
- Collaborate and promote visibility
- Think and work holistically
- Keep it simple and practical
- Optimize and automate

In response to rapidly growing population and tripling of water demands over the past 40 years in the Dallas–Fort Worth (DFW) Metroplex, two major water providers partnered to implement a shared water pipeline. This collaboration, which includes 150 miles of new pipeline, along with several new source water pumps and booster pumping stations, should dramatically increase the reliability and resilience of the DFW-area water supply.

With extensive operational options, complex energy billing structure, high pumping energy costs (US$10 million–$30 million annually), and uncertain future hydrologic conditions, managing costs and risks via operational decisions poses a significant challenge. A digital twin was developed to integrate information sources and optimize operations. Interactive dashboards were also developed to aid in exploring potential strategies by visualizing the flows, energy, costs, and risks associated with each strategy.

Integrating data sources is a key benefit that digital twins provide. In this example, operational decisions were historically made via group discussion using three primary information sources at hand:

- Hydrology and demand forecasts from the hydrologic model
- Pump power estimates from the hydraulic model
- Cost estimates from an energy costing spreadsheet

Without the digital twin integrator, these three data sources were siloed, limiting understanding of the complex interactions and critical information used by the three.

The digital twin integrates these three key data sources, providing a comprehensive data set to enable decision making from a deeper understanding of the system. The digital twin approach also has the indirect benefits of standardizing information flow as well as improving documentation of the decision-making process. The digital twin formulates the hydrologic, hydraulic, and energy cost information into a linear optimization problem, solving for the lowest-cost monthly pumping strategy that satisfies all hydraulic and operational constraints. Critically, the tool develops an optimal pumping strategy for a range of possible future conditions, rather than for a single expected future. With this approach, it is possible to quantify certain risk metrics associated with each strategy, such as the risk of a water supply shortage. Used in this way, the digital twin provided engineers and managers the opportunity to integrate their tacit system knowledge into the decision-making process.

## Optimizing Water Utility Functions With Digital Twins

For a utility to function optimally, it needs to integrate its primary functions, including asset management, operations, and system growth. Integrating digital information is vital to integrating utility functions. Recent advances in sensor technology, hydraulic modeling software, and computing power have increased the feasibility of modeling in real time or creating a digital twin, allowing rapid assessment of alternative strategies.

Since July 2005, the Las Vegas Valley Water District (LVVWD) has used a digital twin for the following applications:

- Developing daily pumping plans to manage energy and water quality
- Managing planned facility shutdowns
- Aiding in emergency response
- Hydraulic model calibration
- Planning for capital infrastructure and asset rehabilitation and replacement

LVVWD's digital twin uses integrated information from wireless sensors, SCADA, GIS, enterprise databases, and its hydraulic model for making optimal and timely decisions. Sensors and software are deployed to provide data and analytics essential for supporting critical utility infrastructure management decisions and to address operational issues. Leveraging digital twins in emergency response was discussed. After using its digital twin, LVVWD has seen a significant improvement in controlling disinfection by products and experienced substantial savings in energy consumption. LVVWD has also had better response to emergencies and planned shutdowns using its digital twin.

In 2014, Colorado Springs Utilities (CSU) created a full-time position to manage its digital twin to continuously forecast the distribution system response for the upcoming 24 hours. Implementation was a unique and difficult experience that took 18 months to set up. CSU has maintained the digital twin in house for the past six years with no outside assistance, using the digital twin to forecast operations for the next 24 hours every morning. With this approach, CSU has moved from reactive operations to proactive operations, and it has used its digital twin to solve water quality issues, automate and refine system controls, and avoid costs. In addition, CSU's digital twin has enhanced communication among engineering, water quality, operations, and valve teams.

## Workshop Participant Takeaways

Creating a digital twin is not an all-or-nothing proposition. As utilities add more validated data from different sources to a digital twin, its usefulness increases. For functionality that depends on many inputs, such as pump performance, consider starting with a pilot project. Select one or two pump stations and assemble as complete a data set as possible. Validate the manufacturer information and sensor results. Use these stations to showcase the capabilities of the digital twin and build excitement for the benefits that might be gained by systemwide implementation.

When transitioning to real-time modeling, hydraulic models without well-calibrated control statements can produce inaccurate forecast results. In many cases it is valuable to first focus on hindcasting, which is easier to achieve with historical control overrides. Hindcasting provides value both for diagnosing events and for calibrating and building confidence in the model's accuracy. Once hindcasting capabilities have been validated, control statements can be added to the model so that forecasting becomes more reliable.

Staff with institutional knowledge on aspects of the utility's system, such as SCADA tag names and parameter units, are key to successful implementation and to achieve unified communication across the organization. Identify the in-house experts and include them in early discussions. Their buy-in and participation in the project can go a long way toward smoothing the initial startup.

During the workshop, breakout groups gathered to discuss questions such as what a digital twin means to your utility and what kinds of problems a digital twin can solve. The following themes emerged from the workshop participants:

**Digital twin development is an integration of systems that supports decision-making and includes sufficient detail required to make those decisions, maximizing levels of service to customers in ways that cannot be achieved otherwise.**

- Digital twin development is an integration of systems that supports decision-making and includes sufficient detail required to make those decisions, maximizing levels of service to customers in ways that cannot be achieved otherwise.
- A digital twin leans more toward a process rather than a product, acting as a targeted behavior and response system.
- Further development of digital twins should address knowledge retention that is commonly lost through retirements, improve possibilities for resource optimization, and reduce stress for operator decision-making.
- Digital twins enable better communication between business functions, improve operation and maintenance efficiencies, and raise customer trust and satisfaction.
- Digital twin development is a journey.

At the conclusion of the workshop, attendees had unpacked different views, yet many commonalities of digital twins were also discovered. Multiple requests for additional workshops and special topic sessions at future conferences were made. It is clear that digital twins will bring a transformational change in how the water industry works and serves the public, and we are only beginning to uncover their possibilities and benefits.

***Editor's note:*** *This article is part of a series aiming to bring clarity and generate dialogue on digital twins in the water industry, developed by members of AWWA's Digital Twins Committee. The authors encourage your feedback and welcome you to participate in the committee.*

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# Extreme Events Increase Operational and Planning Complexity

Sarah Page, Philip Brandhuber, Fuhar Dixit, Benjamin Fennell, Joseph E. Goodwill, and Silvia Vlad

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***Editor's note:*** *Having completed its inaugural Water Quality Matters column series focusing on the theme "Hot Topics in Water Quality," the AWWA Water Quality and Technology Division's committees look to extend the conversation by responding to a common question: What keeps your committee members up at night?*

Water utilities protect public health by providing potable water to their communities every minute of every day; it is at the heart of what they do. Like our physical hearts, our water systems can experience stress, and they are mission-critical in periods of calm or volatility. But volatility is increasing, from both a statistical and anecdotal perspective, because of the increasing frequency of extreme events that can affect potable water systems.

## Extreme Events

Extreme events are difficult to define, but they typically indicate a rare occurrence (e.g., outside of three standard deviations from a normal distribution, or "long-tailed") with an unknown or complex cause. Extreme events also occur over a short period of time relative to the expected life span of water infrastructure. Therefore, a significant storm, wildfire, and years-long drought may all be considered extreme events.

The characteristics of extreme events make them difficult to predict, and they often carry an element of disruption that can affect infrastructure, such as a storm washing out a road. Extreme events also carry second-order effects—consequences that arise from the event that likewise have subsequent consequences (e.g., a storm may result in the loss of electrical service, and that loss in service could affect water treatment processes).

Extreme events and their consequences require significant consideration by the water industry because of their potential to disrupt potable water systems. Here we give examples of extreme events, their water quality impacts and other second-order effects, and recommendations for utility responses.

## Water Quality Impacts of Extreme Events

With increasing frequency, utilities are being challenged by long-tail occurrences of extreme events, as explained in the November 2013 *Journal AWWA* article "Climate Change, Extreme Weather, and Water Utilities: Preparing for the New Normal." These events sometimes challenge water utilities to meet consumer demands while maintaining water quality goals. Such events include the following:

- Floods, fires, and excessive heat or cold
- Intense storms such as hurricanes, blizzards, and tornadoes
- Exceptional amounts of rain, snow, and ice

- Droughts and subsequent water shortages
- Earthquakes and tsunamis

The occurrence of these events in unexpected locations or hard-to-reach areas only compounds the challenges they present.

Extreme events can be local, but long-term trends like drought can present serious regional challenges for water utilities. Also, large-scale events can create competition between neighboring utilities for increasingly scarce, high-quality water sources. Underlying these challenges is climate change, which is predicted to result in even more frequent and intense extreme events, as detailed in the July 2021 *Nature Climate Change* article "Increasing Probability of Record-Shattering Climate Extremes."

Extreme events and their second-order effects influence how utilities meet customer demands, often by increasing demand while reducing supply. Such an approach strains infrastructure and operations. Staffing treatment plants may become difficult, chemical deliveries may be interrupted, electrical power may become unreliable, and the integrity of supply and distribution systems may be compromised.

Second-order effects of extreme events include water quality degradation. When system integrity or treatment processes are compromised, boil-water and do-not-use orders often follow (Table 1). More subtle effects on source water quality caused by extreme events may take time to appear and even longer to subside—if they subside at all. Changing the character of a system's source water can reduce its treatability and may also affect the stability coatings and deposits in the distribution system, potentially leading to other water quality challenges.

Figure 1 provides an overview of the interrelated source water quality, treatability, and distribution system challenges that can arise from water quality changes after extreme events. Although we often

### Extreme Events and Potential Water Quality Impacts

| Type of Extreme Event | Examples | Potential Water Quality Impacts |
|---|---|---|
| Extreme heat/cold | In February 2021, almost half of the population of Texas had some disruption to water service resulting from impacts of Winter Storm Uri. More than 2,200 boil-water notices were issued by public water systems in one week. | System integrity was compromised, requiring high flows through treatment processes to maintain system pressure and resulting in insufficient disinfection and treatment. |
| Extreme precipitation | Abbortsford, B.C., Canada, issued a do-not-use water advisory in November 2021 when an atmospheric river produced a 500-year storm. Extreme precipitation resulted in significant flooding and uncontrollable water main breaches, with parts of the city under 7 feet of water. | The presence of hazardous and potentially toxic materials in the floodwaters undermined water quality beyond the point of a boil-water advisory. |
| Wildfire<br>Watershed<br>Urban | In December 2021, the Marshall Fire in Boulder County, Colo., resulted in multiple cities issuing boil-water advisories as a result of pressure loss and damage to water mains.<br>The 2018 Camp Fire in Paradise, Calif., resulted in benzene concentrations in drinking water more than 2,000 µg/L. | High temperatures compromised distribution system integrity, causing contamination and leaching of chemicals into the water. Source water changes in the character and quantity of organic matter and particulates stressed treatment processes. |
| Drought | Exceptional drought in the summer of 2021 led to multiple cities in Utah running out of water, requiring them to import water from other communities. | Boil-water orders were required because of a loss of pressure. Changing water source chemistry may destabilize distribution system biofilm and scale. |
| Intense storms<br>Hurricane<br>Tornado<br>Blizzard | Hurricane Ida in 2021 caused drinking water disruptions from New Orleans up to Philadelphia, including boil-water orders resulting from flooded water treatment facilities. | Flooding at treatment facilities caused issues with maintaining treatment and required disinfection as well as compromising system integrity. |

**Table 1**

## Possible Effects of Extreme Events on Source Water Quality, Treatment, and Distribution

### Source Water Quality Impacts

| | Extreme Heat/Cold | Wildfire | Extreme Precipitation | Earthquake | Drought | Intense Storms |
|---|---|---|---|---|---|---|
| Increased turbidity | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Changing NOM characteristics | ✓ | ✓ | ✓ | | ✓ | ✓ |
| Increased inorganics (metals, bromide) | ✓ | ✓ | ✓ | | ✓ | ✓ |
| Changing background water quality (pH, alkalinity, hardness) | ✓ | ✓ | | ✓ | ✓ | |
| Increased TOC | ✓ | ✓ | ✓ | | | ✓ |
| Increased color | | ✓ | ✓ | | ✓ | ✓ |
| Objectionable taste and odor | ✓ | ✓ | ✓ | | ✓ | |
| Increased nutrients (nitrogen, phosphorus) | | ✓ | ✓ | | | ✓ |
| Anthropogenic (chemical release, stormwater overflow, road salt) | ✓ | ✓ | ✓ | ✓ | | ✓ |

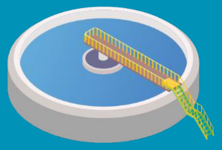
### Treatability Impacts

**Conventional/biological treatment**
- Increased treatment chemical demand
- Reduced UFRV

**Membrane treatment**
- Decreased recovery
- Increased fouling

**GAC/ion exchange**
- Premature breakthrough
- Additional GAC consumption
- Resin fouling

**Disinfection/oxidation**
- Increased oxidant demand
- Increased disinfectant demand
- Inability to meet CT



### Distribution System

**Destabilization of pipe scale/biofilm**
- Color
- Taste
- Turbidity
- Adsorbed metal release

- Increased DBP levels
- Increased Pb/Cu corrosivity
- Increased CSMR

**Residual disinfectant stability**
- Increased demand
- Loss of residual
- Reduced chloramine stability; nitrification

**CSMR—chloride to sulfate mass ratio, CT—chlorine contact time, Cu—copper, DBP—disinfection byproduct, GAC—granular activated carbon, NOM—natural organic matter, Pb—lead, TOC—total organic carbon, UFRV—unit filter run volume**

**Figure 1**

consider the singular effects of an extreme event (e.g., increased turbidity following a major storm), utilities examining the risks posed by extreme conditions are faced with the challenge of considering the compounding effect multiple different events can have when they occur in close succession, such as the potential for algal blooms after a wildfire and a major storm. These complex relationships can be challenging to quantify and predict, even with plenty of climate change data available. As a result, the second-order water quality challenges of multiple extreme events are typically considered only anecdotally and qualitatively.

Although extreme events vary, their water quality concerns have much in common. Thus, systems should focus their efforts on increasing resilience to water quality changes that may be caused by a variety of extreme events.

Typically, treatment processes are highly optimized to source water quality, whereas distribution systems are acclimated to a narrow range of treated water quality. Even minor source changes may have significant effects throughout the system. Many extreme events change baseline water quality parameters, including pH, alkalinity, temperature, the amount and character of total organic carbon, and disinfection byproduct formation potential. Extreme events can create short-term spikes and long-term increases in turbidity and suspended solids, challenging physical, chemical, and biological treatment processes.

In addition, extreme events can create aesthetic concerns such as taste, odor, and color problems; if left unchecked, these problems can reduce public confidence in the supply. Nutrient levels can increase as a higher-order effect of extreme events, leading to nuisance algae or cyanobacteria and cyanotoxins, along with increased biological activity in the source water. More rarely discussed, inorganic contaminants like bromide and nitrate often are released by extreme events, and changes to background water quality can reduce treatability. Lastly, extreme events may compromise source water protection, contaminating water supplies by anthropogenic sources.

Changes to water quality resulting from extreme events typically reduce treatability and increase water loss, although the specific effects on treatment vary by system and treatment technology. Of greatest concern are changes that compromise the ability to meet disinfection requirements, as the failure to adequately disinfect immediately poses public health risks.

Less appreciated are the ultimate outcomes of any of these changes for distribution system stability and water quality. Besides the obvious concern regarding disinfection byproduct formation, disinfectant residual stability, avoidance of nitrification in chloramine systems, and pipe-scale stability are concerns that inherently follow when sources and treatment are challenged by extreme events.

## Drought Impacts

Each of the previously mentioned extreme events has complex interactions with the source and treated water environments (e.g., drought often increases water demand, while existing sources decrease in yield or go dry—sometimes with a related decrease in water quality). Water systems may be forced to rely on emergency interconnections to other systems or put less desirable, lower-quality sources into service that may result in maximum contaminant level exceedances or unwanted increases in the concentration of regulated compounds. In extreme cases, sources may run dry, requiring water to be delivered by truck.

In addition to the water quality challenges posed by lower-quality sources, introducing new water sources into a distribution system can cause rapid upsets in system equilibrium, potentially destabilizing biofilm or scale throughout the system. This may affect parameters like lead and copper levels as well as mobilize opportunistic pathogens like *Legionella*, particularly if the water flow direction changes.

Often in these scenarios, flushing is not an option to mitigate these effects because of water scarcity. Monitoring for relevant parameters is not required at a frequency to capture the effects of destabilization, and customer complaints or illness are the primary indicators of a problem in the system. Although some systems commonly use seasonal sources and manage the associated changes in treated water chemistry, these source changes are anticipated and conducted according to a plan. However, an increase in the frequency and/or magnitude of changes in water chemistry resulting from extreme events can increase the likelihood of problems, even with the best-laid plans.

## Recommendations for Utility Response

To better position themselves in today's changing environment, water systems should consider the following:

- Utility managers can characterize how multiple events happening in succession might affect water quality at the treatment plant and in the distribution system. Although this requires utilities to integrate more complexity into long-term decision-making, identifying any potential issues and mitigation strategies will better prepare the water system and operators to respond in a crisis as well as help identify solutions if multiple events occur at once.
- Utilities can engage in regional planning, management, and risk mitigation that potentially lead to consolidation of water systems and infrastructure. During planning, considering the availability of data, staff, and supply quality on a local and regional scale can be critical to weighing the pros and cons of consolidations.
- Utilities can consider increasing the resilience of their water treatment processes, which may require adopting more sophisticated technologies. In addition, operators should be provided more training and certification so they can better monitor and respond to changes, making real-time decisions to address unique events if they occur.
- Utilities can consider increasing the resilience of their distribution systems. For example, a system could develop an emergency preparedness plan outlining how the utility will provide water service with a minimum 20-psi pressure during an extended power outage (lasting 24 hours or more) and consider system modifications or upgrades required to withstand stresses beyond normal operating conditions.

No matter what strategy they take, utilities should never lose sight of the fact that at the heart of all water quality issues lies the risk to public health and consumer confidence in tap water. Many water systems require significant investment to prepare for extreme events and to prevent a devastating loss of customer confidence if a water quantity or quality problem occurs. Utilities that proactively communicate with their customers are more likely to weather a water quality incident without damaging community confidence.

## Ongoing Development

Extreme conditions can affect many aspects of water quality, so the water industry needs to be flexible and respond in many ways. Increasingly, water professionals must consider water treatment in a systems context, acknowledging the interplay between water treatment capabilities and environmental conditions as well as the reliance on related systems, including the power grid, transportation infrastructure, and supply chains. By developing more robust source protection, treatment strategies, and distribution management approaches, utilities can account for more complexity in their long-term decision-making processes.

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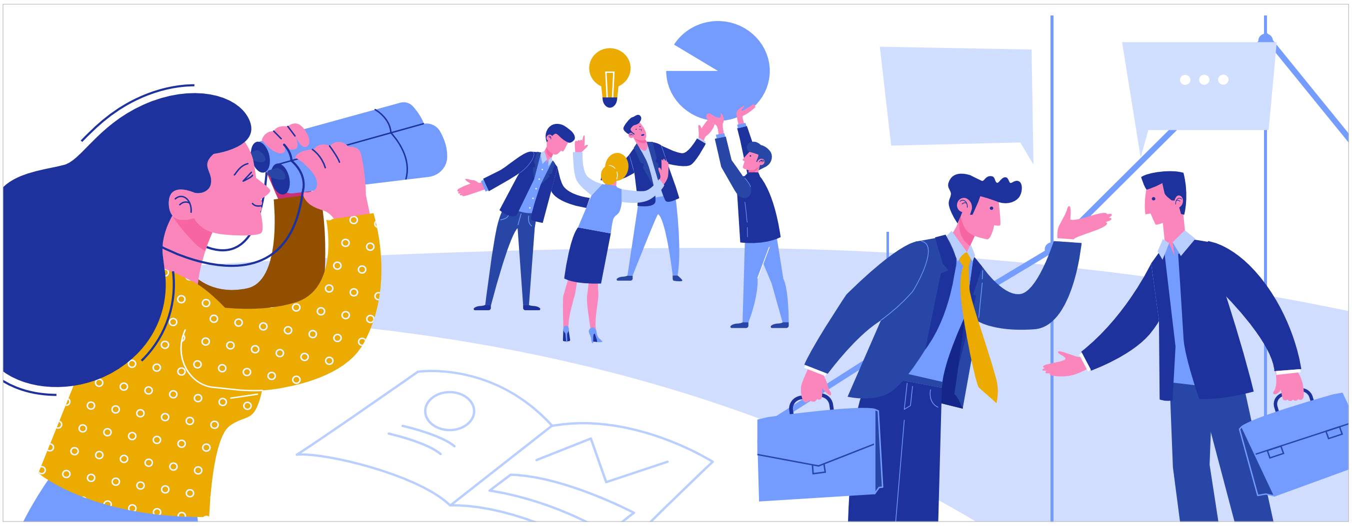
# State of the Water Industry: Workforce, Water Supply, Infrastructure Among Top Concerns

Dawn Flancher



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Supported by 19 years of trending data, AWWA's State of the Water Industry (SOTWI) survey provides an overview of the challenges and opportunities water professionals face in providing safe drinking water and discharging clean water to the environment. Although most of the critical issues identified in 2022 were related to infrastructure and financing, this year's survey shows a more immediate concern about the water industry's aging workforce and anticipated retirements.

## Experienced, Knowledgeable Respondents Provide Insight

Since its inception in 2004, the SOTWI survey has focused on three primary objectives:

- To develop valuable insights regarding key water sector issues
- To identify important issues not being adequately addressed in order to raise awareness and assign a higher priority for these issues
- To identify and track significant water sector trends

In addition to these objectives, the SOTWI survey is fundamentally focused on using the data collected to guide the sector toward greater soundness, help water professionals perform essential roles more effectively, and get a jump on emerging issues before they develop into full-blown crises.

When the survey closed in December 2021, 3,778 water professionals had shared their perspectives. The SOTWI survey strives for the broadest possible base of water sector perspectives, but as in previous years, the individuals who responded tended to be seasoned water professionals, with 48% reporting 20 or more years of water sector experience.

The largest group of respondents (67%) represented water utilities, followed by 11% of respondents representing consulting firms and consultants (i.e., firms or individuals providing technical and engineering services to the water industry). Additionally, survey respondents included individuals associated with water through service providers, academia, science, and regulatory bodies, as well as retired water professionals.

Survey participation invitations were distributed to more than 153,000 email addresses, with the goal of providing uniform responses from states and provinces. To avoid bias, AWWA membership was not considered in the survey distribution. Subsequently, four follow-up emails were sent to this same group between Oct. 21 and Dec. 3, 2021. Links to the survey were also posted on AWWA social media.

The 2022 SOTWI survey straddled the signing of the US Infrastructure Investment and Jobs Act on Nov. 15, 2021, the SARS-CoV-2 omicron variant surge, extreme weather events throughout North America, and a surge in employee resignations and transitions. It is impossible to know which of, or if, these events had any effect on survey responses.

> "As an East Coast water works manager, we rarely contend with water shortages or drought conditions, but the West Coast shortages, particularly Lake Mead and the Colorado River, are extremely concerning to all water management professionals. Alternative water management techniques and protocols must be developed to sustain not only the residents of the Southwest but the hundreds of species of wildlife all along the Colorado."
>
> —2022 AWWA State of the Water Industry survey respondent

## Water Sector Challenges

Every year the SOTWI survey asks participants for their opinion of the current and future health of the water sector. Figure 1 depicts the average scores as rated by all respondents. The current health of the sector is 4.97, on a scale of 1 to 7, with 1 being "not sound at all" and 7 being "very sound," marking a slight decline from the previous year. Looking forward five years, the anticipated soundness of the water industry also saw a slight decline in optimism from 5.01 in 2021 to 4.73 in 2022.

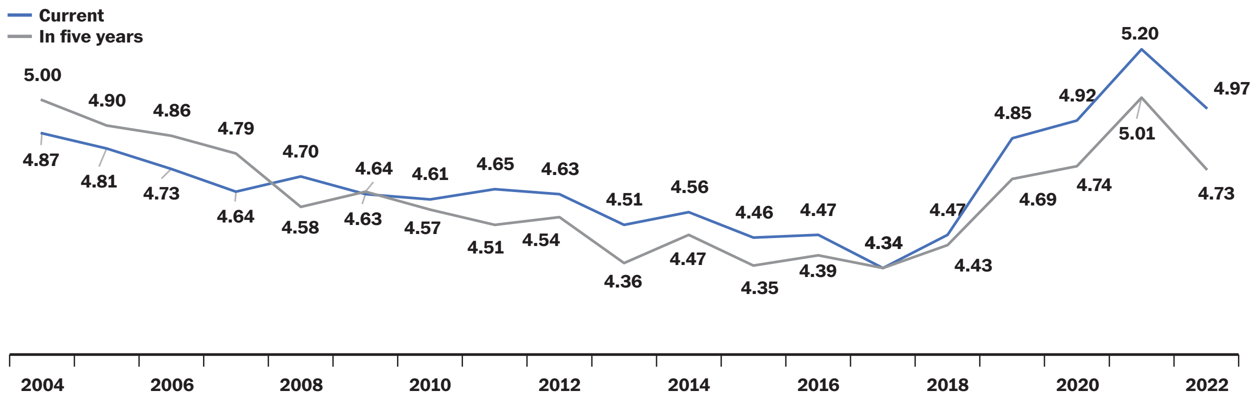
The survey asked how participants view the health of the water sector in their region today and what they think it will be in five years. The current regional health of the water sector as rated by respondents is 5.28; looking forward five years, the anticipated soundness of the water sector in the region where they worked most often was 5.12.

The region-specific scores are typically higher than the general scores. The reasons for the regional results are not immediately apparent, but one explanation is that people likely have a better understanding of the water systems in the areas in which they work, and perhaps they are working to support these very same systems.

## Top Five Critical Issues

Following the soundness ratings were questions asking respondents to rank the most critical issues facing the

**State of the Water Industry, 2004–2022**




**Scores are on a scale of 1 to 7, with 1 being "not sound at all" and 7 being "very sound." Even though there was a slight decline, the 2022 values are higher than the overall 19-year average of 4.65.**

***n* = 3,778 (all respondents)**

**Figure 1**

> "Our industry needs to work very hard to build tomorrow's workforce in the water and wastewater industry. The number of people that will retire in this industry in the next five years is scary."
>
> —2022 AWWA State of the Water Industry survey respondent

water sector. While the sector has many challenges before it, survey respondents ranked the following as the most critical concerns.

### Renewal and Replacement of Aging Water Infrastructure

Aging water treatment and supply infrastructure and the prospect of its failure are real concerns. It is estimated that there are approximately 850 daily water main breaks in North America, at an annual repair cost of more than $3 billion. This cost includes the estimated annual loss of 2.7 trillion gallons of treated drinking water.

Signed into law in November 2021, the US Infrastructure Investment and Jobs Act launched a new era of significant investment in rehabilitating and updating the nation's water infrastructure. This federal law reauthorizes several drinking water programs, expands federal funding for water infrastructure and related programs over the next five years, and commits funding for lead service line replacement.

### Financing for Capital Improvements

Utility revenues generated through rates and fees are used to fund ongoing operations and maintenance activities and capital improvements. Cost recovery refers to pricing water and wastewater services to accurately reflect their true costs and then obtaining these from customers through rates.

Exploring cost recovery or full-cost pricing, the survey asked respondents who identified as utility executive/management and financial officers if they believed their utility would be able to meet the full cost of providing services through customer rates and fees in light of the current and future infrastructure needs for renewal and replacement. Combining those that are not at all able and those that are slightly able, 26.4% of utilities responding are currently struggling to implement full-cost pricing. In addition, 32% of respondents believe they will struggle to cover the full cost of service in the future. Utility executives are perhaps still expecting challenges ahead, seeing as the percentage of respondents who felt that their utilities would be fully able to cover the cost of providing service in the future decreased.

The 2022 SOTWI survey shows that 71.7% of respondents identifying as utility executive/management and financial officers indicate they are planning a rate increase in 2022. Rate increases were preferred to the various funding opportunities currently available (e.g., bonds, loans, reserves).

### Long-Term Drinking Water Supply Availability

Concerns centered on ensuring adequate quantities of treatable water supplies amid drought, growing needs, and protecting water at the source. The 2022 SOTWI survey asked utility participants if they were prepared to meet long-term water supply needs; 53% indicated their utilities are very or fully prepared, which is down from 65% reported in 2021 and 57% in 2020. Investigating the 12% respondents who indicated their utility will be challenged to meet anticipated long-term water supply needs, we find that all sizes of utilities are experiencing similar struggles.

As communities evaluate their water shortage preparedness, there is also an opportunity to better understand regional water supply sustainability. Utility participants were asked whether their utilities were implementing or considering augmentation of existing water supplies, such as desalination of brackish groundwater or seawater, indirect or direct potable reuse, or urban stormwater recovery. Data indicate that there is currently little investment in developing alternative water supplies.

### Aging Workforce and Anticipated Retirements

The 2021 SOTWI survey received numerous comments on the importance of workforce to a sustainable utility future. The 2022 SOTWI survey followed up by asking participants a series of questions on how they rated the aging workforce and the importance of retention. Workforce issues entered the top 10 critical issues facing the water sector in 2018, a concern that has been steadily moving upward. The 2022 SOTWI survey trends show aging workforce and anticipated retirements as the fourth-ranked issue of concern to water professionals.

> "The public perception of the cost of water is very critical. Most communities need to replace aging infrastructure and lead service lines, and the public does not seem to understand that comes with a cost that they will bear with water rates. There still seems to be a belief that water is 'free,' and we need to change that belief so that the public values water service and rates."
>
> —2022 AWWA State of the Water Industry survey respondent

### Public Understanding of the Value of Water Systems and Services

Effectively communicating infrastructure and water supply challenges to customers and key decision-makers is vital, and the water sector has worked to inform the public of the value of water services and resources for decades. While the concepts of safeguarding public health, ensuring customer satisfaction, and protecting the environment are popular, the public does not always favor the required levels of funding to fully support safe and reliable water service.

To explore the perceptions of communication with various groups, the 2022 SOTWI survey asked all survey respondents about their utility's communication effectiveness and what platforms they found useful. More than 54% found their utility effective to very effective in communicating this past year; monthly bills, websites, and social media were the most effective platforms for messaging.

## Trends Help Chart Course Forward

The top five challenges are from a list of more than 20 concerns ranked by water professionals. The water sector is complex, with more than its share of significant challenges. The first step in meeting our goals is to better understand and appreciate these challenges while keeping an eye on the horizon for new concerns.

Now in its 19th year, the SOTWI report is building trending data that show where the water sector has been and how well it has addressed challenges, and it offers a glimpse of a path forward. Continued vigilance and consistent data collection will help AWWA and the water sector navigate what lies ahead.

***Editor's note:*** *This column is based on the full* 2022 State of the Water Industry *report, which can be found online at www.awwa.org/SOTWI.*

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# Customer Assistance Programs and Water Affordability

Lauren A. Patterson, Aislinn McLaughlin, and Martin W. Doyle

## Key Takeaways

Water affordability is a growing concern, with inflation, aging infrastructure, source water protection, climate change, and other factors pushing up the cost of providing water.

Customer assistance program (CAP) rate discounts provide needed assistance but may not be sufficient to ensure that water services are affordable.

Rather than relying on one approach, such as CAPs, a combination of approaches might be optimal for addressing water affordability issues.

*Layout imagery by Wollertz/Shutterstock.com*

In response to growing affordability challenges, some US water utilities have established customer assistance programs (CAPs) to help households pay for water services. In this article, we explore the impact of CAPs on customer bills and affordability metrics at multiple volumes of water usage for 59 drinking water and wastewater utilities in California and Texas. For utilities in this study, CAPs reduced customers' monthly bills for water services by a median of $10 (1,000 gallons used) to $15 (16,000 gallons used), reducing total water bills by 10%–19%. The majority of CAPs applied discounts to the fixed charge, meaning customers using less water experienced greater benefit. While CAPs provide some assistance, the discount may not be sufficient to ensure water services are affordable for some households, particularly those in deep poverty or those with high water usage.

## A Growing Affordability Gap

The costs of providing water services are rising as a result of many factors, including inflation, renewal or replacement of aging infrastructure, increased source water protection, the effects of climate change and population shifts, and more stringent regulations. Rising costs have translated to residential water service rates increasing more than twice the rate of inflation over the past 20 years (Rothstein et al. 2021, AWWA 2019), even as most incomes have remained stagnant (keeping pace with inflation at ~2% increase annually). The combination of higher residential rates and stagnant incomes has created a growing affordability gap. In this article, we focus exclusively on residential customers and refer to them primarily as households.

**Rising costs have translated to residential water service rates increasing more than twice the rate of inflation over the past 20 years.**

The affordability gap does not affect all households equally. Even within a comparatively wealthy community, there are households with low incomes for which the costs of water services are challenging. Further, systemic underinvestment in the infrastructure serving rural communities, low-income communities, communities of color, and tribes has sustained and exacerbated long-standing inequities in water affordability (Patterson & Doyle 2020, DigDeep & US Water Alliance 2019).

Communities that invested in new infrastructure decades ago experience challenges when water-intensive industries, jobs, and wealthier populations migrate to new areas. Out-migration results in infrastructure that is oversized for the remaining demand, leaving stranded assets and debt that must be covered by the shrinking customer base locations (Smull et al. 2022, Doyle et al. 2020, Anderson 2017). Regardless of the causes, the ability to pay for water services is a challenge for many households across communities.

## Customer Assistance Programs and Affordability

Customer assistance programs (CAPs) are one tool utilities use to address water affordability, with approximately a third of larger drinking water utilities offering some type of CAP (Vedachalam & Dobkin 2021, AWWA 2019, EPA 2016). CAPs are effectively subsidies to increase the ability of financially constrained households to maintain access to water services, and they can include "bill discounts, special rate structures, and other means as an approach to help financially constrained customers maintain access to drinking water and wastewater services" (EPA 2016). CAPs were initially intended to provide short-term assistance, but over time have become a means to address the chronic struggles of some households.

Despite their ubiquity, CAPs have received limited research attention (Pierce et al. 2021, Vedachalam & Dobkin 2021, UNC Environmental Finance Center 2017). Much of this previous work focused on exploring CAPs within individual utilities, state regulations, and CAP eligibility and target populations (e.g., income, age, disability), with less research focused on the financial impact on customers and the improvement in their ability to afford water bills. A recent study exploring CAPs in 20 large drinking water utilities found that CAPs had difficulty reaching eligible households (enrolling only 10% to 15% of eligible households) and provided an average discount of $11 on monthly bills (Vedachalam & Dobkin 2021).

Our research further explores CAP discounts on water bills and how those discounts affect affordability for 59 utilities in two states: California and Texas (Figure 1). These states were chosen because they were part of a larger ongoing study using a standardized, open data approach to assess affordability (Patterson & Doyle 2021). Our analysis is limited to 59 utilities that provided CAP rate discount data on their websites, and

## Location of Utilities in This Study

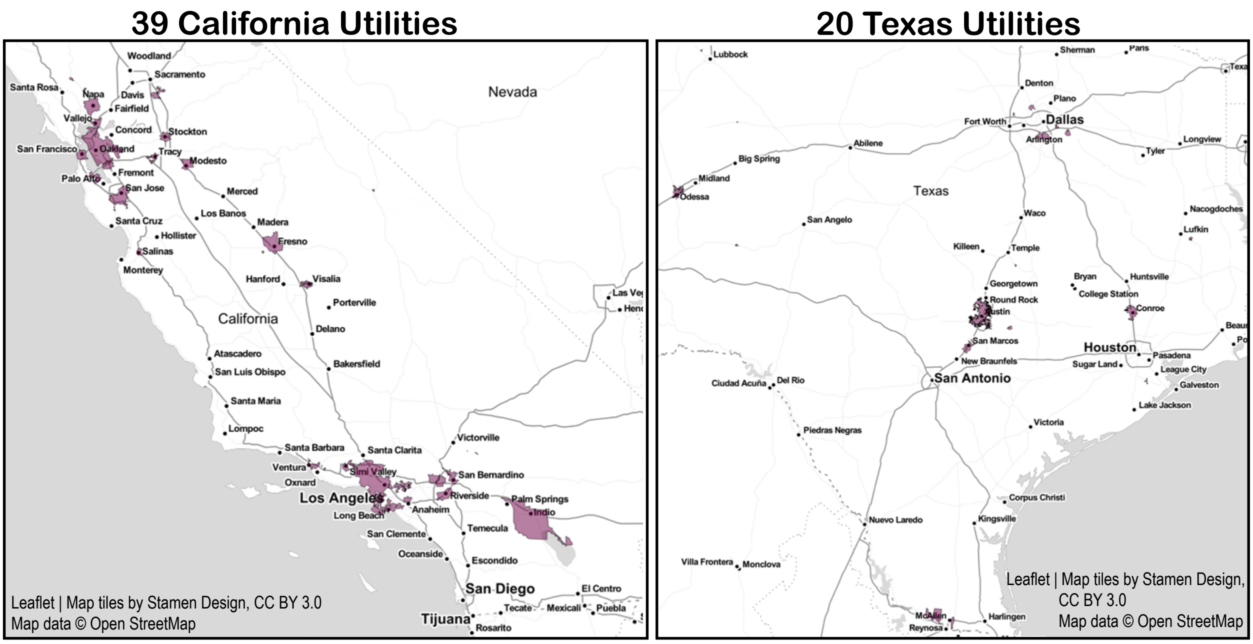



**Figure 1**

while the sample size is small, this approach is generalizable and can expand to include additional utilities as better public data become available.

Three questions were addressed in the study to better understand how CAPs influence water affordability:

- Who is the target audience (e.g., low-income households, seniors, people with disabilities)?
- How much bill relief do CAPs offer compared with the original water bill, and how does that change with water usage?
- Do CAPs make water affordable for low-income households and minimum-wage earners?

> **Customer assistance programs were initially intended to provide short-term assistance, but over time have become a means to address the chronic struggles of some households.**

## Approach to Exploring CAPs and Affordability

### Data for This Study

Our analysis follows the approach developed by Patterson and Doyle (2021) and requires the following data: (1) service area boundaries, (2) drinking water and wastewater rates, and (3) census data; for specific details, refer to Patterson and Doyle (2021). To assess the cost differences associated with a CAP, the analysis also required that the utility have a CAP for either drinking water or wastewater services, and the utility must provide the CAP discount rates online. Data obtained from each utility's website included discount rates and the eligible population to receive a discount: seniors, disabled, low-income, lifeline rates, or multiple criteria (such as a household with a senior who is disabled).

We included 59 utilities in this analysis. In California, 75% of the utilities were large or very large (serving more than 75,000 people). In Texas, 71% of the utilities were small to medium–large utilities (serving

500 to 75,000 people). Fourteen utilities were privately owned, all located in California. The utilities in this database are biased by data availability, so while the results are not a statistically rigorous representation, they provide some insight into the relative scale and potential effectiveness of CAPs for affordability. This analysis also only included the discount of bills and did not take into consideration CAP features such as debt forgiveness or emergency relief, both of which can help make water affordable.

> **In general, as water usage increased, the effect of customer assistance programs to reduce the financial burden decreased.**

### Analytical Approach

The monthly household bill for drinking water and wastewater services was estimated for the original and discounted (CAP) rates at each thousand gallons of water used from 0 to 16,000 gallons per month (gal/mo). Most utilities bill customers using a combination of fixed charges (same charge regardless of water use) and usage charges (charge varies with water usage).

Three affordability metrics were calculated for the original and CAP-discounted bills to estimate how affordability would change within a particular community (Table 1).

- Household burden: measures the financial burden of a representative income of the community by assessing the portion of income spent on water services for the community's lowest quintile income (LQI)—the 20th percentile of household income in the utility service area (Raucher et al. 2019).
- Minimum-wage hours: measures the financial burden for a single minimum-wage earner based on number of hours worked at minimum wage needed to pay for water services (Teodoro 2018). Texas adopted the federal minimum wage of $7.25, set in 2009, while California had a higher minimum wage of $12.00, set in 2019. Local governments in California may provide for a higher minimum wage that is not captured here and may change the results of this metric.
- Income dedicated to water service (IDWS): estimates the percent of households experiencing a similar financial burden when paying for water services (Patterson & Doyle 2021). For example, what portion of households spend more than 5% of their income on water services? A detailed description of how to calculate the IDWS is provided in Patterson and Doyle (2021).

The difference in affordability metrics between the original and CAP-discounted bills was calculated for all three metrics at different volumes of water usage. For the IDWS metric, we applied the CAP-discounted

**Metrics Considered in This Study**

| Metric | Description | Formula |
|---|---|---|
| Household burden | Percent of 20th-percentile household income paying for water services | $\frac{\text{Annual HH Bill (\$)}}{\text{Lowest Quintile HH Income (\$)}}$ |
| Minimum-wage hours | Number of hours worked at minimum wage paying for water services | $\frac{\text{HH Bill (\$)}}{\text{Minumum Wage}\left(\frac{\$}{hr}\right)}$ |
| Income dedicated to water services | Percent of households in a utility spending x% of income on water services | $\frac{\Sigma\left(\text{HH With Income} < \frac{\text{HH Bill (\$)}}{\text{Percent Income to Water}}\right)}{\text{Total HH}}$ |

HH—household

**Table 1**

## Customers Targeted by CAPs in Each State and by Water Service

| Service | State | *N* | Lifeline | Low-Income | Multiple Criteria | None | Senior | Total CAPs |
|---|---|---|---|---|---|---|---|---|
| Drinking water | California | 39 | 1 | 30 | 2 | 5 | 1 | 34 |
| | Texas | 20 | 3 | 3 | 0 | 2 | 12 | 18 |
| Wastewater | California | 39 | 2 | 11 | 4 | 18 | 4 | 21 |
| | Texas | 20 | 0 | 3 | 0 | 7 | 10 | 13 |

CAP—customer assistance program

"Multiple criteria" means the utility required customers to be low-income and seniors or low-income and disabled, for example.

**Table 2**

bill to all households below the 20th quintile (LQI), with the assumption that all low-income households receive customer assistance, representing the maximum potential discount benefit of the CAP. An important limitation of this analysis is that this approach looks only at rate subsidies and does not account for components of CAPs that might forgive debt or provide additional emergency relief.

## Findings

### Eligible Populations for CAPs

Of the 59 utilities in this study, 39 were located in California and 20 were located in Texas. In California, 34 utilities (87%) provided a CAP for drinking water, 21 utilities (54%) provided a CAP for wastewater, and 16 utilities (41%) provided a CAP for both services. In Texas, 18 utilities (90%) provided a CAP for drinking water, 13 (65%) provided a CAP for wastewater, and 11 utilities (58%) provided a CAP for both services (Table 2).

> **Households and utilities would benefit from their investment in CAPs if they can ensure water efficiency in CAP-eligible households.**

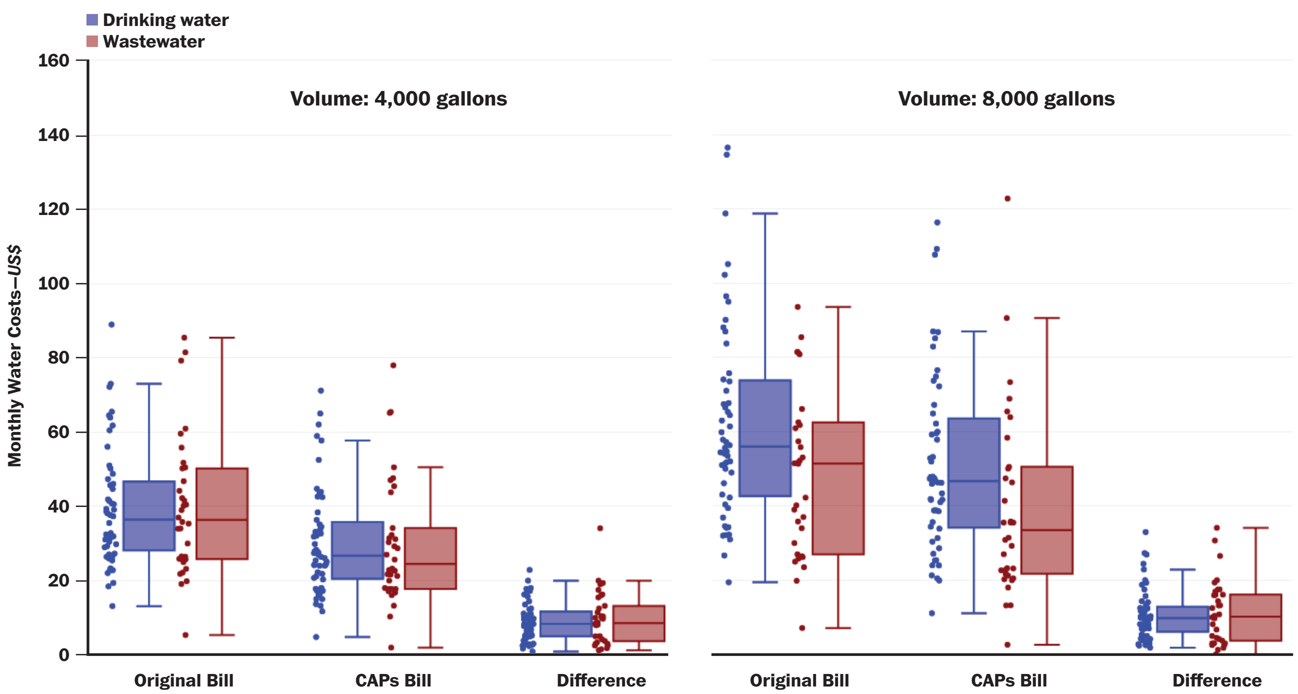
California utilities in this study were more likely to provide CAPs that targeted low-income customers (88% of drinking water utilities and 54% of wastewater utilities). In contrast, Texas utilities were more likely to provide CAPs that targeted seniors (67% of drinking water and 77% of wastewater utilities).

### CAP Relief and Changes in Water Usage

The change in bills for individual water services (drinking water and wastewater) was estimated at 4,000 gal/mo (~50 gpd/person in a household with 2.65 people, as suggested by Raucher et al. [2019]) and 8,000 gal/mo (assumes 100 gpd/person). At 4,000 gal/mo, the median bill for drinking water and wastewater services was $36, with a median CAP-discounted bill of $27 for drinking water and $25 for wastewater. The median discount within a utility reduced the bill by $8.50—a 23% reduction in the monthly bill (Figure 2). As water use increased, drinking water bills generally increased faster than wastewater bills. At 8,000 gal/mo, the median drinking water bill increased to $56 and wastewater to $51; CAP discounts reduced bills by $10 per month for each respective service (18% savings for drinking water and 20% for wastewater).

Almost half of the utilities in this study provided CAPs for both drinking water and wastewater services, meaning the total bill may represent a CAP discount for a single service or for both drinking water and wastewater services. The median total bill (combined drinking water and wastewater) was $71 at 4,000 gal/mo, with a CAP-discounted bill of $60—meaning households typically paid 85% of the original bill. The percent savings a household experienced from CAPs decreased as water use increased, because most CAPs discounted only the fixed charge and not the usage charge. As water usage increased, the relative discount decreased

### Comparison of Monthly Bills[a] at 4,000 and 8,000 Gallons




CAP—customer assistance program

[a]For drinking water and wastewater services

**Figure 2**

so that 16,000-gal/mo households were paying 90% of the original bill (Figure 3).

### CAP Variability

In California, most utilities in this study had CAPs designed to assist low-income households by primarily reducing the fixed charge. Most CAP discounts reduced the fixed charge for drinking water to between 40% and 79% of the original bill; wastewater CAP discounts reduced the fixed charge to between 65% and 83% of the original bill. Few wastewater systems had a discount on the usage charge (i.e., volumetric charge). Water services with usage charges tended to result in only 1%–2% savings from the original bill, even at higher volumes (Figure 4).

In contrast, Texas utilities in this study prioritized CAPs for senior citizens. Interestingly, the design for these CAPs placed a greater emphasis on reducing the usage component. CAP discounts reduced the fixed component of the bill to between 66% and 87% of the original bill. At 8,000 gal/mo, approximately half of utilities did not have a discount on usage, but the remaining half reduced the usage component of the bill to between 80% and 90% of the original usage charge for drinking water. Despite these differences, the overall reduction in CAPs at 8,000 gal/mo was similar for low-income CAPs in California and senior CAPs in Texas (13% to 20% reduction in the original bill) (Figure 4).

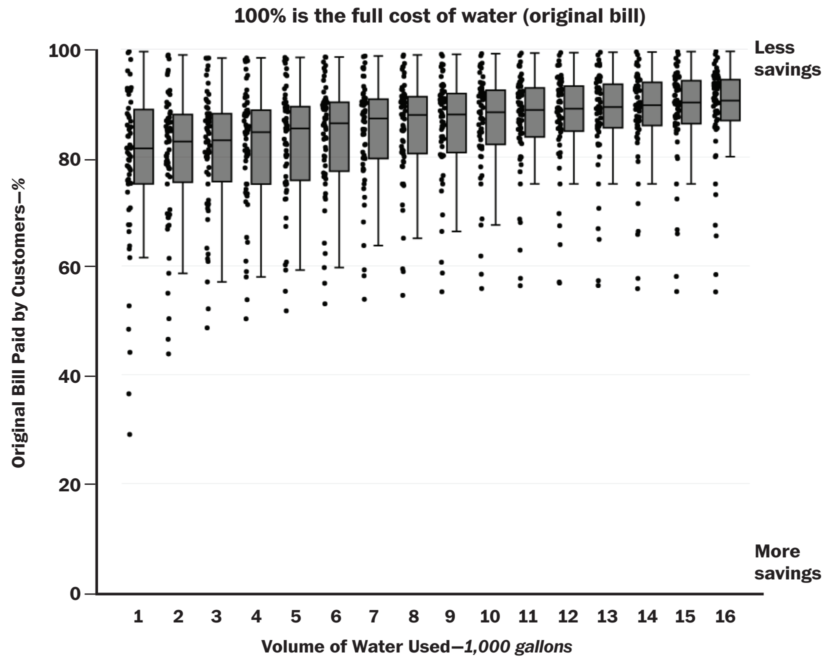
> **In our study, CAPs provided much needed assistance but had minimal impact on making water affordable for households in deep poverty or for households using higher amounts of water.**

### Financial Burdens

In the absence of CAPs, low-income households (i.e., those in the LQI) in the median utility spent 1.6% of their income on water services at 4,000 gal/mo. When participating in CAPs, these households spent only 1.2% of their income on water services (Figure 5). At 8,000 gal/mo, low-income households spent 2.2% of their income on water services, with CAP discounts reducing the financial burden to 1.7%. In general, as water usage increased, the effect of CAPs to reduce the financial burden decreased.

A similar effect existed when measuring affordability on the basis of minimum-wage hours. CAPs reduced the number of hours minimum-wage earners had to work by a median of 1.1 hours for low volumes of water usage to 1.6 hours at higher volumes of water usage per month (Figure 5, part B). A minimum-wage earner without CAPs would spend 7.3 hours of labor to pay for water services at 4,000 gal/mo; CAPs reduced the time spent working to pay for services to 5.6 hours. Three utilities had large savings for minimum-wage earners as volumes increased beyond 4,000 gal/mo. These utilities all had discounts on volumetric water usage for both drinking water and wastewater services, and they eliminated surcharges for CAP customers.

**Percent of Original Bill[a] Paid by Customers Enrolled in CAPs**




CAP—customer assistance program

[a]For drinking water and wastewater services

Figure 3

### Breadth of Affordability Challenges

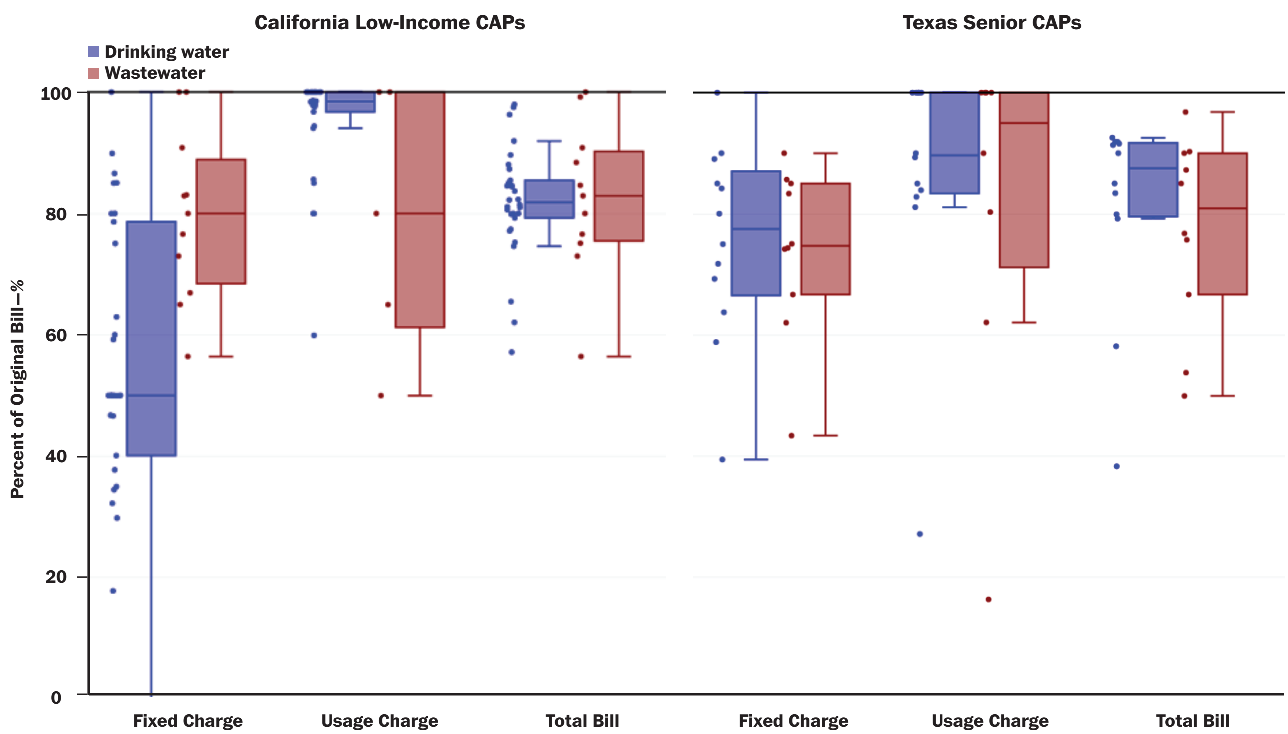
The IDWS metric provides perspective on the breadth of affordability challenges. The IDWS was applied to households earning less than the LQI. Since the income needed to pay less than 2% far exceeds the LQI, we do not see a change in the breadth of affordability challenges until a household spends 3% or more of its income on water services. The percent of households spending more than 5% of their income on water services (roughly a day of labor) decreased from 14.1% of households to 9.7% of households at 4,000 gal/mo (assuming all eligible households use CAPs). At 8,000 gal/mo, households spending 5% or more of their income decreased from 16% of households to 13% (Figure 6).

The benefit of CAPs reducing the breadth of affordability challenges decreases as the financial burden increases. This suggests that CAPs have a greater effect when household incomes are near the LQI and bills are lower. The average $11 CAP discount has a greater effect on affordability metrics for households at or near the LQI because it is sufficient to reduce the amount they were paying from 5.1% of their income to 4.9% (for example). However, while households with a low income benefit from saving $11, they would still contribute more than 5% of their income to pay for water services. As volumes increased, such as from 4,000 to 8,000 gal/mo, CAP discounts tended to increase more slowly. In short, most CAPs truly provide assistance, but may not be sufficient to make water affordable for those in deep poverty or using higher amounts of water.

## Summary of Key Findings

After studying the influence of CAPs on affordability metrics used when setting rates or establishing policies (EPA 1997), we came away with four key findings. First, the

## Change in Original Bill[a] for California Low-Income CAPs and Texas Senior CAPs




CAP—customer assistance program

[a]Based on billed components at 8,000 gal/mo

**Figure 4**

volume of water used to assess affordability is important. CAPs had less impact at higher usage levels because most CAPs discount only the fixed charge or provide small discounts on usage charges. This means low-volume water users received the most benefit, with the range of bill reductions averaging from $10 (low volumes) to $15 (high volumes). The discount is similar to the average savings found in Vedachalam and Dobkin (2021), of $10.76 across 15 utilities. However, their study only explored drinking water bills at large utilities, and they found discounts reduced the original bill by 33%. We found more modest reductions, ranging from an average of 10% (16,000 gal/mo) to 18% (no usage) when looking only at drinking water utility CAPs in our study. CAPs discounting the fixed portion of the bill make the discount easy to implement, and they send a conservation signal; however, homes with leaks or that do not have water-efficient fixtures will continue to have high bills. Thus, households and utilities would benefit from their investment in CAPs if they can ensure water efficiency in CAP-eligible households.

> **CAPs discount only the fixed charge or provide small discounts on usage charges.**

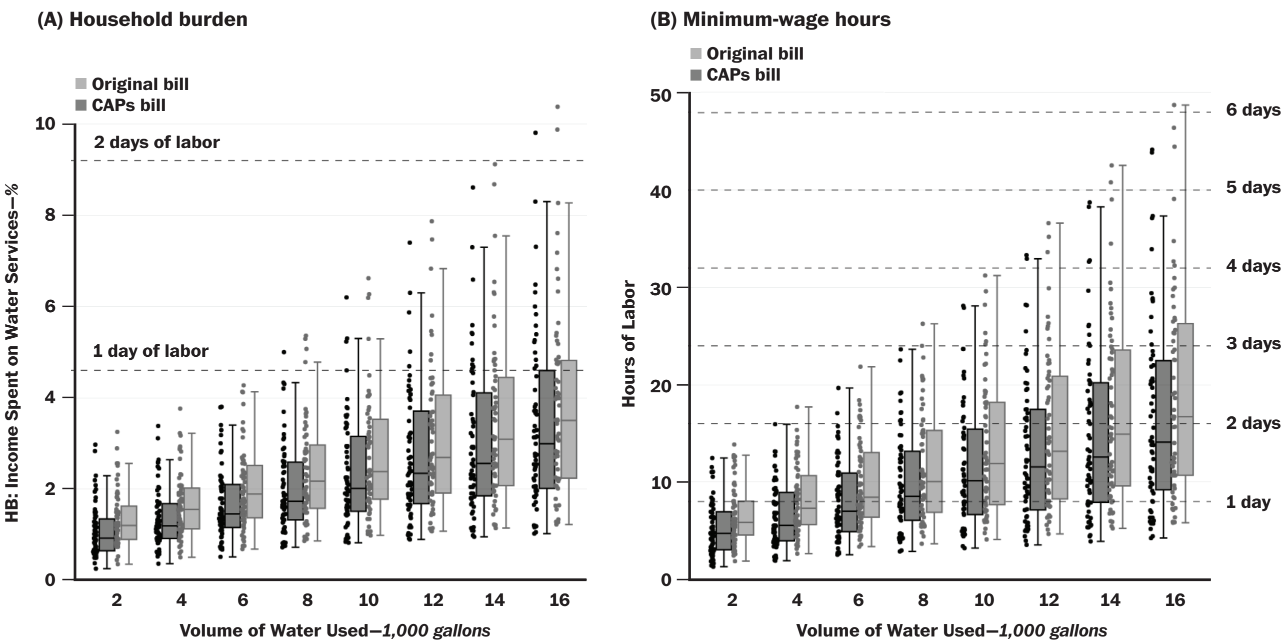
Second, the affordability metric selected is important. CAP discounts will show a larger effect on the minimum-wage-hours metric than the household burden (low-income) metric because any discount will have a relatively higher impact on lower incomes. For example, a $10 discount represents 1.4 hours of labor for someone earning a minimum wage of $7.25. Low-income households tend to earn more than a family with a single minimum-wage earner, saving almost half an hour of labor each month.

Third, CAPs reduced the prevalence of households spending more than a day of labor each month by 3%–4%, with higher volumes of water usage experiencing a smaller reduction. While saving $10–$15 a month is helpful, it might not be sufficient to make water services truly affordable for many households (depending on how a community defines affordability). CAPs are designed to provide assistance, but that assistance should be extended to ensure water is truly affordable.

Lastly, the CAPs in our study were focused on different populations; in California, eligibility tended to be based on income, while in Texas eligibility tended to be based on age. It is unclear how much of this difference was a result of our sample or if there are broad distinctions between states regarding the target population for CAPs. In California, privately owned systems regulated by the Public Utility Commission offer low-income rate assistance programs (Onda & Tewari 2021). The clear regulations allowing for low-income rate assistance are likely a significant driver for CAPs in privately owned systems in California. Establishing eligibility criteria has important implications for who is and isn't eligible to receive assistance. Many utilities specify homeownership as a requirement (excluding renters who may have difficulty paying for water services) or income limits that leave some households burdened but unable to receive assistance. While our study was limited in its ability to assess eligibility, other studies, such as Vedachalam and Dobkin (2021) have explored eligibility requirements.

**While saving $10–$15 a month is helpful, it might not be sufficient to make water services truly affordable for many households.**

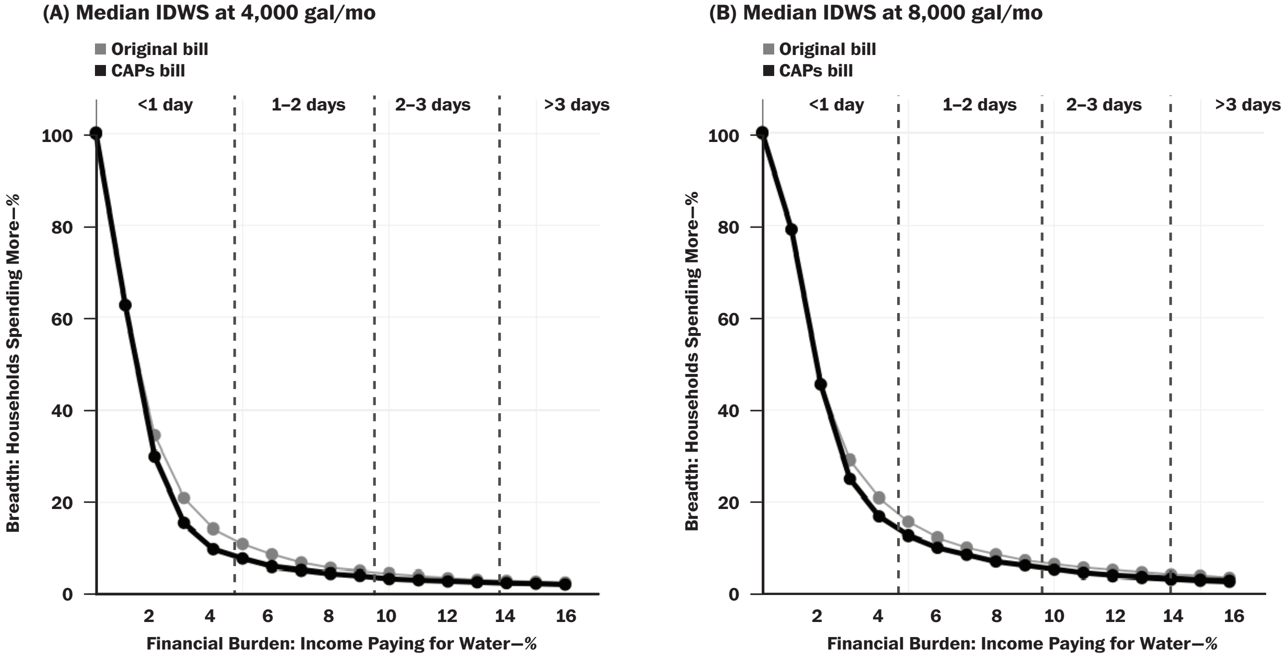
**Change in Household Burden (A) and Minimum-Wage Hours (B) for Original Bills and CAPs**




CAP—customer assistance program, HB—household burden

**Figure 5**

**Low-Income Customers' Median IDWS for Original or Discounted/CAPs Bill at 4,000 (A) and 8,000 gal/mo (B)**




CAP—customer assistance program, IDWS—income dedicated to water service

**Figure 6**

## Policy Implications

CAPs are one of many proposed approaches to address the affordability gap (Pierce et al. 2021). Some approaches focus on reducing utility costs through improved water efficiency, utility consolidation, and innovative financing. Other approaches focus on subsidizing the costs borne by households that cannot afford to pay for water services through rate structures, crisis relief, and CAPs. However, few studies empirically demonstrate the effectiveness of these approaches through an affordability lens that looks at how many utilities are participating, how many eligible households participate, and how water is made more affordable for customers in need.

Studies that have access to utility data to assess the effectiveness of CAPs to protect against shutoffs and nonpayments are also needed (Pierce et al. 2021). Other studies have prioritized understanding how many utilities participate in CAPs (EPA 2016), or have made policy recommendations around how to design CAPs to be more successful (Vedachalam & Dobkin 2021). In our study, CAPs provided much-needed assistance but had minimal impact on making water affordable for households in deep poverty or for households using higher amounts of water. The relative effectiveness of CAPs to make water affordable has been recognized by several utilities; Philadelphia Water Department, for example, created a CAP program that provides assistance relative

> **Understanding drivers and approaches and how they interact will allow decision makers to assess which approaches might be most appropriate to address the underlying causes creating affordability challenges.**

to a customer's income level to ensure their water bill is affordable (Mack et al. 2020). Linking the amount of assistance to income levels can help ensure the outcome of CAPs extends from assistance to affordability (Leonard et al. 2020).

The newly created federal Low-Income Household Water Assistance Program (LIHWAP) is intended to provide funds to help low-income households pay for water services. The design and deployment of this program will require many utilities to develop systems similar to CAPs to assess eligibility and distribute funds. Local and state governments need to continue evaluating the success and shortcomings of different CAP approaches to test and adapt designs most appropriate to the different conditions of communities (Vedachalam & Dobkin 2021, Mack et al. 2020, UNC Environmental Finance Center 2017).

CAPs provide one approach to address affordability challenges. Additional research is needed to understand how proposed approaches (Pierce et al. 2021) affect household affordability and when different approaches are most effective. For example, CAPs that prioritize discounting fixed charges might best serve customers when coupled with a water efficiency program that provides customer education, repairs leaks, and installs water-efficient fixtures for high-water-usage, low-income households. A combination of approaches may be far more effective than a single approach. Understanding drivers and approaches and how they interact will allow decision makers to assess which approaches might be most appropriate to address the underlying causes creating affordability challenges.

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## AWWA Resources

- **A Snapshot of Water and Sewer Affordability in the United States, 2019. Teodoro MP, Saywitz RR. 2020. *Journal AWWA.* 112:8:10. https://doi.org/10.1002/awwa.1551**
- **Cost Recovery and Affordability in Small Drinking Water Treatment Plants in Alberta, Canada. Janzen A, Achari G, Dore MHI, et al. 2016. *Journal AWWA.* 108:5:E290. https://doi.org/10.5942/jawwa.2016.108.0047**
- **Consider Water and Sewer Rate Affordability. Qureshi N, Hanson R. 2019. *Opflow.* 45:3:10. https://doi.org/10.1002/opfl.1156**

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# Using Sanitary Survey Findings to Identify Risk Management Challenges

Austin Heinrich, Deborah Vacs Renwick, Richard J. Weisman, Ashley Greene, Stig Regli, Kevin Roland, and Kenneth Rotert

Key Takeaways

Sanitary survey data can be broadly evaluated to understand the most prevalent issues occurring within public water systems.

The most commonly identified deficiencies are associated with monitoring and reporting, finished water storage, and treatment.

Reviewing sanitary survey findings and common deficiencies may help officials proactively determine water system infrastructure issues and utility training needs.

*Layout imagery by APChanel/Shutterstock.com*

Sanitary surveys are conducted at all public water systems (PWSs) in the United States to assess their capability to supply safe drinking water. These surveys are used to identify risks or deficiencies within water system infrastructure, operations, and management and are an important tool for primacy agencies to oversee and assist PWSs in complying with the Safe Drinking Water Act (SDWA). States or other agencies with primacy—i.e., the authority to implement and enforce US Environmental Protection Agency (EPA) regulations—are responsible for completing sanitary surveys and reporting information collected to EPA.

In this study, we reviewed information collected by primacy agencies during sanitary surveys to identify the most frequent deficiencies found at PWSs in the United States. Analysis of deficiencies found during sanitary surveys helps to characterize the potential challenges faced by water systems in providing safe drinking water and helps systems and regulatory authorities prioritize risk management efforts and provide technical assistance.

Deficiencies were identified using sanitary survey data reported to EPA's Safe Drinking Water Information System (SDWIS, federal version; EPA 2017a). Within SDWIS, records were extracted from 48 states and the District of Columbia for sanitary surveys conducted at surface water systems, including systems with ground water under direct influence of surface water (GWUDI) from Jan. 1, 2010, to Dec. 31, 2017. Our analyses indicate that the most prevalent sanitary survey deficiencies reported to SDWIS were found in the areas of monitoring and reporting, finished water storage, and treatment. These results will help primacy agencies and PWSs to better evaluate water system infrastructure and utility training needs.

## Sanitary Survey Components and Requirements

In the United States, sanitary surveys are required under the 1998 Interim Enhanced Surface Water Treatment Rule (IESWTR) (EPA 1998) and the 2006 Ground Water Rule (GWR) (EPA 2006a) for surface water systems (including GWUDI systems) and ground water systems, respectively. They must be conducted at least once every three years for community and once every five years for non-community PWSs (40 CFR § 142.16, *Special Primacy Requirements*), but requirements for community water systems can be reduced to every five years if they meet specified performance criteria.

Sanitary surveys are used in conjunction with other regulatory and nonregulatory approaches to accomplish the following:

- Identify potential issues that may result in public health risks
- Enhance communication between the water system and regulator
- Help PWSs maintain regulatory compliance

Under the IESWTR and GWR, complete sanitary surveys comprise eight water system areas, which are referred to as "elements":

- Source
- Treatment
- Distribution System
- Finished Water Storage
- Pumps
- Monitoring and Reporting
- Operator Compliance
- Management and Operation

Primacy agencies have flexibility in developing and implementing their sanitary survey programs, and differences between programs can include the following:

- Required training and personnel for conducting the surveys (e.g., primacy agency or primacy agency–appointed)
- The content and format of inspection forms and reports, deficiency definitions
- Priority areas within the eight elements

Further, primacy agencies may choose to conduct sanitary surveys more frequently than the minimum requirements. They may also conduct sanitary surveys using a phased approach, evaluating specific elements over multiple on-site visits (40 CFR § 142.16 (3)(iii)). In recent years, some components of the sanitary survey have been done virtually.

### Significant and Minor Deficiencies

Deficiencies identified under the eight water system elements are commonly reported as either significant or minor. Significant deficiencies are defined as "serious sanitary deficiencies identified in water systems which include, but are not limited to, defects in design,

> **Analysis of deficiencies found during sanitary surveys helps to characterize the potential challenges faced by water systems in providing safe drinking water and helps systems and regulatory authorities prioritize risk management efforts and provide technical assistance.**

operation, maintenance, or a failure or malfunction of the sources, treatment, storage, or distribution system that the primacy agency determines to be causing, or has potential to cause, the introduction of contamination into the water delivered to consumers" (EPA 2019). Examples of significant deficiencies include cross connections, cracks in the walls of storage tanks, and ongoing, unaddressed violations (EPA 2019). Examples of minor deficiencies include failure to update water distribution maps or upgrade treatment equipment (EPA 2008). Minor deficiencies may be used to characterize issues that do not directly affect public health, although there may be longer-term public health implications in some cases if they are not corrected.

The primacy agency determines deficiencies and corresponding corrective actions. Under the GWR, primacy agencies are required to define at least one significant deficiency for each of the eight elements of a sanitary survey. For systems using surface water or GWUDI (referred to as "subpart H" systems, per CFR § 141.70, Subpart H—*Filtration and Disinfection*), the primacy agency must describe how it will decide whether a deficiency identified during a sanitary survey is significant (40 CFR § 142.16(b)(1)(ii)). As such, similar or identical deficiencies could be designated as either significant or minor depending on primacy agency implementation and other factors. For example, one state's online procedures for conducting sanitary surveys noted that some deficiencies could be either significant or minor, depending on the circumstances. Additionally, surveyors can make recommendations on improvements to water system components and operations that are not directly associated with deficiencies.

### Additional Benefits of Sanitary Surveys

Sanitary surveys have benefits beyond finding and fixing deficiencies. For example, sanitary surveys have been recognized as tools for building capacity development (Shanaghan et al. 1998), which improves a system's ability to deliver high-quality water by ensuring it has adequate technical, managerial, and financial capacity. Rayburn et al. (2011) referred to sanitary survey relevance for addressing distribution system issues as part of a broader effort to identify priorities for distribution system research and information collection. Blanchard and Eberle (2013) described the use of sanitary surveys in Washington State as a tool for reducing emergency requests.

### Study Purpose

In this study, we evaluated sanitary survey data reported to SDWIS by states, the District of Columbia, tribes, and US-governed territories, with the objective of identifying the elements associated with the most frequent deficiencies and recommendations. SDWIS was queried for completed sanitary surveys, with visit dates ranging from Jan. 1, 2010, to Dec. 31, 2017. This date range was chosen to account for the effects of the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) and the Stage 2 Disinfectants and Disinfection Byproducts Rule (DBPR), both of which first became effective in 2009.

Analysis was limited to records from subpart H systems reported in 48 states and the District of Columbia. Two additional primacy agencies did not report any deficiencies and/or recommendations and were excluded. Records from inactive systems were also excluded. The resulting data set contains nearly 49,000 records from 14,550 PWSs (11,448 community and 3,102 non-community), serving more than 214 million people.

**Minor deficiencies may be used to characterize issues that do not directly affect public health, although there may be longer-term public health implications in some cases if they are not corrected.**

## Sanitary Survey Data and Methods

SDWIS offers the most comprehensive data available on sanitary surveys on a national scale. The information is stored in tables with a record (row) for each sanitary survey, with columns containing water system identifiers (e.g., water system ID, name, state), survey dates, findings arranged by survey element, and a comment field. Each record contains survey findings in separate fields for each survey element, and more than 95% of the fields are populated.

Although there are only eight comprehensive elements per EPA requirements and accompanying guidance (EPA 2019, 2008, 1999), SDWIS uses 11 fields to describe the eight sanitary survey elements. Figure 1 presents a crosswalk of the eight sanitary survey elements ("eight elements") and the 11 corresponding fields in SDWIS ("SDWIS elements"). Moreover, the monitoring and reporting element corresponds to "data verification" in SDWIS. For the purposes of this analysis, the additional fields of security, financial, and other evaluations were evaluated as subcategories within the management and operations sanitary survey element.

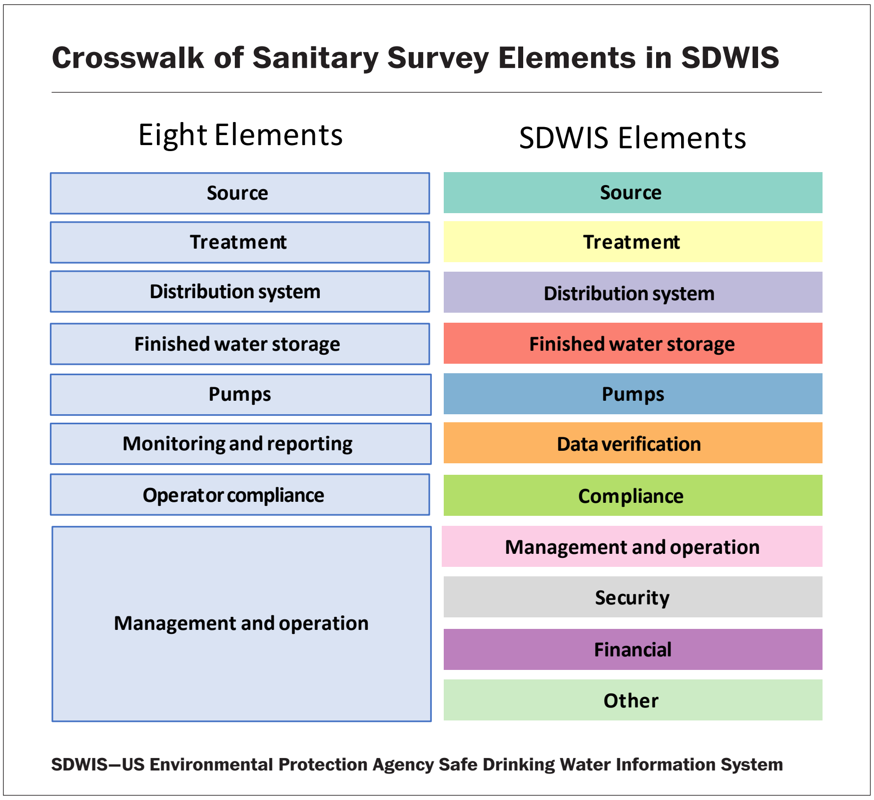



**Figure 1**

There are several survey finding options allowed in SDWIS under each of the 11 element fields: significant deficiencies, minor deficiencies, recommendations, not evaluated, not applicable, and an option to leave the element field blank.

### Data Set Representativeness

The number of sanitary surveys extracted from SDWIS available after data filtering was compared with the system inventory available in SDWIS for the fourth quarter of 2017 for the same 48 states and the District of Columbia. The 14,550 systems with sanitary surveys in the data set represent approximately 90% (93.7% of community, 78% of non-transient non-community, and 80.4% of transient non-community) of the total SDWIS inventory of active surface water or GWUDI systems (16,105). The number of surveys reported per PWS ranged from one to 79, and on average, states reported more than three sanitary surveys per PWS during the eight-year period.

Some primacy agencies conduct and report their sanitary surveys in phases (e.g., by individual facilities) and/or as part of other assessments. Approximately 25% of systems had at least four surveys conducted during the years reviewed in this analysis. The number of surveys reported may also be influenced by increased frequency requirements set by the primacy agency, or partial reports marked as "complete." Sanitary surveys used to meet requirements under the Revised Total Coliform Rule (RTCR; EPA 2013), or RTCR-related assessments used to partially complete sanitary surveys, may have also contributed to more reports than expected for the years of data for which the RTCR was effective. Additionally, some details from sanitary surveys may not be available within SDWIS, which may add complexity to reporting and factors into representativeness as well.

Primacy agencies using outstanding performer designations may also influence the representativeness of the underlying data set. Primacy agencies may reduce the frequency of conducting sanitary surveys for community water systems designated as outstanding performers to no less than every five years on the basis of prior positive sanitary survey results (40 CFR § 142.16(3)(ii))).

## Analysis and Results

Two data sets were generated for analysis. The first data set was used to evaluate the designations under each of the SDWIS elements (referred to as the "element field" data set). The second data set (derived from the element-field data set) compiled the last two sanitary surveys from each water system conducted in the years 2010–2017 and was used to evaluate the comment field (referred to as the "comment field" data set).

### Element-Field Data Set

The element-field data set contains nearly 49,000 sanitary survey records from 14,550 systems (Table 1). Surveys with significant deficiencies were distributed relatively evenly between community and non-community systems. Surveys with minor deficiencies and those with recommendations were reported more commonly in community than non-community systems. Sanitary surveys with minor deficiencies were the most common in

## Counts of Completed Sanitary Surveys for Subpart H Systems With Deficiencies or Recommendations in SDWIS by System Type, 2010–2017[a]

| System Type | Total Systems *n* | Total Surveys *n* | Total Surveys With Significant Deficiencies *n (%)* | Total Surveys With Minor Deficiencies *n (%)* | Total Surveys With Recommendations Made *n (%)* |
|---|---|---|---|---|---|
| Community | 11,448 | 40,296 | 4,457 (11.1) | 12,103 (30.0) | 10,055 (25.0) |
| Non-transient non-community | 768 | 1,898 | 175 (9.2) | 394 (20.8) | 384 (20.2) |
| Transient non-community | 2,334 | 6,484 | 617 (9.5) | 1,029 (15.9) | 1,037 (16.0) |
| Total | 14,550 | 48,678 | 5,249 (10.8) | 13,526 (27.8) | 11,476 (23.6) |

SDWIS—US Environmental Protection Agency Safe Drinking Water Information System

[a]If a survey contained multiple deficiencies or recommendations, it was counted once when creating the summary table.

**Table 1**

the data set (making up approximately 28% of all surveys), followed by surveys with recommendations (approximately 24%) and surveys with significant deficiencies (approximately 11%).

For all further analysis of the SDWIS data in this study, only those records identified in Table 1 containing deficiencies (significant or minor) and/or recommendations under one or more of the 11 SDWIS elements were included. By considering only the surveys with these designations, sanitary survey assessment areas that are receiving the most deficiencies and recommendations can be identified.

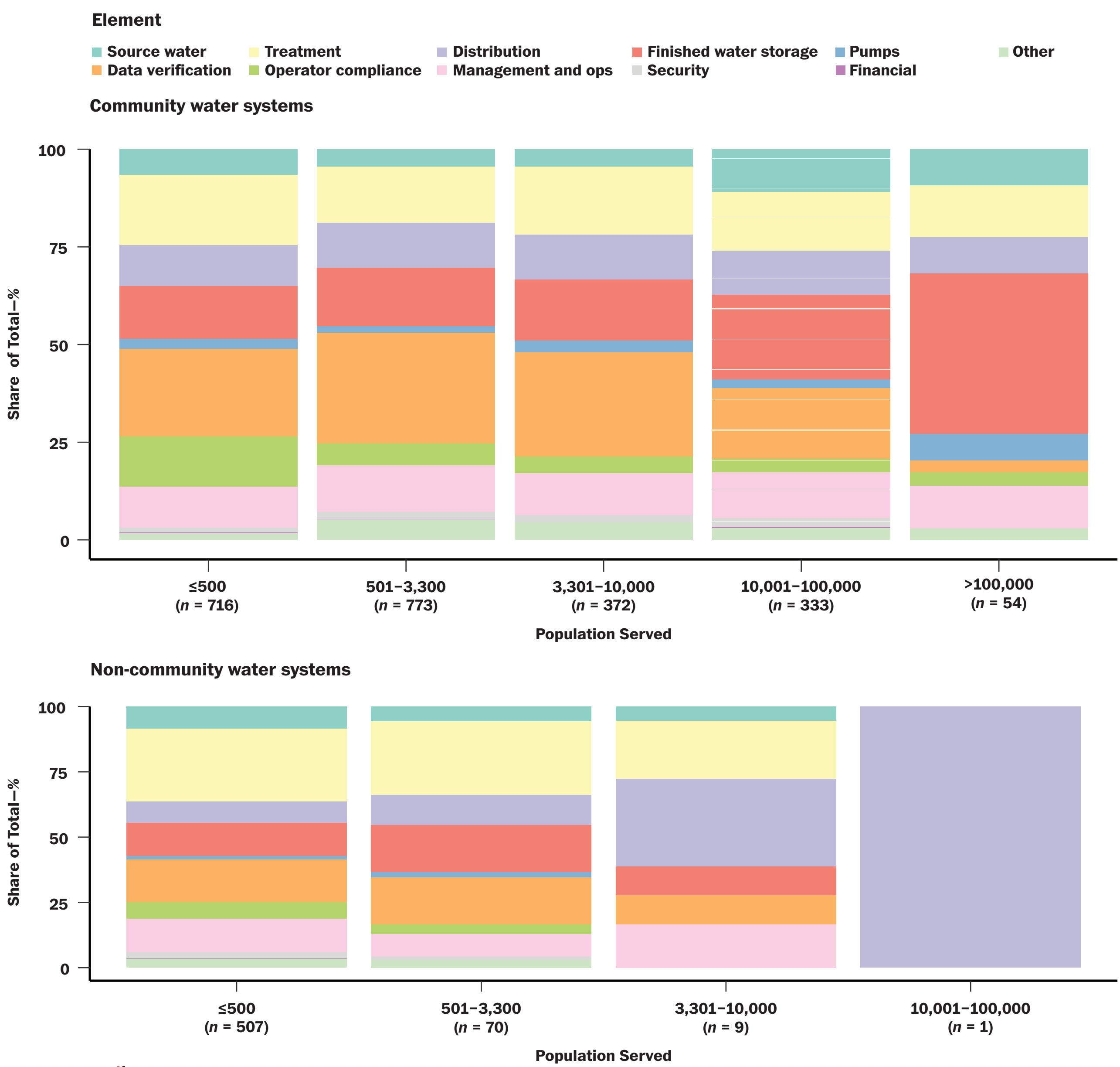
To determine the sanitary survey elements with the most occurrences of significant deficiencies, we compared the percentage of significant deficiencies within the 11 SDWIS element fields and separated results by population-served bins (Figure 2). The number of systems reporting surveys within each population bin is reported on the *x*-axis. Two systems in the data set reported different populations served across their surveys with significant deficiencies, and in those cases, the population served was assigned from the most recent survey provided. For presentation purposes, surveys were labeled from both non-transient and transient non-community water systems as "non-community water systems."

**Among the 5,249 surveys with significant deficiency findings, the most common deficiencies for all water system types pertain to finished water storage, data verification, and treatment.**

Among the 5,249 surveys with significant deficiency findings, the most common deficiencies for all water system types pertain to finished water storage, data verification (i.e., monitoring and reporting "element"), and treatment. The percentage of significant deficiencies associated with finished water storage increased with system size for community water systems. Conversely, the percentage of significant deficiencies associated with data verification decreased with system size. These findings are likely influenced by PWS characteristics. For instance, large systems tend to have more storage facilities relative to small systems, and small systems may lack technical, managerial, and financial capacity, which can affect the data verification element. The proportion of significant deficiencies under the distribution element was similar across population-served bins for community water systems, but the proportion increased with system size for non-community water systems.

A similar review of minor deficiencies and recommendations showed that the percentages (and distribution) of surveys with minor deficiencies and recommendations

## Distributions of Significant Deficiencies[a] by System Type and Size, 2010–2017




ops—operations

[a]Significant deficiencies may have been identified under more than one element. Not all elements in the key had sufficient deficiencies to be visible in this figure (e.g., security, financial).

**Figure 2**

largely paralleled those for significant deficiencies. There was less heterogeniety across elements, and the percentages follow the same trends with respect to system size as significant deficency observations.

### Comment-Field Data Set

The comment-field data set was assembled by reducing the element-field data set to a size that allowed for manual review. Because of the time-intensive nature of manually reviewing records, reviewing the comment field for all sanitary surveys in the data set was infeasible. Therefore, the last two surveys conducted by each subpart H system were manually analyzed, an approach that ensured at least two surveys per system were considered from time periods after the LT2ESWTR (EPA 2006b) and the Stage 2 DBPR (EPA 2006c) became effective. Records with no results in the comment field were removed from further analysis. The resulting comment-field data set contained 1,039 survey comments from 802 systems (615 community, 59 non-transient non-community, and 128 transient non-community) in 34 states. Comments reported in this data set were reviewed independently to determine if they were provided for a significant deficiency, minor deficiency, or recommendation.

A list of categories was developed to encompass a range of topics relevant to sanitary conditions and operational issues—e.g., repeated breaks or insufficient pressure in the distribution system; inadequate follow-up on previous deficiencies (see Table 2). The categories were developed prior to evaluating the comment field using best professional judgment and the available information on sanitary deficiencies within the guidance for subpart H systems (EPA 2019, 1999). Each category represents an issue that might indicate a deficiency or recommendation. These categories were then manually assigned to each comment on the basis of text in the comment field. Comments with text that fell outside the scope of these categories were marked as "uncategorized issues."

The comments contained information relevant to all categories, with some issues being more common than others. Some survey comments represented multiple issues and were assigned more than one category. Table 2 presents summary information on 10 categories that were assigned most frequently to the comments, in descending order.

Next, we looked at records in the comment-field data set to see if that survey had also been marked as having

**Top 10 Most Common Sanitary Survey Deficiency Categories[a] for Subpart H Systems**

| Deficiency Category Description | SDWIS Element | Surveys With Category Assignment *n (% of all surveys)*[b] |
|---|---|---|
| Unprotected existing or potential cross-connections | Other | 280 (26.9) |
| Failure to monitor according to system's monitoring plan(s) or established procedures | Data verification | 238 (22.9) |
| Breakdown of treatment equipment or lack of redundancy | Treatment | 167 (16.1) |
| System storage is incorrectly sized or has design issues | Finished water storage | 136 (13.1) |
| Out-of-date emergency response plan | Security | 123 (11.8) |
| Uncategorized issues | NA | 111 (10.7) |
| Inadequate source water intake construction/condition | Source water | 110 (10.6) |
| No storage tank cleaning, inspection, and maintenance program | Finished water storage | 107 (10.3) |
| System components are not securely protected, and/or security alarms are not functional | Security | 99 (9.5) |
| Designated operator is not certified at the grade required | Operator compliance | 70 (6.7) |

NA—not applicable, SDWIS—US Environmental Protection Agency Safe Drinking Water Information System

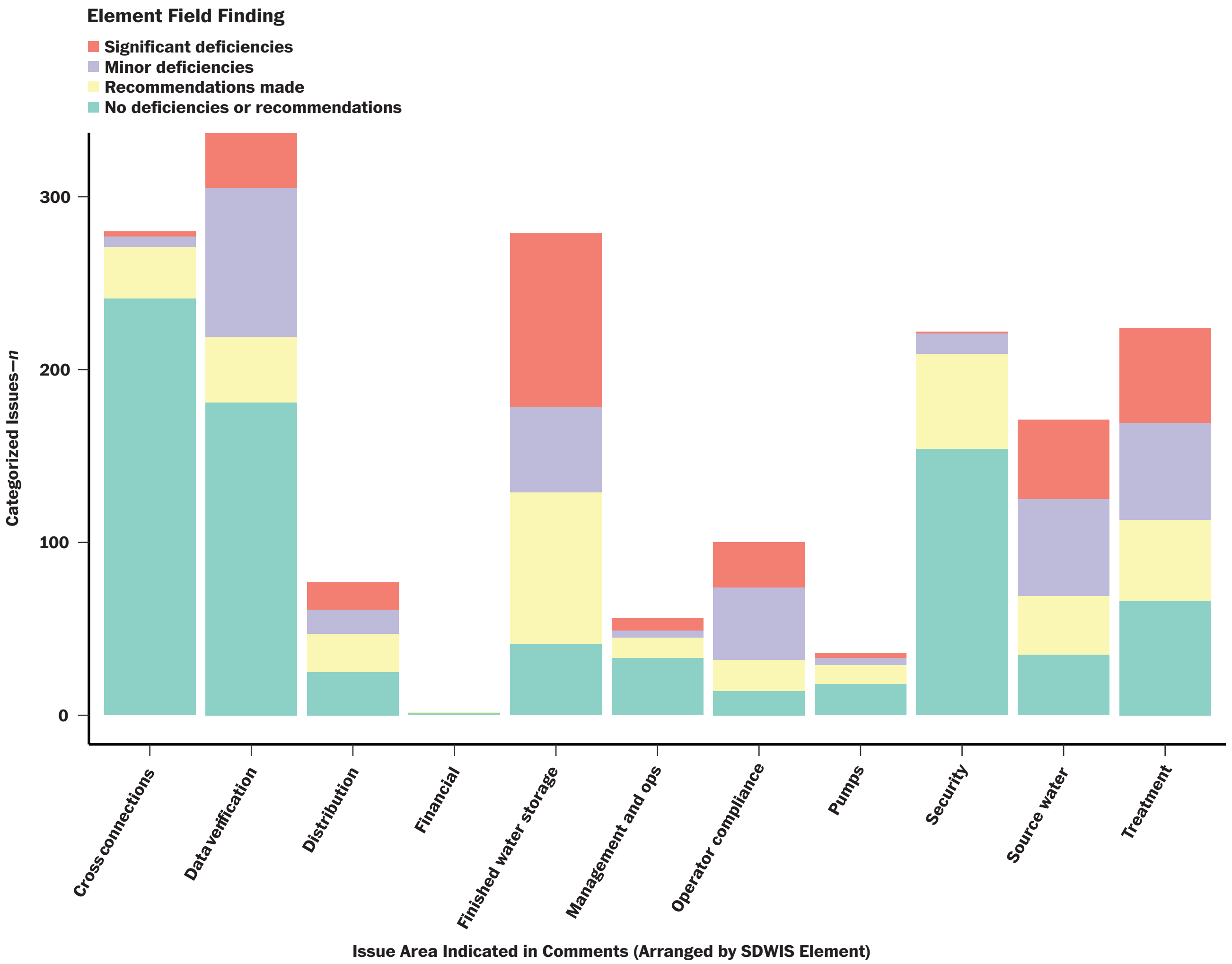
[a]Categories were assigned on the basis of comment field.

[b]Percentages are derived by taking the number of survey comments containing information on the categories (third column) and dividing by the total number of survey comments evaluated (1,039). As some surveys contain comments relating to more than one category, the percentages may add up to more than 100%.

**Table 2**

deficiencies or recommendations. After counting how many times each category appeared in the comments, the counts were aggregated on the basis of the 11 SDWIS elements assigned to the categories. Only the category on cross-connections was developed under the "other" SDWIS element, which is labeled as "cross-connections" for presentation purposes. Figure 3 shows how often categories in each element area were mentioned in the survey comments (represented by the count on the *y*-axis). When a category was assigned to a comment, the record was examined to see if that survey had also been marked as having deficiencies or recommendations in the category's respective SDWIS element field (see legend). For example, more than 200 issues related to

**Number of Categorized Issues[a] Arranged by SDWIS Element, Layered With Element Field Finding**




ops—operations, SDWIS—US Environmental Protection Agency Safe Drinking Water Information System

[a]Categorized issues were assigned on the basis of comment field.

**Figure 3**

security are described in the comment field, but most of those surveys do not have deficiencies or recommendations made in the "security" element field.

For the comment-field analysis, the most prevalent comments were related to data verification, cross-connections, and finished water storage. Compared with the element-field analysis, a larger proportion of comments contained information related to security and cross-connections. Finished water storage, data verification, source water, and treatment had the greatest number of deficiencies (in the element field), with corresponding issues indicated in comments.

When issues were identified in the comments, there were not always designations in the element field indicating a need for improvement in that area. These differences are represented by the teal coloring in Figure 3, where no deficiencies or recommendations are reported in the element field. For example, comments related to cross-connections were found in both treatment and distribution areas; however, the only category on cross-connections was placed under the "other" SDWIS element. Some surveyors identifying cross-connection issues in the comment field may have also indicated those deficiencies in the treatment and distribution system element fields.

## Additional Considerations

In this analysis, we found that useful information was provided in both the SDWIS element fields and comment fields, and that taken together, these two information sources provided a more comprehensive understanding of common deficiencies. Reviewing surveys with deficiencies and recommendations provided valuable insight on specific water system and operational issues and is also meaningful when used at the primacy agency level. For example, Oxenford and Williams (2014) evaluated sanitary survey data in SDWIS for Colorado community water systems, and distribution system and treatment-related deficiencies were the top two failures requiring corrective actions.

Our analysis of the SDWIS element-field data set indicated that most significant deficiencies pertain to the elements of finished water storage, data verification, and treatment. After reviewing the comment-field data set, most of the issues described in comments were found to be associated with data verification, cross-connections, finished water storage, security, treatment, and source water. Some issues in the comments were not designated with deficiencies or recommendations in the respective element field; this dissimilarity may be due to differences in primacy agency or individual surveyor reporting practices.

### Program Implementation Considerations

Considering the representativeness of the SDWIS data set, it is reasonable to conclude that this analysis reveals broad-issue areas in water systems. However, it's important to recognize that the findings could be influenced by differences in PWS characteristics and sanitary survey programs across primacy agencies. Variation across primacy agency information on significant deficiencies was apparent in online searches; for example, a comparison of significant deficiency lists for finished water storage on two state websites showed that leaks were considered significant deficiencies in one state but not explicitly by the other. Surveyors also choose different words to describe similar deficiencies. These differences add uncertainty when comparing deficiencies and recommendations across programs. In addition, the time period of data considered for this evaluation (i.e., 2010–2017) does not reflect recent challenges experienced by PWSs such as with extreme weather and cybersecurity attacks.

> **Our analysis of the SDWIS element-field data set indicated that most significant deficiencies pertain to the elements of finished water storage, data verification, and treatment.**

As discussed, primacy agencies have flexibility in developing, implementing, and administering their sanitary survey programs, which influences the SDWIS data available for analysis. The use of electronic tools for conducting sanitary surveys, such as tablets and cell phones, is changing how surveys are being conducted and reported, potentially allowing for quicker and streamlined reporting. Furthermore, drone technology is being used during sanitary surveys to collect real-time images and video of storage facility rooftops and other remote locations that are otherwise difficult to access and inspect (AT&T 2019).

Some primacy agencies use applications on desktops or mobile devices to complete sanitary survey reports, whereas others are paper based. In addition to improving efficiency, electronic tools may improve communication between PWSs and states, which may have positive outcomes for public health protection and allow for quicker identification, response, and correction to any possible issues.

## Proactive Protection of Public Health

In the United States, sanitary surveys are an important tool used by primacy agencies and water systems to proactively protect public health. Broadly evaluating sanitary survey findings and common deficiencies may also help primacy agencies assess and prioritize water system infrastructure issues and utility training needs. For example, some sanitary survey elements identified as areas of concern in this study, such as treatment or finished water storage, also make up a large amount of water system infrastructure funding needs nationwide (EPA 2018).

Primacy agencies that choose to conduct more detailed evaluations of deficiencies found in water systems under their authority may benefit from the methods introduced in this study. Similar analyses at the state and/or utility level may be helpful in improving operations and maintenance practices and identifying and prioritizing capital projects to better manage sanitary risks. These analyses are relevant when looking across states (as was done in this analysis) and could be helpful for states looking within their programs or at specific types and sizes of systems, for example, focusing on smaller community or non-community water systems for certain types of deficiencies.

Within a framework of sanitary survey rule requirements, such as addressing the eight elements or responding to significant deficiencies, primacy agencies are given latitude in how they can conduct the surveys and assign deficiencies. Furthermore, significant deficiencies that go uncorrected may result in drinking water rule violations and adverse public health consequences. An in-depth analysis of these deficiencies could identify underlying causes of violations and help regulators improve SDWA compliance. Programs such as EPA's Area Wide Optimization Program (EPA 2017b) provide compliance assistance to water systems and may help to address issues in the areas of treatment and distribution that could be identified as deficiencies during sanitary surveys.

## Disclaimer

The views expressed in this article are solely those of the authors and do not necessarily represent those of the US Environmental Protection Agency or the federal government.

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## AWWA Resources

- **Aligning Quality Assurance Requirements and Water Quality Monitoring Goals. Eaton A, Burlingame G. 2021. *Journal AWWA.* 113:9:22. https://doi.org/10.1002/awwa.1803**
- **Mapping Ground Water Rule Requirements: Sanitary Survey and Corrective Action. McMahan EK, Lopez-Carbo M. 2010. *Opflow.* 36:9:8. https://doi.org/10.1002/j.1551-8701.2010.tb02347.x**
- **Understanding Small Water System Violations and Deficiencies. Oxenford JL, Barrett JM. 2016. *Journal AWWA.* 108:3:31. https://doi.org/10.5942/jawwa.2016.108.0040**

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# Consumer Response to Boil Water Notifications During Winter Storm Uri

Ashleigh M. Day, Khairul Islam, Sydney O'Shay, Kristin Taylor, Shawn P. McElmurry, and Matthew W. Seeger

## Key Takeaways

Boil water notifications (BWNs) issued during 2021's Winter Storm Uri were typically followed, especially in households with children present and those with higher income.

Cascading failure of interconnected systems (such as power and drinking water) inhibited some individuals from being able to follow boil water guidance.

Of the people who boiled their water following BWNs, more than 92% reported boiling it for 2 minutes or more.

*Layout imagery by Roschetzky Photography/Shutterstock.com*

In February 2021, Winter Storm Uri moved across the southern United States, bringing cold temperatures, record levels of snow, and damaging ice. For example, the Dallas–Fort Worth area, which typically experiences temperatures of 40 to 60°F in mid-February, had 12 consecutive days of temperatures below freezing, with the lowest temperature (–2°F) recorded for the area occurring on Feb. 16, 2021 (NWS 2021). Compounding the effects of the extreme cold, the storm also caused widespread power outages, affecting more than 9.7 million people in the United States and Mexico (HARC 2021). In Texas, power outages were caused by widespread electrical grid failures, and this intensified the power-related risks to public health and safety.

## Drinking Water and Winter Storm Uri in Texas and Oklahoma

Because of the power loss and freezing weather, nearly 15 million Texans experienced some disruption to their primary source of potable water (HARC 2021). Due to the loss of power at water treatment plants and the rapid freeze/thaw cycle causing pipe leaks, boil water notifications (BWNs) were issued widely across Texas and Oklahoma. According to the Texas Commission on Environmental Quality (TCEQ), in the six weeks before Uri (Feb. 12–16, 2021), there were approximately 39 BWNs per week in Texas. The week that Uri occurred, beginning on February 12, 2,055 BWNs were issued.

Although Uri dissipated after Feb. 16, 2021, approximately 1.4 million Texans were still unable to depend on public drinking water systems for safe and reliable drinking water (Oxner & Garnham 2021). More than 200,000 Texans were still without water on February 25, and snow, ice, and freezing temperatures persisted (HARC 2021). BWNs were also being issued in Oklahoma and other states. On February 18, the Oklahoma Department of Environmental Quality recommended a statewide "precautionary boil advisory to ensure that people have safe water" for residents who experienced "extremely low or no water pressure" (OkDEQ 2021).

## BWNs

BWNs are cautionary messages intended to inform the public about potential or known risks in drinking water and to persuade at-risk individuals to take protective actions, such as boiling tap water or using alternative sources of water (O'Shay et al. 2020). The US Environmental Protection Agency (EPA) and Centers for Disease Control and Prevention (CDC) provide guidance on what should be included in these messages (Dearing Smith 2019). Disseminating these risk messages is critical to protecting the public (Bradway et al. 2015), and some water systems collaborate with local or county health departments to disseminate these risk messages.

To protect public health during water emergencies, BWNs must be communicated effectively and efficiently to consumers. However, it is not always clear whether at-risk communities receive these messages in a timely fashion or if the public follows these recommendations. The challenges of timeliness and receptiveness to BWNs are further complicated during disasters and other events when consumers do not have regular means of communication and access to resources. During Uri's aftermath on Feb. 18, 2021, for example, at least 216 communication outages were reported in Oklahoma and Texas, affecting more than one million users (FCC 2021), and many residents lost access to power—both electric and gas—that they would typically have used to boil water (TCEQ 2021).

## Water and Health Infrastructure Resilience, and Learning Study

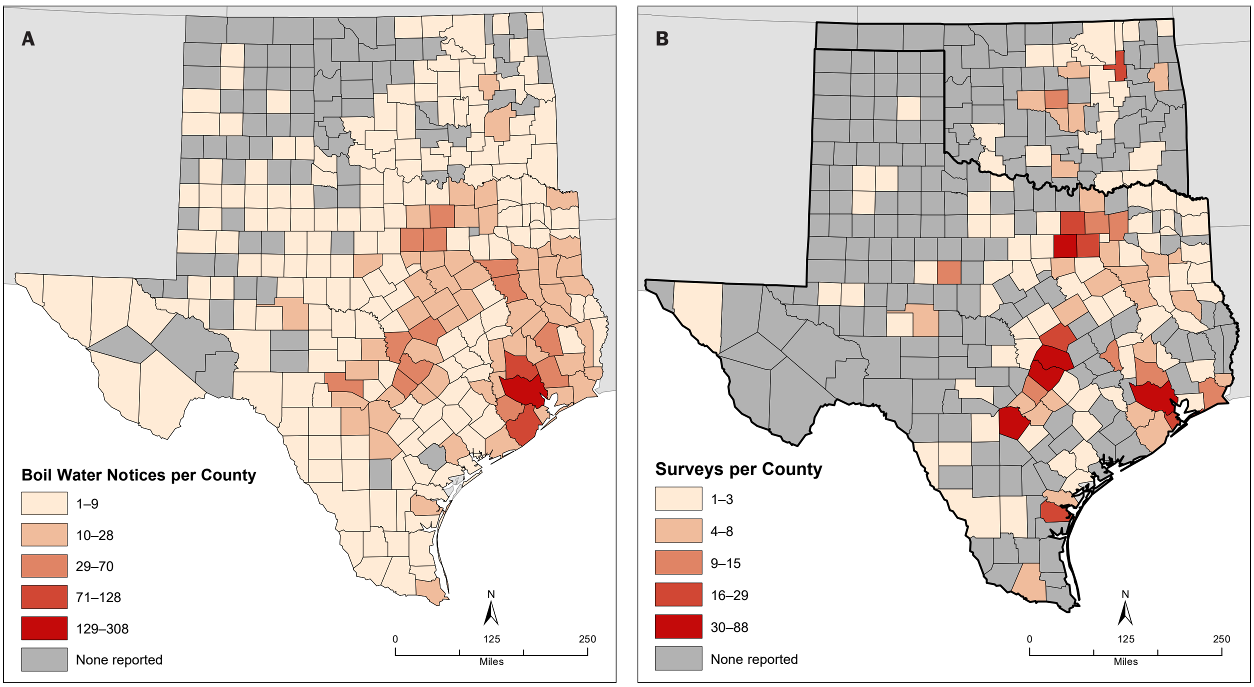
To better understand how people respond to BWNs, we conducted a cross-sectional survey immediately following Winter Storm Uri as part of the Water and Health Infrastructure Resilience, and Learning (WHIRL) project funded by the National Science Foundation. After approval from university institutional review boards, we used a snowball sampling technique to recruit participants and a targeted social media (Facebook) advertisement campaign to distribute a survey. Responses from adults (18-plus years old) living in Texas or Oklahoma during the storm were collected March 2 through April 21, 2021 (Figure 1).

The survey took participants approximately 7 minutes (median response time) to complete. Almost all the survey respondents (99.9%) reported they were affected by the winter storm from Feb. 14 to 26, 2021. Overall, there were a total of 893 participants: 775 from Texas, 101 from Oklahoma (including Indian reservations), and 17 other participants (did not identify, etc.). Survey participants tended to be female (86%), older (median age was 45–65 years), better educated (73.3% had a bachelor's degree), more affluent (median annual family income was $75,000 to $99,999), and more often White (87.4%) compared with the general population of Texas and Oklahoma (Table 1).

## BWNs Overwhelmingly Followed

The majority (83.2%) of the participants reported they received boil water or other water-related notices. Thirteen percent reported they were unaffected by the BWNs and 3.6% of respondents indicated they were unsure about whether they were under a BWN. Survey respondents highlighted different forms of notices they

**2021 Boil Water Notifications in Texas (A, Feb. 12 to April 21) and Survey Responses (B, March 9 to June 14), *n* = 893**




**Source: Created by Felice G. Sperone, Wayne State University. 2020 TIGER/Line® Shapefiles (machine-readable data files) prepared by the US Census Bureau, Geography Division**

**The counties of 300 boil water notifications in Texas (10.8%) were not reliably identified and are therefore excluded from the map.**

## Figure 1

received: 82.8% received a specific "boil water" advisory or notice, 12.7% received a "do not drink" order, and 4.6% received a "do not use" order.

The majority (79.5%) of the participants who believed they were under a BWN reported that they boiled water before using it. This rate of boiling water is consistent with compliance rates (70% and 90%) reported in a randomized survey conducted via phone during boil water events in Oregon (Harding & Anadu 2000), slightly higher than the median reported compliance rate (68%) found during a meta-analysis of 11 publications evaluating the response to boil water events (Vedachalam et al. 2016), and slightly less than the 87.5% of survey respondents that refrained from drinking unboiled tap during a Boston boil water event (Galarce & Viswanath 2012).

Survey results suggest that higher-income individuals (Figure 2) and participants with children in their home were more likely to boil water. In the context of this study, this suggests that higher-income individuals might be more likely comply with a BWN; although how this observation holds up across more diverse racial and ethnic populations is unclear.

Given the relationship between employment and income, we wondered if employment status might be related to compliance with BWNs. A study by Rundblad et al. (2010) in the United Kingdom found that unemployed individuals are more likely to comply with BWNs than employed individuals. As shown in Figure 2, higher-income groups had greater employment than low-income groups and unemployment was inversely related to the BWN compliance. While it may be intuitive that greater employment is associated with greater income, these results appear to contradict the findings of Rundblad et al. (2010).

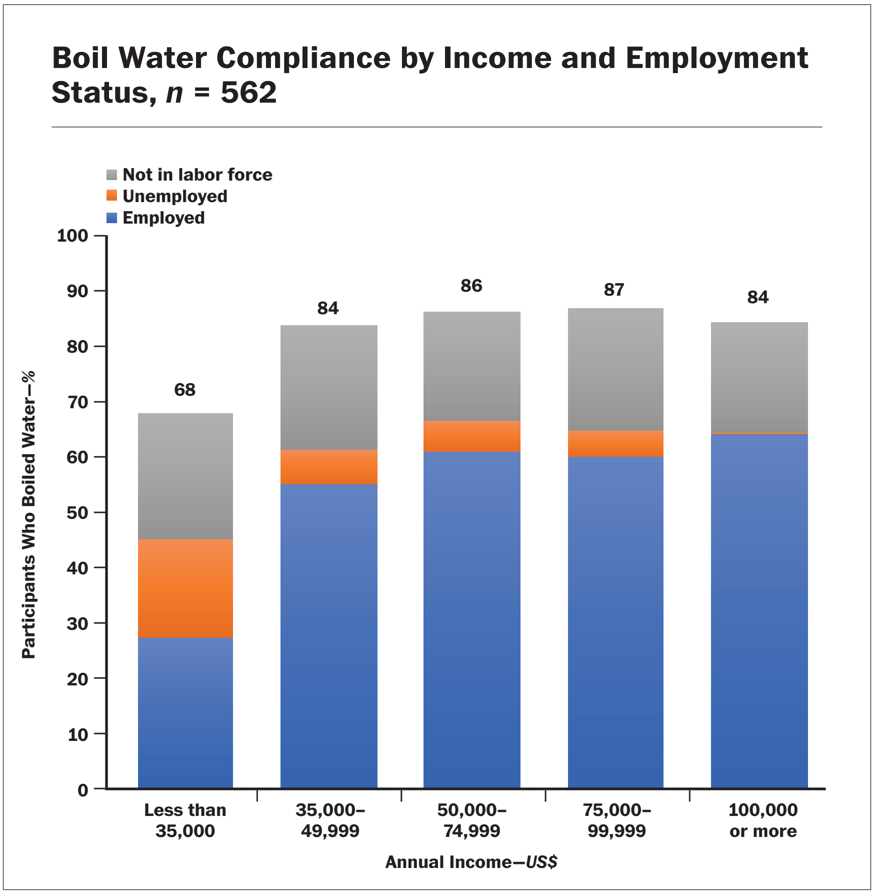



**Figure 2**

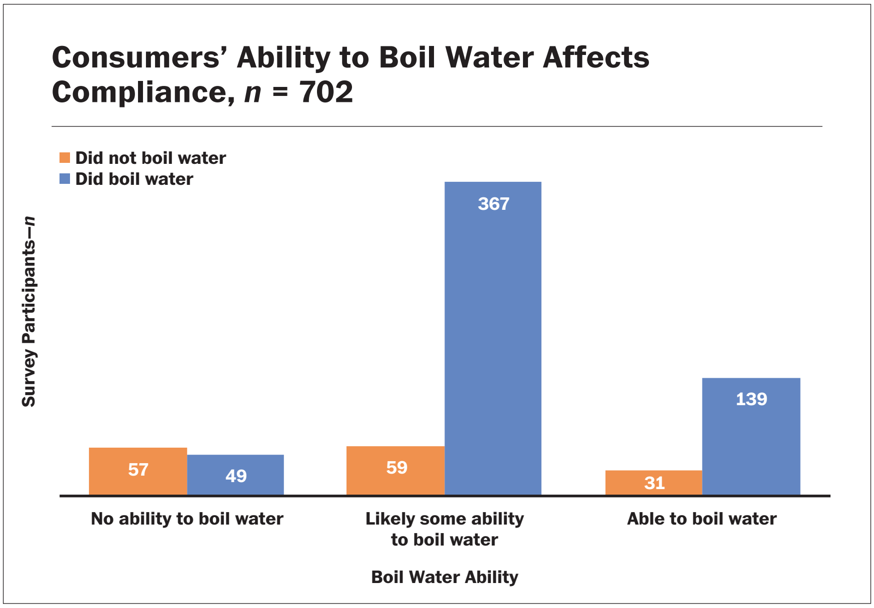



**Figure 3**

When no child (under 18 years) resided in the home ($n = 392$), the proportion of survey respondents that reported boiling water was 79.6%. When a child resided in the household ($n = 237$), the proportion of survey respondents that reported boiling water increased to 87.3%. This increase was statistically significant (chi-square test: $p = 0.013$). These results suggest water providers should consider improving their messaging to lower-income individuals who do not have children in the home.

During Winter Storm Uri, slightly more than half of survey respondents (53.2%) reported they had no running water, 75% had low water pressure, 28% had discolored water, 21% had water with bad smell, and 31% had frozen water pipes. More than half, 58%, reported not having electricity or gas service, while 45% of respondents did have the electricity and gas service typically used to boil their water. Consumers who were told to boil their water and did not have the capacity to do so may have become frustrated and forced to turn to alternatives such as bottled or stored water.

To assess the effect of losing other services, respondents were grouped into three categories:

- Those who were able to boil water (they had both electricity and gas service)
- Those who had some ability to boil water (they had electricity or gas service, but not both)
- Those who were not able to boil water (they had neither electricity and gas service, and reported having "no other way" to boil water).

As shown in Figure 3, compliance with BWNs was higher when consumers had at least some capacity to boil water. It is not surprising that, of respondents who reported having at least some ability to boil water ($n = 596$), 85% reported boiling water. When residents did not have an immediate way to boil water—e.g., no gas or electric service ($n = 106$)—then boil water compliance decreased by nearly half, to 46.2%. The ability to boil water had a statistically significant effect on whether residents boiled water (chi-square test: $p < 0.005$).

The survey results also indicated that respondents with a minor (i.e., child) in the home were more likely to boil water than respondents without a minor in the home. Having a child (or children) presents a unique set of challenges and considerations that may orient parents or guardians to be more risk aware, and more likely to comply with recommendations such as BWNs. This demographic may also create a specific set of needs that requires additional information during a BWN, such as how to safely make baby formula or if their child can safely take a shower during a BWN (see CDC 2016). Simply, caretakers overseeing children likely need more tailored information during these events.

## Boil Water Patterns and Uses During Winter Storm Uri

Participants were asked how frequently they boiled water for drinking and how long water was boiled before use. A large majority (81%) of the respondents reported boiling water in a way that is close to compliant with the BWN: 15% boiled most of the time, 3% boiled some of the time, and less than 1% boiled water only to some extent. Additionally, one of the common questions consumers have about boiling water is for how long they should boil it. On the basis of recommendations from the CDC (2021), consumers should maintain a full boil for at least 1 minute. Of those who reported boiling water, the survey results indicate that more than 92% of respondents boiled their water for 2 or more minutes (Figure 4), exceeding CDC guidance for populations living at elevations below 6,500 feet.

During Winter Storm Uri, 85% of respondents reported using water from alternative sources, including

- purchased bottled water (81%),
- water collected from emergency distribution centers (13%),
- melted snow and ice water (27%),
- water stored before the storm (41%), and
- water collected from lakes or other surface water sources (3%).

As shown in Figure 5, almost all the respondents said they used boiled or bottled water for drinking (94%), cooking (79%), and brushing teeth (79%).

In communicating BWNs to consumers, it is important to clearly highlight what uses require boiled water.

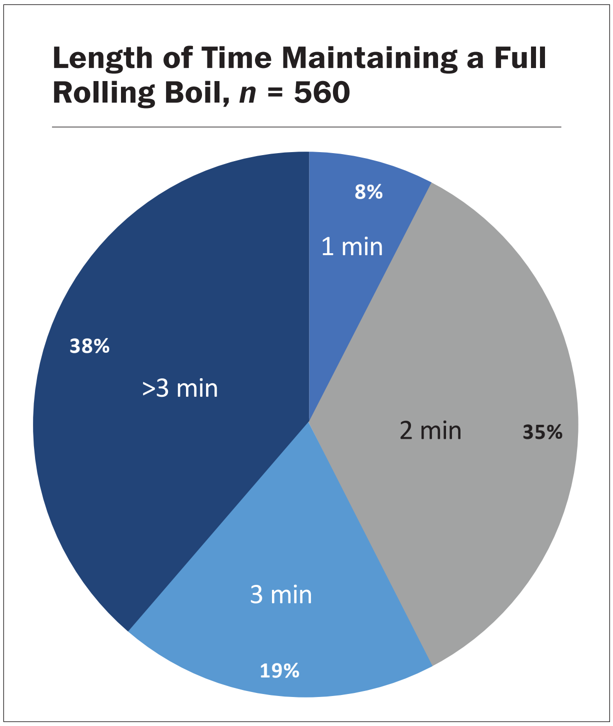



**Figure 4**

According to the CDC (2016), during a BWN, boiled water (or bottled water) should be used for the following:

- Any consumption purposes such as drinking, cooking, washing food preparation surfaces, washing fruits and vegetables
- Brushing teeth
- Caring for pets
- Making baby formula
- Washing baby bottles and nipples
- Making ice

Communicating this information clearly, however, is even more complicated during an event like Winter Storm Uri, when communication channels, especially wireless phone service, were disrupted; in addition, some consumers lost electricity/power, so they couldn't receive messaging via television, social media, etc. Winter Storm Uri showed that officials need to use multiple pathways to communicate BWNs during extreme weather events and anticipate that some of those channels might go down during an event.

## Implications for BWNs

Results of this study on BWNs in Texas and Oklahoma during Winter Storm Uri indicate the overwhelming majority of water consumers follow boil-water recommendations. People with higher levels of income and children in the household are more likely to comply with BWNs. Additionally, parents with young children—especially those with infants—may need guidance beyond what is required for other consumers.

The effectiveness of BWNs can be improved as the utility better understands the situation and its target audience, but this can be difficult during an emergency. When power and gas service are disrupted, consumers may not have the capacity to respond to BWNs. This limited capacity should be acknowledged when the BWNs are issued and in such cases, consumers should be directed to other sources of clean water.

Finally, we recommend that warnings about extreme weather and possible power disruptions preemptively include information about BWNs and storing water. For example, working with local weather reporters to include information about BWNs and storing water when discussing extreme weather events may help residents better prepare for the temporary loss of water services. In addition, general efforts during normal times are necessary to educate the public about what a BWN means and how it should be implemented to keep everyone safe during an emergency.

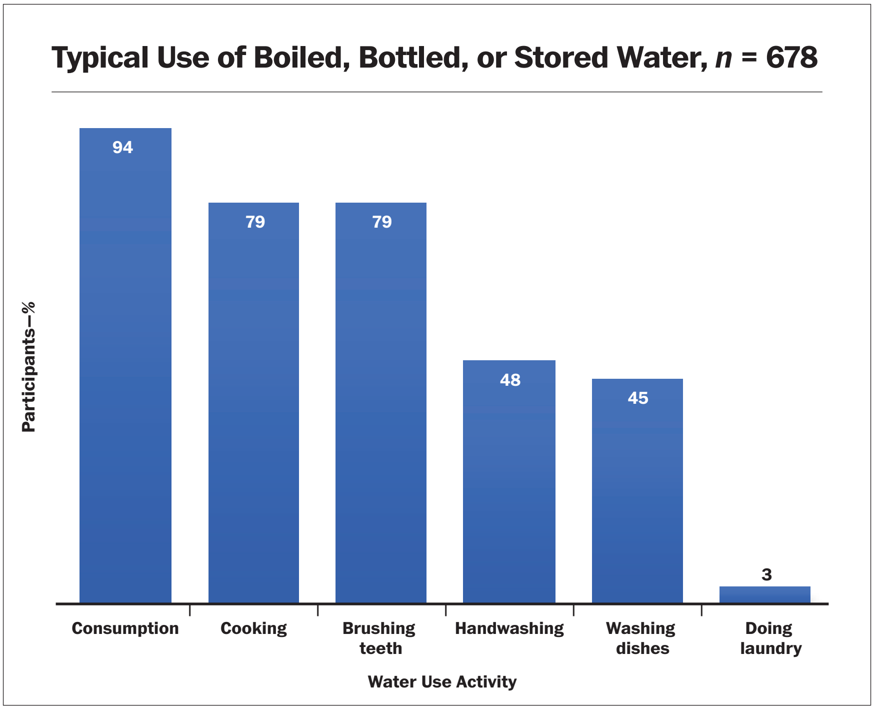



**Figure 5**

## Acknowledgment

We appreciate the insights and feedback provided by the WHIRL team. This work was performed in accordance with the University of Texas at Tyler (IRB-FY2021-129) and Wayne State University (IRB-21-02-3278) Institutional Review Board policies and supported by the National Science Foundation (NSF) under grant number CMMI-1832692. The content is solely the responsibility of the authors and does not necessarily represent the official views of the NSF.

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## AWWA Resources

- **Power of Partnerships: Public Health and Water Systems Protect Community Health Together. Robb K, Via S, McDonald A, et al. 2022. *Journal AWWA.* 114:2:42. https://doi.org/10.1002/awwa.1866**
- **Getting the Message Out: A Boil Water Advisory and Customer Response. Bradway S, Akagi Y, Messier S. 2015. *Opflow.* 41:11:26. https://doi.org/10.5991/OPF.2015.41.0071**
- **Effective Emergency Response Begins Long Before a Storm Hits. Nardi P. 2019. *Opflow.* 45:7:8. https://doi.org/10.1002/opfl.1214**

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# Melinda Friedman

## Honored With 2022 A.P. Black Research Award

The A.P. Black Research Award was established in 1967 in honor of Alvin Percy Black to recognize outstanding research contributions to water science and water supply rendered over an appreciable period of time.

The recipient of the 2022 A.P. Black Award is Melinda Friedman. She is president and cofounder of Confluence Engineering Group LLC and based in Seattle. Before starting Confluence in 2008 with her husband Michael, Melinda spent 16 years as a consultant and partner at Economic and Engineering Services Inc. and as the Northwest Water Quality Program lead at HDR Inc. in Bellevue, Wash.

Melinda has 30 years of experience providing research and engineering services related to source water and distribution system water quality evaluation, regulatory compliance, comprehensive planning, and optimized treatment practices. As a recognized leader with respect to distribution system water quality research and optimization, she has led and participated in numerous research efforts and helped to prepare many prominent industry guidance manuals published by AWWA, The Water Research Foundation, and the US Environmental Protection Agency.

Throughout her career, Melinda has been an active volunteer through AWWA. She is a past trustee (1998–2000) of the Pacific Northwest Section (PNWS), and she is past chair (1996–1998) as well as a current member (1992–present) of the AWWA PNWS Water Quality Committee. Nationally, Melinda has been a member of AWWA's Distribution System Water Quality Committee and the Inorganic Contaminants Research Committee. She has presented at AWWA's Annual Conference & Exposition and the association's Water Quality Technology Conference, most years, for the past 28 years.

As president of Confluence, Melinda is also an active sponsor of numerous events throughout the year, including Water For People's annual event, held at the Brightwater Education and Community Center in Snohomish County, Wash. In recognition of her extensive contributions of time, talents, and expertise, Melinda was awarded AWWA's George Warren Fuller Award in 2017 for distinguished service to the water industry.

Kenneth Mercer, editor-in-chief of *Journal AWWA,* interviewed Melinda to learn about her entrance into water research and the water community, her career path and the founding of her own firm, and her perspectives on influences and challenges for research and the water industry as a whole. The interview that follows has been edited for clarity and length.

**You graduated with an undergraduate degree in environmental conservation and a minor in chemistry from the University of New Hampshire (UNH), then added a master's degree in civil engineering, also from UNH. How did you choose your education path, and what were your driving considerations at the time?**

I have always been an outdoor enthusiast and passionate about environmental protection. In the mid-1980s, acid rain and nuclear power were big issues in the Northeast. At UNH, as at most college campuses at the time, there were student organizations, protests, and marches to generate awareness of these issues. I joined the student committees but quickly realized that I was not the protesting type, and that instead I preferred to focus on finding solutions to problems. This became a turning point in my thinking that led me to pursue a more rigorous, science-based degree by adding a chemistry minor to my environmental conservation degree.

During senior year, I took a Marine Pollution course in the Civil Engineering Department with Dr. Taylor Eighmy (now president of University of Texas San Antonio). I was quite engaged in the class, and Dr. Eighmy offered to help me pursue a master's degree in civil engineering, despite the lack of an undergraduate engineering degree. He planted a seed that would germinate after I traveled out West with my then boyfriend, now husband and business partner Michael Hallett. I honed my chemistry skills working as a lab technician at Aquatic Research, a commercial chemistry lab in Seattle. From there, Michael and I landed US Fish and Wildlife Service volunteer research positions, studying juvenile sockeye salmon on Kodiak Island in Alaska.

After this life-changing adventure, I was ready get to work on my master's degree. I began taking night classes to chip away at the civil engineering prerequisite courses—it was not easy! Eventually I was offered a research assistant role in the UNH Civil Engineering Department, working with Dr. Nancy Kinner on a project focused on biodegradation of BTEX compounds using nitrogen as an electron acceptor. (Dr. Kinner is currently the UNH director of the Coastal Response Research Center and director of the Center for Spills and Environmental Hazards.) The project required a blend of chemistry, microbiology, and complex laboratory skills, which suited my background quite well.

During graduate school, I also served as teaching assistant for Dr. Robin Collins' Water Chemistry/Physical–Chemical Treatment class (which taught me everything I needed to know about the carbonate system and solubility curves for corrosion control studies—thank you, Dr. Collins!), and we used Snoeyink and Jenkins' *Water Chemistry* textbook (1980 edition). I had to dig deep into nearly every page of that book, and to this day I still consult Snoeyink and Jenkins—it is torn and tattered, sitting right on my desk! I am honored to say that Dr. Vern Snoeyink has since become a trusted industry friend and advisor.

All in all, completing a master's degree in civil engineering without an undergrad degree was such a demanding and yet fulfilling experience that I did not even consider a PhD. After three-plus years of hard academic and scientific research efforts, I was ready to get out into the industry and start solving environmental problems!

**What initially drew you to water research? Did you always know that potable water was the area you wanted to study and work in? What traits or strengths contributed to your success in applied research?**

It must have been fate! Given the topic of my master's thesis, I assumed I would find a job cleaning up oil spills. Michael and I knew we wanted return to the Pacific Northwest, so I started cold-calling Seattle-area

Early-run sockeye salmon on Karluk Lake, Kodiak Island, Alaska, 1988. *© 2022 Melinda Friedman*

Dr. Nancy Kinner in her famous red hat, 1993. *© 2022 Melinda Friedman*

engineering and research firms, in alphabetical order, straight out of the yellow pages. I got lots of "no thanks," but when I got to "E," a gentleman named Gregg Kirmeyer at Economic and Engineering Services (EES) said he would be willing to meet for lunch.

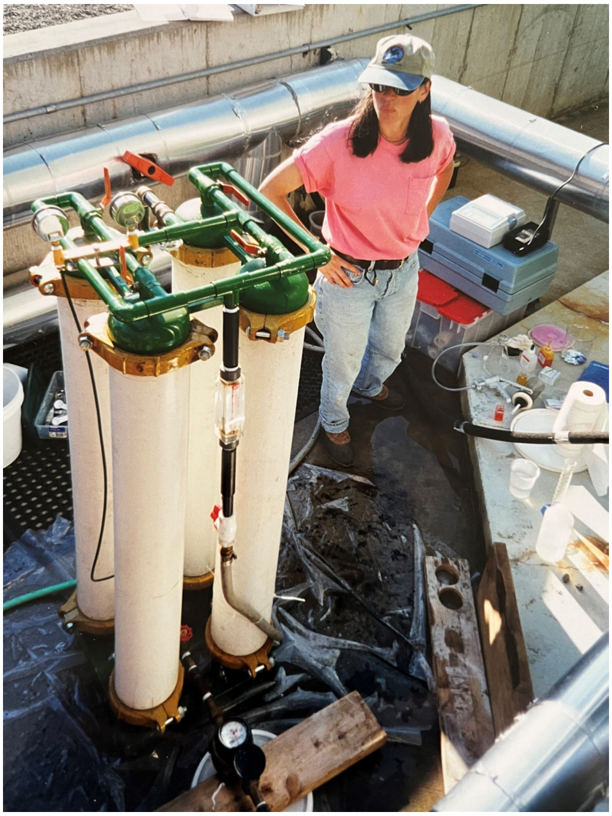
We sat down at the restaurant and he explained that EES did a lot of work in distribution systems. Believe it or not, I asked, "What's a distribution system?" Honestly, I wasn't sure if he meant distributing goods or services or what. Without missing a beat, on the napkin in front of him, Gregg took out a pen and drew a little house and said, "This is the water treatment plant." Then he drew a bunch of lines crossing each other and said, "This is the distribution system." Oh, my. But Gregg took it in stride and still offered me my first consulting engineering job!

My nontraditional, multidisciplinary background combining chemistry, field sampling, microbiology, and knowledge of engineering principles was the perfect foundation to work alongside Gregg and begin understanding the complex world of distribution systems.

**After UNH, you joined EES, ultimately becoming its first woman partner and also the youngest partner at the time. When EES was purchased by HDR Engineering Inc., you became the lead of HDR's Northwest Water Quality Program. What are some of the big lessons you took away from your various roles?**

The consulting business model forces you to be efficient with labor and finances—you are not afforded extra time or funds to redo work, or to explore endlessly in search of an answer. Your labor pool is your fellow engineers, all being paid at market rates with billable-hour goals. Journal articles were mostly prepared on our own time, after billable goals and project deadlines had been met. Consulting taught me how to organize a project approach, negotiate and budget a scope of work, conduct and manage the project, tease out key findings, and to prepare useful reports for our clients.

Gregg Kirmeyer displaying rocks jammed against a hydrant barrel during water main flushing. *© 2022 Melinda Friedman*



Manganese removal pilot study in Oak Harbor, Wash. (late 1990s). *© 2022 Melinda Friedman*

Showing the water chemistry love at Metro Vancouver Regional District (1995). *© 2022 Melinda Friedman*

My first manganese pilot study (1992). *© 2022 Melinda Friedman*

Gregg Kirmeyer could see my potential and after our working together for six years, he sat me down to ask if I "had the fire in my belly" to invest in the company and assume financial risk, expand my leadership role, and share the experience with other partners. While I may have understood less about strategic business planning, shareholder agreements, and bylaws compared with the senior partners, being a younger partner allowed me to steer the company in other important areas, such as diversity issues—I was able to get domestic partner benefits included in our health insurance plan.

My tenure as a partner at EES was somewhat short-lived because the company was sold to HDR Engineering. This was a huge career change for me—going from a partner in a 75-person firm that I had planned to help lead for the next 20 years, to Northwest Water Quality Program lead in a 4,000-person (and growing) firm. HDR provided new opportunities to work with nationally acclaimed researchers and engineers, and to get a glimpse into the workings of a large, multifaceted civil engineering firm. I enjoyed the work and collaboration with new colleagues but never felt that a large firm was the right fit for me. I missed the niche-firm business model at EES.

### As a young professional (including as a graduate student or as a new consultant), can you recall a specific teacher or mentor who steered or influenced your career? What was the best advice and/or lesson(s) that you learned from them?

One particular experience certainly stands out. I was presenting a poster at my first industry event during graduate school in the late 1980s (it was not an AWWA function). In the same exhibit hall, there were women in bikinis, high heels, and lab coats moving quite suggestively around wastewater equipment. I have since learned that these women were called "booth babes." Needless to say, I was extremely uncomfortable and found it difficult to concentrate on my poster and share my research findings.

When I got back to school and told Dr. Kinner, she looked me in the eye and said words along the lines of "Yup, it's tough. But you need to be able to do your job anywhere, even with people you don't necessarily understand or agree with. This can be a hard industry, and these are some of the realities about working in it."

I was taken aback, since I guess I was expecting a long, empathetic discussion about how hard it was to be a female in a male-dominated industry (Dr. Kinner was the first female engineering professor at UNH). We probably discussed options for directly addressing the issue, such as lodging a complaint with the event organizers. But that wasn't the part of the conversation that stood out to me. It was the tough-love realization that life will be filled with obstacles, and it is up to each of us to find our own navigable paths around them if we want to move forward.

### It can be difficult for consultants to stay connected to research during their careers; how have you kept research integrated with the various technical and management roles you took on? Over this same period, how did your professional growth shape how you manage people?

In addition to conducting bench, pilot, and field project work at EES with our many utility clients, Gregg Kirmeyer had the vision to pursue Water Research Foundation (WRF) projects and formed teams with top scientists, utility managers, universities, regulators, and researchers across the world.

I had the opportunity earlier in my career to collaborate on a variety of complex WRF and AWWA WITAF [Water Industry Technical Action Fund] projects with Mark LeChevallier, Michèle Prévost, Jeff Rosen, Anne Camper, Vanessa Speight, Walter Grayman, Charlotte Smith, Laurie McNeill, Steve Reiber, Alan Roberson, Phil Brandhuber, Gregory Korshin, and Rich Valentine. The projects had a Project Advisory Committee as well as utility participants. Gary Burlingame, Steve Estes-Smargiassi, Jeff Swertfeger, Kan Oberoi, Steve Via, Mike Schock, David Cornwell, Yone Akagi, Dan Giammar, Michelle DeHaan, Robert Cheng, and Eva Nieminski each provided important guidance to our research teams that improved the value and practicality of the finished products.

At times it was quite challenging to manage these complex projects with multidisciplinary teams. But together we published materials of critical importance on topics such as corrosion control, pressure transients, pathogen intrusion, microbial source tracking, coliform occurrence and control, effectiveness of flushing and other main-cleaning strategies, disinfectant residual stability, and metals accumulation and release. Each project was equivalent in many ways to a master's or PhD thesis, and I had the pleasure publishing with several graduate students as they earned their degrees while working on our projects.

It didn't take long to realize that one of the fastest tracks to success was to seek out and work with people who are either smarter than you, think differently from you, or ideally both. In 1999 a young engineer named Andrew Hill joined the EES Water Quality Group. His impeccable and deep understanding of both civil and chemical engineering was a terrific match for my "bigger picture" approach to developing industry guidance.

Working with Andrew significantly deepened my understanding of inorganic chemistry, mass transfer, mathematical applications to data sets, and so much more. Together we came up with elegant solutions and presentations of research data that could be communicated to a wide-ranging audience. He worked with me on many of the projects described here, and we work together to this day at Confluence Engineering Group, where Andrew serves as technical lead on most projects, and senior project manager on many. It is fantastic to see him take his place as a principal investigator on WRF projects, publish the research that he has led, and to be recognized in his own right as the water quality, treatment, and distribution system expert that he is.

Andrew Hill and Alexander Vetrovs conducting field work for Economic and Engineering Services in the early 1990s. *© 2022 Melinda Friedman*

### In starting your own firm—Confluence Engineering Group LLC—how long had you been considering it, and what were you concerned with/worried about when you went on your own?

My earliest inspiration, even before considering starting my own company, came from Charlotte Smith (now a professor in the School of Public Health at UC Berkeley), who had been running her own water quality consulting business. She provided the first vision of what might be possible—a female, being your own boss, and doing important water quality work on a national stage! That looked like a great gig to me.

By 2008, I had been commuting from Seattle to Bellevue for 16 years. I had two young children at home, and I was often gone from 7:00 a.m. to 7:00 p.m. Whether at EES or HDR, I was managing a small staff, delivering work products, developing annual budgets, and responsible for finding the majority of the work—pretty much running a small business. It was my husband Michael who suggested that we give it a go on our own. He had been running his own small remodel contracting business for about 10 years and along with Al Vetrovs, now also working with Confluence, often did field work and constructed and operated pilot plants for EES and HDR. Michael could build, wire, plumb, and fix anything, plus he knew how to do payroll, taxes, and other accounting functions.

The reality of starting our own business together was that there would be no backup salary, backup health insurance, IT department, human resources, word processing—nothing! Plus, we had two young kids to think about. Although the risks were very real, we had very little doubt about our chances of success in the long run.

One surprise, however, was that we didn't qualify as a woman-owned business because of community property laws where we reside. Nonetheless, I am proud that we have competed for and won every single contract based on our firm's merits, skills, and quality of work, and not due to or in spite of my gender. Dr. Kinner was right!

### Is there a particular success or failure in your career that set you on your path or that influenced it greatly?

Like many in our industry, I would have to say the events in Flint, Mich., led to a turning point in how we do business, and how I personally view the impacts of our work on customers and clients, and our role in building trust with the public. Prior to Flint, I might have been less forceful in our recommendations to clients because they often are difficult and expensive to implement. But we now know that introducing a new source of supply or changing the chemistry of an existing supply can have disastrous consequences if not adequately planned for and addressed.

> **No water system should ever tell its customers that discolored water is only an aesthetic concern. This is rarely, if ever, true.**

It can be extremely rewarding to help water utilities overcome water quality crises. But I have also had the very difficult and heart-wrenching job of standing up at public meetings, including in Flint, looking out at the public who are desperate to be heard, seeking answers to very difficult questions, and who do not necessarily trust the "experts" who have been brought in from afar. I am still at a loss in trying to reconcile the lived experience of the residents, the misinformation campaign spurred on by celebrities, and the actual water chemistry data that practitioners rely on throughout the world to determine that our water is safe to drink.

### What are some of the challenges to conducting research that combines science, engineering, and public health?

Working on distribution systems can be compared with being a doctor. A water system presents you with a problem, you ask lots of questions and collect readily available existing data, but you cannot see inside without sophisticated equipment or invasive procedures. Plus, there can be hundreds or sometimes thousands of miles of potential problems out there. I enjoy thinking through the various chemical, microbial, and physical factors that could be contributing to the problem, starting at the source and working down into the system.

This is where Confluence has excelled in the research arena by developing useful, proven protocols to support defensible scientific approaches to diagnose and heal ailing systems. We have developed sampling and pipe profiling techniques, pipe tap libraries, accumulation mass calculators, deposit inventory normalization techniques, and other data interpretation tools so that we can get a handle on system-specific conditions and potential risks posed by legacy deposits. By using consistent profiling techniques, we can attempt to compare one portion of the system with another, or even with other water systems. This allows our clients to understand the magnitude of potential problems and prioritize their response efforts. There are never enough resources to clean every pipe in a system, so reliable and effective prioritization strategies are crucial.

### What are some of the challenges facing the water industry today?

Within water distribution systems, I believe the next biggest challenge after lead will be manganese. It is everywhere, no matter what type of water source, treatment used, water main material, or age of pipe. We are learning more about direct neurological and other health impacts of manganese, even at levels commonly seen in some water systems.

No water system should ever tell its customers that discolored water is only an aesthetic concern. This is rarely, if ever, true. Aside from any direct health effects from manganese, building on the excellent research conducted by Mike Schock, Darren Lytle, Rich Valentine, Steve Reiber, and others, our research has demonstrated that manganese (and iron) accumulate and concentrate other regulated metals such as lead, arsenic, thallium, antimony, and even radionuclides. These "legacy deposits" are present at some level in every single water distribution system, and they do not magically stop accumulating at the meter to the premise.

Potentially more concerning, release or exposure events are not always visible. Just as with lead, changes in water chemistry can release these co-accumulated metals, and the typical visual cues to avoid drinking the water, such as cloudiness or discoloration, may not occur.

There is no way to avoid all water quality risks in distribution systems, but tools and training are available to minimize and respond to potential problems. Utilities must ensure they have done their due diligence to prepare their distribution systems for change by following industry best practices.

### How have you observed your research driving regulations, and alternatively, how have regulations driven your research?

In the United States, elements of our research were used to support concepts in the Revised Total Coliform Rule, which moved away from the prescriptive measurement of total coliform as the primary indicator of distribution system integrity to more of a best management approach through use of comprehensive assessments and fixing deficiencies. In another example, our 2010 WRF manual, *Criteria for Optimized Distribution Systems*, was adopted by the AWWA Partnership for Safe Water and serves as the standard by which systems can voluntarily conduct self-assessments and demonstrate continuous improvement toward maintaining distribution system water quality and protecting public health.

Our work on metals accumulation and release in distribution systems might be a bit ahead of its time, at least in the United States. Currently, the compliance point for metals is at the point of entry to the distribution system, not within the distribution system where these regulated metals accumulate and can be released. However, Health Canada has used our research on manganese accumulation and release to support elements of its revised *Manganese in Drinking Water* guideline.

EPA's Lead and Copper Rule and recent revisions have required us to continue learning about the effects of introducing or alternating water sources and changes to treatment strategies on lead and copper release and other unintended consequences within the distribution system. We have learned the importance of using harvested materials with intact legacy deposits and scales whenever possible in pipe rig studies, and how to better fabricate materials when harvesting is not possible, for use in coupon or pipe rig studies.

### What is your favorite research project that you've worked on that those in the water industry have probably not heard of?

I am serving as a Project Advisory Committee member on a jointly funded WRF/Centers for Disease Control and Prevention (CDC) project that is looking at impacts of pressure events on gastrointestinal illness in US water systems. It is an extension of the Nygard et al. study that was published in the *International Journal of Epidemiology* in March 2007. I have really enjoyed learning more about how the CDC approaches epidemiological studies involving drinking water. I believe the CDC researchers have also enjoyed learning more about the realities and challenges of operating distribution systems to protect public health.

### How have your international experiences influenced your research? Do you have an experience that was especially influential on your thinking, research, or practice?

In 2011 I was invited to observe ice pigging in Bristol, United Kingdom. Randy Moore, a mentor, friend, and innovation leader in our industry, knew that Confluence was doing cutting-edge research on main-cleaning techniques and applications, and I traveled with Utility Services Group (Randy's employer at the time) to observe the European practice. It was illuminating to witness the differences in how our systems are designed and operated (the UK hydrants that I observed are below grade and only have a 2-inch port, limiting velocities that can be achieved during flushing) and how these design differences and available resources have resulted in different operations and maintenance practices and procedures, and innovation in our respective countries.

### You've been a volunteer in AWWA in various roles, including chairing several committees at the section, national, and international levels. How has AWWA helped you in the different facets of your career through its conferences, committees, networking, and knowledge exchange?

Without a doubt, becoming active in AWWA changed the entire arc of my career. Committee work is the great equalizer in our industry—everyone is volunteering their time and expertise, and all of that knowledge and opportunity for collaboration and relationship building is there for those who get involved. It is through committee work, manuals development, and conferences that deeper relationships are formed, ideas are exchanged, and if you are so inclined, you can develop a name for yourself. As a consultant in a small firm, I see AWWA conferences as the number one networking opportunity we have to share our ideas and expertise, and to continue learning from our colleagues and coworkers across the industry.

As I get older, one of the most rewarding aspects of AWWA conferences is to watch the next generation find their place in the field. I have great respect for my UNH professor and master's thesis committee member Dr. Jim Malley, who over the years brought throngs of students to national AWWA conferences, giving them the chance to present posters, to speak, and to interact with the industry at large. He would contact many of us alumni ahead of time and organize dinners and drinks, giving us all a chance to look forward, reflect, and rekindle connections.


Catching up with Dr. Jim Malley at AWWA's Water Quality Technology Conference, 2018. *© 2022 Melinda Friedman*

Michael Hallett profiling a swabbing run in California (2019). *© 2022 Confluence Engineering Group*

Melinda and Michael in 2022. Confluence founders, hubby and wife, best friends for life! *© 2022 Confluence Engineering Group. Photo by Heleyna Holmes*

**On the personal side, please comment on how you've been finding your work–life balance during the pandemic and any support from family or friends you want to spotlight.**

First and foremost, having a super-human husband, father to our kids, business partner, and best friend is the most important element of my success, work–life balance, and overall happiness. Michael always put my career first and held down the fort while I was away as well as during many late nights working at home. He had the original vision of creating Confluence. We now have a superb, dynamic, "small but mighty" crew working together to tackle complex water quality challenges from source to tap. We are continuously pushing each other to expand our collective expertise and capabilities, win new projects, and do the highest-quality work possible. I am extremely proud of our dedicated team.

My parents have each served as personal and professional role models in their own unique ways, throughout their time on this earth. To this day, Mom is still a constant source of support, love, friendship, and great advice!

When you (mostly) love your work, it all blends together with personal happiness. Looking back on 30 years and the number of colleagues whom I now consider friends, including many who should be considered "competitors," is just astounding: decades of working together, raising kids, watching each other rise through the ranks of our organizations, sharing successes and challenges, working through public health emergencies together, teaming up, competing—all the while sharing common goals. We all have accomplished so much together! It is thrilling to think of what discoveries and advances are yet to come.

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The Confluence team, ensuring the water stays clean! From left to right: Alex Mofidi, Stephen Booth, Chris McMeen, Virpi Salo-Zieman, Melinda Friedman, Michael Hallett, Danbi Won, Al Vetrovs, and Andrew Hill. *© 2022 Confluence Engineering Group. Photo by Heleyna Holmes*

# Past, Present, and Future AWWA Presidents Share Thoughts on AWWA's Past Two Years

AWWA's staff have worked primarily from home during the past two years as a result of the COVID-19 pandemic. They returned to Denver headquarters on a staggered schedule of in-office and at-home work in March 2022.

## Melissa Elliott | AWWA Immediate Past President

I recently hosted a couple who were in the Colorado mountains visiting us for the weekend. While our husbands did some spring skiing, I got to enjoy some wine and conversation with my guest, who happens to be an emergency room nurse. I wanted to know what the past two years have been like for her, and fortunately she wanted to share. She had a surprisingly upbeat perspective on COVID and our society's response to what was certainly one of the most devasting, disappointing, frightening times in our history.

As I listened to her talk about her personal experiences with caring for people who were so ill, scared, and alone, the word *resilient* kept popping up in her stories. Her colleagues were resilient. The families she interacted with were resilient. The entire public health profession may have been shocked and battered by the pandemic, but she believes it was resilient and that we will see a stronger healthcare industry as a result. I know this doesn't reflect how all nurses feel, but I identified with her story because my colleagues, friends, and fellow AWWA volunteers also have been resilient and strong during the past two years.

I have spoken about my term as the "virtual" AWWA president before, but to summarize, it wasn't what I expected when I was elected in 2019 and pandemics were still science fiction for most of us. I never laid eyes on another AWWA member for an entire year except through a laptop screen. What I learned from that time is that, like my friend, we have a lot to be upbeat about, a lot to share, and a lot of areas where we sprang forward without looking back.

**I learned firsthand how when things look to be at their worst, that's when people can come together to be their best.**

**—Melissa Elliott**

AWWA's members have bonded over shared experiences, and now they are experts at virtual engagement. Like me, they worked diligently at keeping their connections to other members strong during the COVID pandemic—first tentatively through webinars to share their knowledge, then through virtual happy hours to check on friends and colleagues, and eventually through full-on conferences to share information and best practices.

AWWA became a convenor, and myriad virtual offerings from the association and its sections became normal places to be. Unlike many work-related virtual settings, what I witnessed at AWWA events was more personal and less transactional. People wanted to see how others were—to check on them or to share a laugh and the latest news. I am forever grateful for all the connections we have made and maintained because of AWWA.

As my year as AWWA's virtual president came to an end at the first (and hopefully only) all-virtual ACE21, what I most looked forward to was the gavel-passing ceremony, which was held in person outside AWWA's headquarters in Denver. Given the relatively new miracle of vaccinations, then-incoming president Chi Ho Sham flew to Denver so we could pass the gavel together. It was truly a highlight of my presidential term.

These days I am thrilled to be out and about at in-person section conferences and meetings once again. However, like my friend the nurse, I know the impact we all had when it was needed most. I learned firsthand how, when things look to be at their worst, that's when people can come together to be their best.

## Chi Ho Sham | AWWA President

In June 2021, I took my second trip out of Boston since March 2020, when I traveled to San Diego for my last in-person Technical & Educational Council meeting. I was fully vaccinated, so I could travel to Denver to be with Melissa Elliott in person for the gavel-passing celebration on June 17. That was the first time I got to be with her and many of the AWWA staff since AWWA's winter board of directors meeting at the start of 2020.

From mid-March 2020 to June 2021, pretty much all AWWA committee, division, council, executive committee, and board of directors meetings were converted to virtual meetings because of COVID-19 concerns. Instead of interacting in person with Melissa so I could learn from the best communicator I know in the water community, I had to resort to using remote platforms to work with her and other volunteers and staff. Although we have become familiar with the use of virtual platforms to run meetings and communicate, it's difficult to build relationships and trust through a flat screen.

The gavel-passing ceremony in Denver was a beacon of hope during the devastating pandemic. At that gathering, we were optimistic that the worst was behind us. The first AWWA conference I participated in was the 2021 Membrane Technology Conference in West Palm Beach, Fla. Melissa was able to attend the 2021 Utility Management Conference in Atlanta, then the Water Infrastructure Conference in Phoenix and the North American Water Loss Conference in Austin, Texas. Along with the Water Quality Technology Conference that I attended in Tacoma, Wash., participation at AWWA's in-person knowledge exchange events have returned to about 60%–70% of pre-COVID levels.

**I am pleased that I was able to get a few meaningful projects off the ground by working with our outstanding volunteers and staff on my three Cs: collaboration, creativity, and celebration.**
**—Chi Ho Sham**

In addition to AWWA conferences, AWWA sections have returned to in-person events. Being in New England, I was able to attend the Connecticut Section member appreciation picnic in the summer and the New England Water Works Association annual conference in New Hampshire in the fall of 2021. Moreover, I was invited by the Missouri Section to celebrate its 75th anniversary and the Florida Section to celebrate its success as one of AWWA's fastest-growing sections.

As of this writing, I have returned from the 2022 Young Professionals Summit and Utility Management Conference in Orlando, Fla. Spending time with our younger water professionals has been rewarding and inspiring, as they are so forward-thinking and resilient! Their discussions at the event on diversity and inclusion, workforce development, public trust, and innovation among utility leaders were thoughtful and impactful. With the water community facing many workforce and supply chain challenges, we need everyone to come together to tackle many complex problems.

In reflecting on my fast-paced year, I am pleased that I was able to get a few meaningful projects off the ground by working with our outstanding volunteers and staff on my three Cs: collaboration, creativity, and celebration. These accomplishments include the following:

- Followed Melissa's effort to promote diversity and inclusion by speaking about this topic at several meetings and continuing to support AWWA's Diversity & Member Inclusion Committee's efforts
- Worked with AWWA's awesome staff to kick off the Source Water Protection Week celebration in the last week of September 2021 (https://news.awwa.org/SWPW)
- Collaborated with the North American Lake Management Society, Aquatic Plant Management Society, and US Army Corps of Engineers to put together a five-part webinar series on cyanobacteria and cyanotoxins in reservoirs (https://bit.ly/3qfsOrd)
- Collaborated with the American Water Resources Association, Babbitt Center for Land and Water Policy, and the American Planning Association to develop a Findings Statement and Call to Action on Connecting Land & Water for Healthy Communities (https://bit.ly/3qaCLpK)
- Prepared an article on the circular economy of water, which will be published in *Journal AWWA* later this year
- Worked with AWWA's chief executive officer David LaFrance and AWWA's president-elect Joe Jacangelo on Water 2050 (see next section)

## Joe Jacangelo | AWWA President-Elect

In January 2021, I had the honor of being selected by AWWA's board of directors as president-elect. I spent this past year learning even more about the association, and being part of AWWA's leadership group, Executive Committee, Finance Committee, and board of directors provided me with greater insight on how best to drive my presidential goals to fruition. Most importantly, this time allowed me to develop relationships with the colleagues with whom I will be working closely.

The past two years have presented major challenges to our water community in the form of SARS-CoV-2, the etiologic agent of COVID-19. The pandemic placed an incredible burden on our water community and on the global population. Being formally trained in public health, I often deal with research issues related to microbial contaminants. That which stood out to me during this time was how the water community reacted to the COVID-19 challenge. In the early days of the pandemic, when little was known about the disease and its transmission, or when it was difficult to get personal protective equipment, or surges occurred due to viral variants, our community continued to supply clean and safe water to consumers. Our core principle remained clear: protect public health! We showed an incredible amount of courage and resilience, and I would like to give a special shout-out to utility operators who held the front line during this time.

So what does the future hold? In terms of COVID-19, we have seen a rapid decrease in disease burden throughout North America. I am hopeful that trend continues and our return to normalcy is fully realized. But it is incumbent upon on all of us to keep a watchful eye and stay prepared, as we don't know what the future holds in terms of future microbial-based challenges.

As AWWA's president, I intend to continue to emphasize the great work fostered by Melissa and Chi Ho, including programs and efforts around diversity and inclusion, young professionals, source water protection, and member value and engagement, among others. In particular, one project you will hear me emphasize and promote considerably is Water 2050. Facing a rapidly increasing world population, the potentially deleterious impacts of climate change, and the need to create a more sustainable water future, we need to take a long-term view of what the water landscape will look like in 2050. This will allow AWWA and its sections to create better strategic plans and programs as well as adapt to future changing conditions as needed. The usefulness of such a plan will not be limited to our association and members. Anyone or any entity whose activities involve water will be able to gain better insight into where the water field is heading and employ the various outcomes of this initiative.

> **We need to take a long-term view of what the water landscape will look like in 2050.**
> **—Joe Jacangelo**

To realize the best possible future of water in the year 2050 will require a lot of innovative, out-of-the-box thinking. Toward that end, AWWA is planning a series of five think tanks focusing on specific drivers of water's future. Thought leaders from our membership and those who work in adjacent water areas will be invited to attend. We will need your input too, so please stay tuned!

I am looking forward to working with AWWA's board, councils, divisions, committees, and members during the next year. I foresee a bright and positive future for our organization, and together, we'll continue to do great things!

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# Prepare for UCMR 5 Implementation

Chris Moody

The Unregulated Contaminant Monitoring Rule (UCMR) is a recurring national water quality monitoring program required by the Safe Drinking Water Act (SDWA), and the US Environmental Protection Agency (EPA) finalized the fifth rule (UCMR 5) on Dec. 27, 2021. UCMR requires EPA to identify up to 30 unregulated contaminants for inclusion in the monitoring program to inform regulatory decisions for drinking water standards, and EPA is currently preparing for UCMR 5 monitoring activities, which will begin Jan. 1, 2023, and end on Dec. 31, 2025.

Water systems should begin preparing for the monitoring and reporting requirements of UCMR 5, as well as the public communications that will need to account for the increased public concern surrounding per- and polyfluoroalkyl substances (PFAS). EPA is planning several efforts related to PFAS that will amplify public attention concerning the rule's results. These efforts include developing and promulgating a primary drinking water standard for perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS), new health advisories for hexafluoropropylene dimer acid (HFPO-DA, or "GenX") and perfluorobutanesulfonic acid (PFBS), and revised health advisories for PFOA and PFOS. Beyond drinking water, EPA is preparing to propose a hazardous substance designation for PFOA and PFOS, which will increase attention on detection efforts under UCMR 5.

## Public Water System Requirements

Previous UCMR programs have required monitoring for all public water systems serving more than 10,000 people and for a representative sample of 800 smaller systems. UCMR 5 requirements will extend to a broader group of systems, potentially doubling the number of systems that participate. As with previous UCMRs, all systems serving more than 10,000 people will participate, along with 800 representative systems serving fewer than 3,300 people. Under UCMR 5, all systems serving between 3,300 and 10,000 people may also be required to participate. The number of these systems that will be required to participate is subject to EPA funding, which must cover associated shipping and analytical costs, but EPA estimates that adequate funding is available. The agency has sent notifications to large systems and a portion of the small systems that must participate; it also has committed to notifying additional small systems subject to monitoring each year six months in advance of the respective year (July 1).

As part of the UCMR 5 monitoring program, samples will be collected and analyzed for 30 total contaminants: 25 PFAS using EPA method 533, four PFAS using EPA method 537.1, and lithium using EPA method 200.7 or an analytical method. Samples must be collected at entry points to the distribution system and will include two samples five to seven months apart for systems with groundwater sources or four quarterly samples for other sources (surface water, groundwater under influence of surface water, or mixed sources).

As with previous UCMR programs, representative sampling for multiple groundwater wells can be conducted provided the sources (1) are in close proximity to and draw from the same source as the representative well, (2) represent wells with the highest annual volume that are most consistently active, and (3) will be in use at the scheduled sampling time. Also, representative sampling can be conducted for systems that purchase water with multiple connections from the same wholesaler.

In addition to water quality monitoring requirements, water systems will be asked to submit facilities information. Some information (service area zip codes, disinfectant types, and treatment processes) has been collected previously and will need to be confirmed. UCMR 5 will require additional data, including information on previous PFAS and lithium testing and prior awareness of potential current and/or historical sources of PFAS affecting each facility's water supply.

EPA has prepared an information compendium for contaminants to summarize key information, such as health effects. This compendium will help inform public communications for water systems implementing UCMR 5.

## Preparing for UCMR 5

Applicable water systems should begin to prepare for UCMR 5. Specifically, water systems should verify receipt of either an email or a mailed letter notifying them of participation in UCMR 5. This notification includes a one-time-use "customer retrieval key" and directions to set up the Central Data Exchange account with EPA's UCMR reporting system, the Safe Drinking Water Accession and Review System (SDWARS). Systems should contact EPA's implementation contractor at ucmr5@glec.com if the notification email or letter was not received.

Using SDWARS, systems should complete pre-monitoring activities by Dec. 31, 2022, beginning with establishing points of contact, indicating service zip codes, nominating additional users for the system, and reviewing the sampling location inventory. Small systems should indicate a physical shipping address for sampling kits and respond to the specific UCMR 5 data elements. All systems should review EPA's draft sampling schedule and, if needed, request modifications. Large systems have the opportunity to review and modify schedules through Dec. 31, 2022, in SDWARS, but after this date must contact EPA via email at ucmr_sampling_coordinator@epa.gov to request any changes. Small systems also may request that EPA modify their schedule by sending an email to UCMR5@glec.com.

For systems that intend to use a groundwater representative monitoring plan (GWRMP), plans should be submitted at least six months before the first scheduled sampling event. Systems scheduled for sample collection in 2023 should submit plans by Dec. 31, 2022. GWRMPs approved under previous UCMRs may be used for UCMR 5 if there are no significant changes since their prior approval. Requests to amend GWRMPs (e.g., adding a well) must be submitted. Systems can submit plans and amendment requests for GWRMPs by emailing ucmr_sampling_coordinator@epa.gov. Representative sampling from wholesaler connections (multiple connections from one wholesaler) does not require EPA approval.

As with previous UCMRs, large systems serving more than 10,000 people will be responsible for contracting with a laboratory for analytical services. EPA has posted and will continue to update its list of approved laboratories in advance of UCMR 5 implementation. Systems can email questions to ucmr5@glec.com.

AWWA has developed the following resources that may be useful as water systems complete UCMR 5 requirements: *Trending in an Instant: A Risk Communication Guide for Water Utilities* (https://news.awwa.org/Trending) and *Source Water Evaluation Guide for PFAS: Technical Support for Per- and Polyfluoroalkyl Substances Policy* (https://news.awwa.org/PFASGuide).

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