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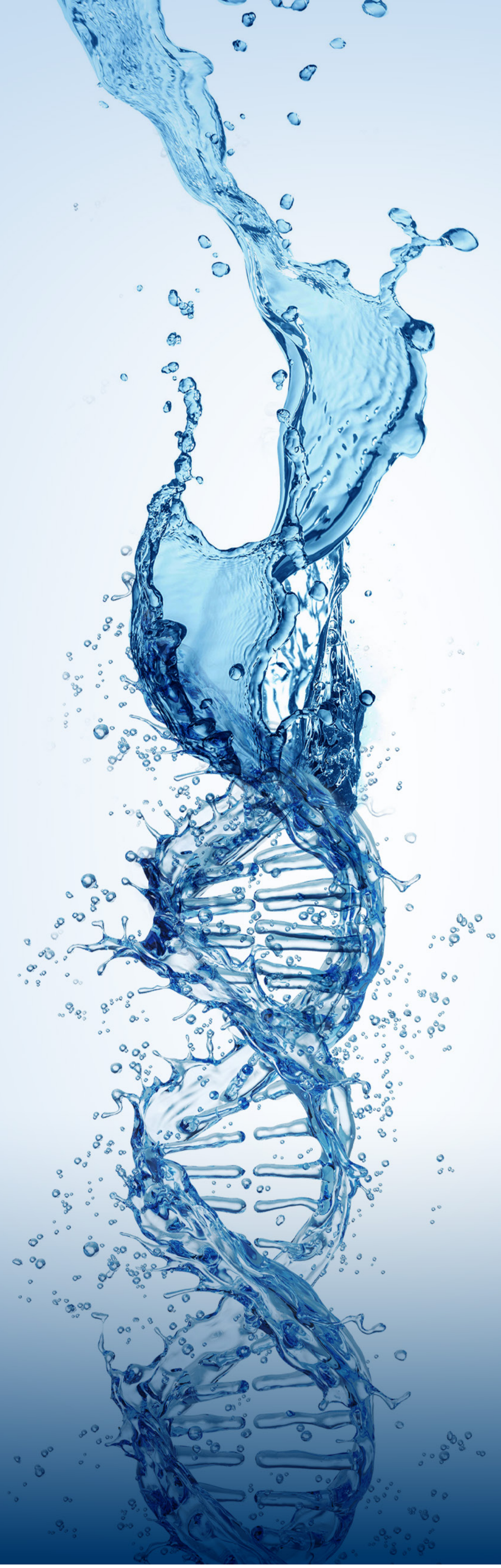

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FROM THE EDITOR

By Kevin Westerling
Chief Editor, editor@wateronline.com

Clearing LCRI Hurdles

Assessing what lies ahead in the 10-year race to go lead-free, otherwise known as the Lead and Copper Rule Improvements (LCRI).

It's been clear for the past decade, since the Flint water crisis, that the U.S. government is committed to eventually removing all lead from water distribution systems. For those who understand drinking water infrastructure, it was just as obvious that this ambition was fraught with difficulties around how to locate, how to pay for, and how to replace all lead-leaching pipelines, especially when the problem pipes are lead service lines (LSLs) on private property. But that's exactly what must be done over the next decade.

With the finalization of the Lead and Copper Rule Improvements (LCRI) on October 8, the full scope of the challenge was made official. It requires drinking water systems to identify and replace lead pipes within 10 years, while implementing stricter water testing and lowering the action threshold for lead from 15 µg/L to 10 µg/L. The rule also emphasizes better communication with communities about lead risks, pipe locations, and replacement plans.

Backed by $2.6 billion in new funding from the Bipartisan Infrastructure Law that will be distributed through the drinking water state revolving funds (DWSRF) program — with nearly half designated for disadvantaged communities — alongside $35 million available in competitive grants, the initiative targets the 9 million homes still served by lead pipes.

It's a noble and right-minded pursuit, to be sure. According to CDC and WHO, there is no safe level of lead in a child's blood. The need is therefore apparent, but that doesn't remove the difficulties in reaching the lofty goal.

Here are four prominent issues that arise, along with strategies for addressing them:

1. **Locating Lead**

   Problem: Identifying LSLs can be time-consuming and difficult, but water systems already know this having (hopefully) submitted their initial inventory of service line materials by Oct. 16, 2024, pursuant to the Lead and Copper Rule Revisions (LCRR). However, while the LCRR allowed for the "unknown," the LCRI requires water systems to regularly update their inventories and identify the materials of *all* service lines.

   Solution: Municipalities can invest in technologies such as predictive modeling, ground-penetrating radar, and smart water meters to locate lead pipes. Public engagement is also helpful, as residents may have valuable information about past plumbing work.

2. **High Cost of Replacement**

   Problem: The cost of replacing lead service lines can range from a few thousand to tens of thousands of dollars per line, depending on local conditions and the length of the pipe.

   Solution: To address the high costs, municipalities and utility companies can seek federal and state funding (see EPA's website identifying available funding sources). Offering subsidies or financial assistance to low-income households can also help alleviate the burden.

3. **Disruptions to Communities**

   Problem: Replacing service lines often requires digging up streets, sidewalks, and yards, which can be disruptive to communities. In addition, property owners need to be notified and grant permission for replacements, leading to delays.

   Solution: Communication with residents and local planning authorities is crucial. Offering clear timelines, minimizing disruption by employing trenchless technologies, and ensuring property owners understand the long-term benefits of the project can mitigate resistance.

4. **Health Risks During Replacement**

   Problem: Lead can be disturbed during the replacement process, causing short-term spikes in lead levels in drinking water.

   Solution: To minimize this risk, utilities should flush pipes immediately after replacement and provide filters to affected households. Educating residents on how to avoid lead exposure during the replacement process (e.g., using cold water for cooking and drinking) is also important.

Despite these challenges (and many others sure to crop up over the next decade), by accessing available financial assistance, committing to clear communication, embracing innovative technologies, and leaning on regulatory support, U.S. water systems will meet the aggressive lead-free mandate and do what they always do: provide safe drinking water for their communities.

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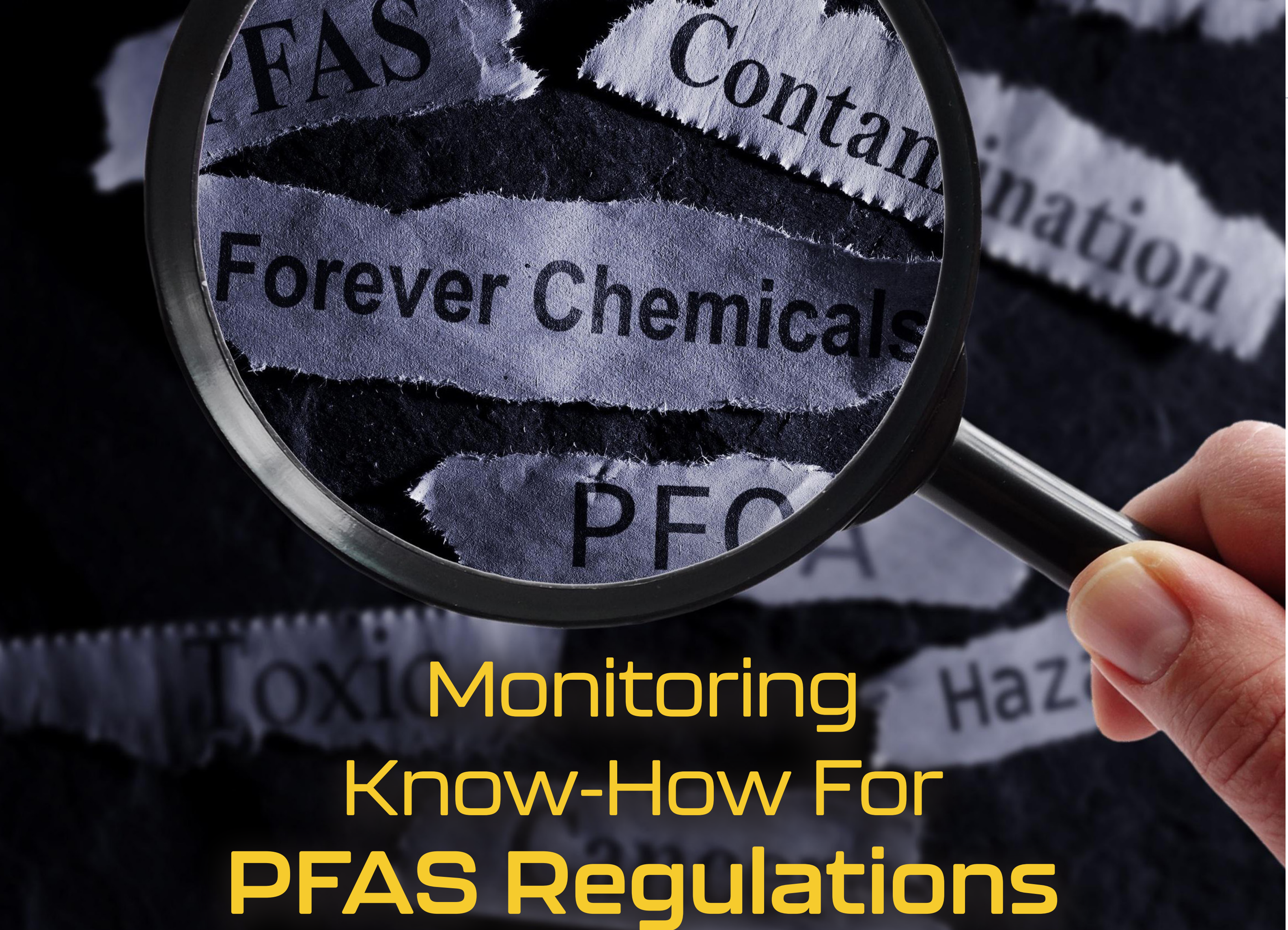

Monitoring Know-How For PFAS Regulations

By Kevin Westerling

A Q&A to explain and resolve issues confronting water suppliers as they endeavor to comply with the monitoring requirements of federal PFAS regulations.

The road to an environment — and drinking water — completely free of per- and polyfluoroalkyl substances (PFAS) will be a long one, but the U.S. EPA is working faster than usual to solve the problem of these "forever chemicals." Before public water systems (PWSs) are mandated to treat down to Maximum Contaminant Levels (MCLs) established by the EPA's recently finalized rule, PWSs must first monitor for PFAS to see where they stand.

To better understand the new rule and its requirements, as well as best practices for accurate and efficient monitoring, I spoke with Peter Rundell, business development manager and environmental testing expert at Microbac Laboratories. Peter has garnered extensive experience in the industry after having earned a Bachelor of Science in environmental studies from the State University of New York College of Environmental Science and Forestry. He's at the forefront of understanding and navigating the complexities of environmental testing, particularly in areas like PFAS regulations and compliance, making him ideally suited for this moment, these challenges, and the following Q&A.

What are the monitoring requirements and timelines pertaining to the recently finalized PFAS regulations for drinking water systems?

On April 10, 2024, the EPA finalized legally enforceable regulations for the National Primary Drinking Water Regulations (NPDWR) under the Safe Drinking Water Act (SDWA) for six PFAS, including PFOA, PFOS, PFHxS, PFNA, HFPO-DA, and mixtures containing two or more of PFHxS, PFNA, HFPO-DA, and PFBS.

Peter Rundell
Environmental Testing Expert
Microbac Laboratories

Public water systems have three years, until 2027, to complete the initial monitoring phase, followed by ongoing compliance monitoring, outlined below. By 2027, PWSs must also provide public information about PFAS levels in drinking water.

If initial monitoring shows that drinking water levels exceed the maximum contamination levels, then PWSs have five years, until 2029, to implement solutions to reduce PFAS levels. Beginning in 2029, water systems exceeding MCLs are required to take action to reduce the PFAS levels and notify the public of their violation of the MCLs.

What is required for ongoing compliance monitoring will be based on the results of the initial monitoring data.

What monitoring methods are available for meeting the new rule's requirements, and how are they fundamentally different?

Within the first three years, Community Water Systems (CWS) and Non-Transient Non-Community Water Systems (NTNCWS) must complete the initial monitoring at all entry points to their distribution system.

Based on system size and source water at an entry point, systems must conduct initial monitoring either twice or quarterly during a 12-month period as follows:

- Surface water systems serving all population sizes: Samples are collected quarterly, two to four months apart, within a 12-month period.
- Groundwater systems serving > 10,000 customers: Samples are collected quarterly, two to four months apart, within a 12-month period.
- Groundwater systems serving ≤ 10,000 customers: Samples are collected twice, five to seven months apart, within a 12-month period.

Alternatively, primacy agencies can allow systems to use previously collected monitoring data to satisfy some or all of the initial monitoring requirements if the sampling data meets the monitoring requirements. Data collected using EPA Methods 533 or 537.1 as part of UCMR 5, state-level, or other appropriate monitoring campaigns will meet the monitoring requirements.

For instance, Microbac Laboratories already conducts analyses following EPA Methods 537.1, which tests for 18 PFAS chemicals. When combined with EPA 533, this tests for 25 total PFAS chemicals. The EPA 533 is considered the gold standard for drinking water analysis as it tests for the most PFAS chemicals. Microbac also conducts analyses following the new official EPA 1633 method, which tests for 40 PFAS chemicals in groundwater, wastewater, sludges, and solids.

After the initial monitoring phase, PWSs must begin ongoing compliance monitoring at all entry points to the distribution system. What is required for ongoing compliance monitoring will be based on the results of the initial monitoring data. If samples have PFAS levels above the trigger at an entry point, they must perform quarterly sampling. After four consecutive samples at less than the trigger, they can reduce sampling to once yearly. Then, after three years of levels less than the trigger, it can be reduced to triennial (once every three years) compliance monitoring. On the other hand, if system samples are already less than the trigger values at the entry point during the initial monitoring phase, the sampling frequency can be reduced to triennial at the end of that initial three years. Systems with multiple entry points may establish different compliance monitoring schedules for each entry point depending on their monitoring results.

What considerations come into play for choosing the best monitoring tool for a particular water system?

The EPA encourages all PWSs to contact their state laboratory certification program to seek state primacy program guidance on selecting a qualified lab to complete PFAS testing requirements. Even if your state does not yet have a certification program for PFAS, the EPA still prefers that you contact them to help guide you in selecting a qualified laboratory. They will likely direct you to a laboratory that is certified nationally to monitor PFAS under the UCMR 5 Program rather than choosing a laboratory that is not certified.

What are some monitoring pitfalls or common mistakes for operators to avoid?

The most common monitoring mistake is not following the sampling guidelines established by the states or laboratories; be sure to follow your laboratory's recommendations closely.

Another common issue is that, since PFAS limits are set very low, it can be easy to accidentally introduce PFAS into the samples from outside the water source. There are multiple precautions you can take on testing day to avoid this. For instance, avoid wearing clothing or boots with waterproofing like Gore-Tex, Tyvek, etc. Additionally, certain fabric softeners, fragrances, cosmetics, moisturizers, sunscreens, and insect repellents may also contain PFAS, so avoid wearing those on the day of sampling. Latex gloves must also be avoided as they contain PFAS; powderless nitrile gloves are a safer alternative but may still contain low levels of certain PFAS, so be sure the gloves only touch the outside of the sampling bottle. Finally, do not use permanent markers, Post-it notes, or waterproof paper since many also contain PFAS; use only ballpoint pens and regular notepads without sticky adhesives or waterproofing.

Conversely, are there tips or tricks to improve monitoring outcomes?

Here are some tips to improve outcomes and ensure more accurate test results.

- Always have a plan in place before you proceed.
- Always follow the list of sampling precautions that your laboratory provides.
- To avoid contamination of the samples, follow all the recommendations above to avoid using anything on sampling day that could contain PFAS (e.g., avoid Gore-Tex, sunscreen, insect repellants, latex gloves, permanent markers, etc.).
- Collect only your PFAS samples on the day of collection, or at least collect them first. Do not collect other samples with them because some sampling bottles contain Teflon.
- Make sure the samples are iced and placed in a clean cooler. If using blue ice blocks, ensure they are certified PFAS-free.
- Use the same cooler each time you do your PFAS sampling and only use it for PFAS samples; never store other samples in it.

What role does monitoring play on the wastewater/industrial side, for PFAS source identification, control, and treatment?

Monitoring the wastewater/industrial side can play an important role in seeing what is coming from the upstream side. Some states have instituted requirements for monitoring for PFAS or absorbable organic fluorine (AOF) in the influent, effluent, and industrial sludges for wastewater treatment plants. Some states have eliminated the use of PFAS in products made in their states. These measures will help eliminate PFAS at the entry point of PWSs and the environment.

The new method for wastewater and sludge monitoring is EPA 1633, which covers 40 PFAS chemicals. Some laboratories are using other methods, such as AOF and TOF (total organic fluorine), but these do not measure individual PFAS chemicals and are used more as a screening method to help indicate the need for further testing. The testing of PFAS has evolved greatly over the last 10 years and will likely continue to evolve as new chemicals are added to the monitoring requirements.

There are many ways of controlling and treating PFAS in water systems. Resins, granular activated carbon, and reverse osmosis are currently being used to remove PFAS from drinking water. Many new technologies are also currently being developed.

The most common monitoring mistake is not following the sampling guidelines established by the states or laboratories.

What are the biggest challenges about PFAS rules compliance, and how can they be overcome?

Since the PFAS limits are set very low, it may be difficult for many systems to comply with the SDWA regulations when their levels are at or above the regulation limit. They will have to comply by implementing expensive systems to remove the PFAS from their drinking water. It will take time before PFAS sources are reduced, which puts the financial burden of addressing PFAS on the PWSs. This may be difficult for some systems, which may have to rely on taxpayer money to pay for it. Additionally, many individuals, municipalities, and states are now suing the companies that produce PFAS to help compensate them for cleanup costs.

The PFAS program is expected to evolve in the future to include additional PFAS chemicals that are not yet regulated. New test methods are currently identifying 30 or more chemicals that are not considered in the newly adopted regulations. ■

About The Author

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STRESS RELIEF For Water Distribution Systems

Identifying challenges and solutions for the management of aging drinking water infrastructure.

By Ainsley Lawrence

Americans use a lot of water — about 82 gallons per day. Per family, over the course of a year, about 9,400 gallons of that is wasted due to leaks, cracks, and faulty plumbing[1]. On a national level, this corresponds to over 900 million gallons of wasted water annually.

It's not just homeowners who are fretting over leaks, cracks, and inefficient plumbing. Many of the nation's municipalities now face critical challenges of maintaining aging water distribution systems.

Failing to address these issues can lead to significant costs and environmental damage. Municipalities that need to replace or restore their water systems can get ahead of the curve by utilizing emergent technology such as smart sensors and acoustic leak detectors to identify issues and begin proactive maintenance.

Assessing The Damage

The American Rescue Plan Act (ARPA) freed up funding for many municipalities that needed to tackle the aging water infrastructure. After decades of underfunding, this represents a much-needed boost to the budgets of many water utility firms and government agencies. The average state is spending 10% of its ARPA budget[2], or $20 million, on water repairs.

The funding that states like Idaho and Alabama (which have contributed $300 million and $600 million, respectively) have poured into water system management must be utilized effectively to ensure that long-standing supply issues are managed properly. Municipalities must address existing and emergent challenges including:

Failing to account for the age of pipes and potential contamination can cause exposure to parasites in water systems and increase the risk of exposure to per- and polyfluoroalkyl substances (PFAS).

- Cracks, leaks, and faults
- Lead service lines
- Emerging contaminants
- Climate-related risks such as flooding, storms, and droughts

Municipalities that suspect they need to upgrade their water infrastructure can partner with service providers to properly assess the damage and begin maintenance efforts. Partnering with utility firms can aid efforts to:

- Detect leaks and assess the severity of the damage
- Complete non-invasive damage detection to determine the remaining useful life of the infrastructure
- Monitor pressure in real time
- Complete no-dig lead service line surveys

Many utility firms now use automated tools to detect signs of damage and schedule repairs. These advanced technologies can aid municipalities' efforts to assess water quality and schedule maintenance without turning off supply or otherwise disrupting normal functioning.

Assessing Water Quality

Managing aging water systems is as much about tracking poor water quality as it is about improving existing systems' efficiency. Effectively assessing the quality of the water on offer through public systems is key, as research published by the U.S. EPA[3] shows that water quality can be undermined by factors such as:

- Biofilms
- Corrosion
- Intrusion
- Leaching
- Water age

This can undermine public health and increase the risk of waterborne disease. Failing to account for the age of pipes and potential for contamination can cause exposure to parasites in water systems and increase the risk of exposure to per- and polyfluoroalkyl substances (PFAS).

Smart Tools

Assessing the quality and condition of existing water distribution systems is easier today than ever before. Technicians no longer need to switch off the supply to find leaks and shouldn't need to manually assess fluctuations in pressure. Instead, modern utility firms can lean on a host of smart tools that collect and analyze water-related Big Data. This can help municipalities keep track of:

- Water demand
- Flow
- Pressure
- Asset condition
- Pressure transients

Keeping track of the data points can reduce the risk of customer disruption and aid efforts to assess changes in water distribution systems. Delving into the realm of Big Data can help municipalities prioritize elements of their system that are in greater need of repair/replacement than others. This can smooth out efforts to improve supply, reduce leakage, and reduce the risk of bursts.

Predictive Maintenance Solutions

Many aging water distribution systems do not need to be replaced immediately. However, systems that are coming toward the end of their usefulness need to be regularly maintained using proactive tools that maximize the lifespan of the equipment. Municipalities can extend equipment longevity by following equipment maintenance best practices:

- Simple maintenance tasks like lubricating, cleaning, and replacing minor worn parts such as valves
- Regularly retraining employees to reduce wear and tear
- Improving public awareness of non-flushable items to reduce strain on water systems
- An emergency response plan to improve recovery times if an aging water system becomes damaged

A proactive approach to maintenance can reduce long-term costs while protecting the public from issues like contaminated water. This is key to efforts to manage aging water distribution systems, as replacing water systems will require a coordinated long-term approach to operations.

Collecting Big Data can help municipalities decide whether to replace or repair existing assets. When deciding between repair and replacement, municipalities should consider the costs and performance associated with new assets. Utility firms should also use smart technology to conduct root cause analysis, as this reduces the risk of replacing a part damaged by an upstream fault. Strategically replacing/repairing parts is particularly important today, as water quality regulations are becoming increasingly stringent.

Conclusion

Municipalities finally have the funding they need to replace aging water distribution systems and protect public health. However, governmental agencies will need to lean on smart tools and emergent technology to accurately assess the challenges associated with replacing or repairing existing infrastructure. An AI-driven approach to decision-making can aid efforts to collect key data points and will ensure the leveling up of the nation's water systems causes minimal disruption. ■

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About The Author

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Securing Remote Monitoring Systems In Water Distribution Networks: Key Insights And Strategies

Introducing eight security principles to enhance utility resilience and protect sensitive data.

By Christian Bonawandt

The increasing adoption of remote monitoring technologies has revolutionized the management of water distribution systems. These technologies provide real-time data that enhances efficiency, reliability, and resilience. At the same time, they have also introduced new risks in the form of security vulnerabilities. A recent study published in *Engineering Science & Technology Journal*[1] offers three key insights to securing remote monitoring systems in water distribution networks, which highlight the importance of comprehensive security measures, the challenges posed by remote monitoring technologies, and the lessons learned from international collaborations.

Challenges And Risks

The study highlights several key areas of vulnerabilities that can compromise the security and functionality of water distribution networks. Remote monitoring systems are vulnerable to cyber-attacks, including malware, ransomware, and phishing. Such threats can exploit software vulnerabilities, disrupt system operations, and compromise data integrity. As a result, they pose a risk of potential service disruptions, public health risks, and damage to public trust.

Much of these risks stem from the complexity of integrating remote monitoring systems with existing legacy infrastructure. Many water distribution networks use a mix of old and new technologies, which can create vulnerabilities if not properly secured. Utilities must give careful consideration of both cybersecurity and operational challenges when combining new technologies with legacy systems to prevent potential weaknesses from being exploited.

The vast amount of sensitive data produced by remote monitoring systems also raises data security and privacy concerns. The authors recommend using robust encryption and authentication mechanisms to mitigate the risk of data breaches and unauthorized access.

Lastly, many utilities struggle with limited resources, both financially and in terms of technical expertise. This is particularly true of those that serve remote areas, developing regions, or small communities.

Utilities must give careful consideration of both cybersecurity and operational challenges when combining new technologies with legacy systems to prevent potential weaknesses from being exploited.

Principles Of Effective Security

The authors conclude that securing remote monitoring systems in water distribution networks requires adhering to eight core security principles. These principles should be used to guide the design, implementation, and management of security measures, ensuring that systems are robust, adaptable, and sustainable against evolving threats.

1. ***Defense in depth.*** Utilities must employ multiple layers of security controls to protect information systems. This approach, inspired by military strategy, involves integrating various protective mechanisms, including physical security, network defenses, application safeguards, and data encryption. Each layer acts as a barrier, ensuring that if one fails, others continue to offer protection.

2. ***Least privilege.*** This practice limits access to the minimum necessary for users and systems to perform their functions. By restricting permissions to only what is needed, this principle reduces the potential impact of breaches and the risk of unauthorized access. In remote monitoring systems, applying least privilege helps prevent misuse and limits damage from insider threats.

3. ***Segmentation and isolation.*** Utilities should create distinct zones within a network and manage access among them. This is crucial for safeguarding sensitive areas, such as operational technology networks, from vulnerabilities in less secure zones, like corporate IT networks. By containing security breaches within isolated segments, utilities can reduce the risk of lateral movement by attackers.

4. ***Continuous monitoring and response.*** Ongoing surveillance of network activity and a proactive incident response plan allows for early detection of anomalies and potential threats, enabling prompt intervention. An effective response plan ensures that security breaches are quickly contained and mitigated, minimizing operational disruptions.

5. ***Security by design.*** The authors advise integrating security measures from the earliest stages of system development. This means incorporating security considerations into the design, development, and deployment phases. Addressing security from the start helps identify and address vulnerabilities early, resulting in more resilient systems.

6. ***Scalability and flexibility.*** Security measures must be both scalable and flexible to adapt to the growing and changing needs of water distribution networks. As networks evolve or new technologies are integrated, security solutions should scale effectively and adapt to new threats, incorporating emerging security technologies and practices.

7. ***Sustainability and maintainability.*** Remote monitoring systems should be both environmentally sustainable and easy to maintain. This involves regular updates, patches, and reviews to ensure ongoing effectiveness against new threats. It also considers energy-efficient technologies to enhance overall system sustainability.

8. ***Stakeholder engagement and training.*** Finally, engaging stakeholders and providing continuous training are vital for maintaining security awareness and readiness. Educating system operators, users, and management about security practices and their roles is crucial. Training programs should be regularly updated to reflect current security trends and threats.

Securing remote monitoring systems in water distribution networks is essential to safeguard against evolving cyber threats and operational vulnerabilities. By adhering to core security principles, utilities can enhance their resilience and protect sensitive data, ensuring reliable service for communities. Continuous stakeholder engagement and training will further empower organizations to stay ahead of potential risks, fostering a secure and efficient water distribution infrastructure ■

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PFAS FILTRATION: Designing For Smaller OPEX And Footprint

Keys to bring down the cost of PFAS treatment for operations with limited resources – or any operation using media filtration.

By Conrad Hopp

In April of 2024, the U.S. EPA announced two regulatory actions targeting PFAS (per- and polyfluoroalkyl substances), also known as "forever chemicals" due to their persistence in the environment and associated health risks. The first of the two, published on April 10, outlines drinking water standards for six individual PFAS and combinations therein. Nine days later, the EPA announced its rule designating two PFAS compounds, perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic (PFOS), as hazardous substances under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). These rulings will require the installation and operation of PFAS treatment technologies at municipal drinking water utilities as well as federal and industrial sites that utilized or manufactured PFAS.

The EPA has designated three technologies as best in class for PFAS treatment: granular activated carbon (GAC), ion exchange (IX), and reverse osmosis. Of the three technologies, GAC and IX, often collectively referred to as media filtration, are considered the gold standard for PFAS treatment due to cost advantages and performance reliability. When designing a media filtration system, there are two components that impact capital and operating costs:

1. Media selection
2. Mechanical design.

With thousands of systems due to come on-line in the years ahead, minimizing cost is essential to ensuring public money is used efficiently. While multiple factors must be considered in the design of filtration systems — including media selection — mechanical design is a centerpiece of cost and performance optimization.

Media Selection

Designing a media filtration system starts with selecting the most effective media given the unique water quality of each site. When comparing IX and GAC, the former is generally more

Metric per Industry Standards	GAC	IX
EBCT (minutes, PFAS Removal)	10	2
Hydraulic Loading (gpm / ft²)	2-10	6-18

cost-effective than the latter. While GAC is cheaper than IX resin per cubic foot, it requires a longer empty bed contact time to effectively treat PFAS. As a result, 5x more media are required to treat the same flow rate. This, in combination with a lower hydraulic loading rate, means that GAC systems require a larger footprint and higher capital costs.

In addition to capital costs, long-term operating costs such as media replacements must be considered. Organic compounds, including total organic carbon (TOC), compete with PFAS for adsorption sites on activated carbon. For the anion selective IX resin, anions like nitrate, sulfate, or chloride compete for exchange sites. The presence of co-contaminants can harm treatment performance and drive up the cost of ownership depending on media. Co-contaminants that require removal to a maximum contaminant level (MCL) may dictate media selection. For example, if removal of volatile organic compounds (VOCs), total trihalomethanes (TTHMs), or general TOC is critical, GAC may be preferred. Selecting the best media requires a deep understanding of the complex chemistry that underpins PFAS removal in the presence of a variety of co-contaminants.

Regardless of which media is right for the job, pressure vessels are required to facilitate the filtration process and have served water providers for decades to combat an extensive list of contaminants. However, system failures and expensive operational costs related to the mechanical design of pressure vessels can frustrate providers aiming to distribute clean, affordable water to their ratepayers.

Mechanical Optimization — 4 Tenets Of Pressure Vessel Design

Emphasis is often placed on media selection for longevity and operational costs; however, the mechanical design of pressure vessels is equally critical. Mechanical design not only impacts the performance and longevity of the media but also energy consumption, construction costs, and maintenance. Equipped with the four tenets of pressure vessel design, engineers can optimize vessel performance and maximize lifespan, providing customers the simplest and lowest cost of ownership. The four tenets are as follows:

1. Hydraulic performance
2. Media optimization
3. Corrosion management
4. Long-term operation & maintenance.

Hydraulic Performance

Designing for hydraulic performance is critical for minimizing energy consumption and maximizing media lifetime. When designing a pressure vessel for optimal hydraulic performance, engineers must pay attention to three regions:

1. The overdrain — where water enters the system and is distributed onto the media
2. The media bed — a resin or carbon-based media that removes contaminants
3. The underdrain — nozzles or a slotted pipe that separates treated water from media.

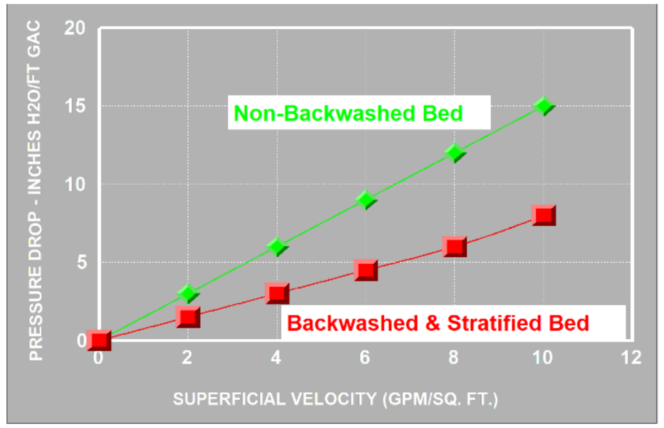
The coordinated sizing and geometry of these three regions dictates the long-term performance of a pressure vessel and has considerable effects on corrosion rates, lifespan, and operational costs. Each region must work in harmony to create a flow pattern that is linear and uniform where water moves parallel to the media with minimum mixing to ensure even contact. Achieving "plug flow" within the media bed under ideal hydraulic conditions is critical for effective treatment.

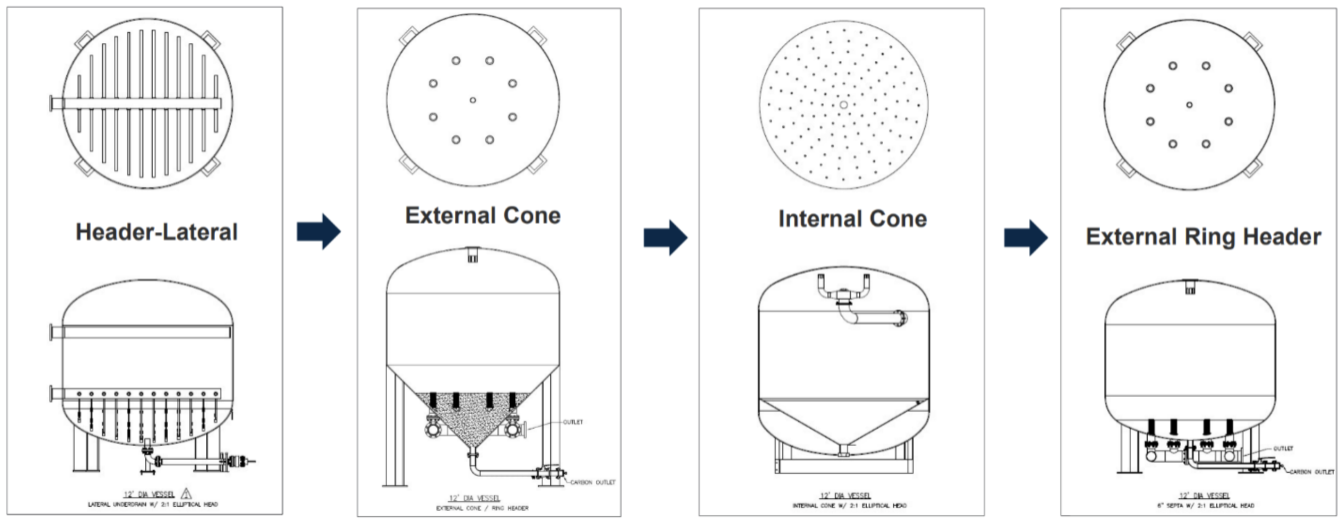
The Overdrain

Overdrain design establishes the pressure differential and distribution patterns within the system to provide optimal plug flow. Designs can vary from simple inlet diffusers to multi-point distributors, depending on the characteristics of the media used. IX resin beads are spherical and uniform in size, whereas activated carbon is a mixture of coarse materials. When resin is used in large-diameter vessels, such as a typical 12-foot-diameter vessel, a multi-point distributor is installed to ensure better flow distribution over the resin bed to prevent channeling at the higher hydraulic loading rates or movement of the bed itself. With GAC applications, lower hydraulic loading rates mean a basic diffuser or splash plate can provide sufficient distribution.

The Media Bed

Plug flow rate of a water column through the media bed is designed to maximize treatment kinetics and allow enough time for the migration of contaminant compounds to the surface of treatment media. Unlike ion exchange resin beads, carbon granules are made up of a mixture of coarse material. When carbon is loaded into a pressure vessel, it must be backwashed to stratify the carbon bed and minimize pressure drop. The figure below shows pressure drop for backwashed and non-backwashed carbon





beds with respect to changing superficial velocity. It is important to work with a vendor who can provide support from concept to commission.

The Underdrain
Four well-established underdrain designs play an equal and opposite role to the overdrain, maintaining appropriate outflow rates, plug flow, and pressure differentials. Each design can meet water quality and treatment goals. Underdrain design has improved incrementally to reflect the latest advancements in engineering, leading to the external ring header commonly used today when analyzed through the four tenets. An evolution of underdrain design is shown in the figure above. Older designs are still used today, even with advancements, due to vendors' knowledge and manufacturing capabilities. The three main designs commonly employed today are:

1. Header-lateral or hub-lateral — This design employs a horizontal drainage pipe with laterals to drain treated water. Some designs include drop-offs of the laterals down to the bottom of the vessel.

2. Internal cone — This is similar to a colander and is welded inside the unit.

3. External ring header — The external ring header uses nozzles and screens and fits flush with the vessel.

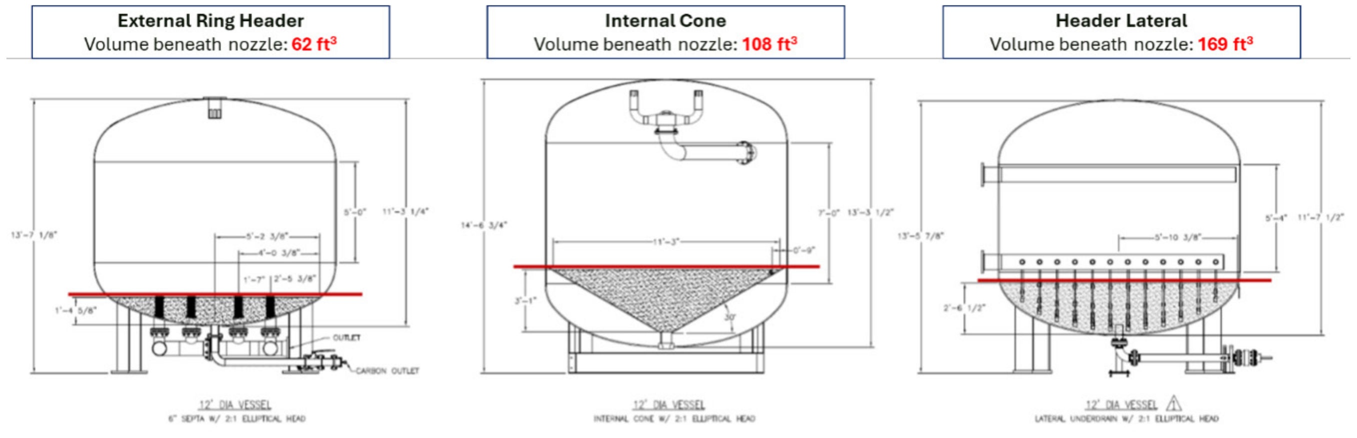
Using the external ring header — the latest evolution in underdrain design — reduces head loss throughout the system. Pressure drop for a 12-foot-diameter GAC system with 700 cubic feet of GAC operating at 1,000 gpm is 6 PSI for the external ring header vs. approximately 12 PSI for older designs. For end users that require multiple systems, this can translate to millions of dollars in energy savings over the operating lifetime.

Media Optimization
After media is selected for a specific job, optimizing its performance through mechanical design is critical to minimizing operational costs. There are two important factors to consider: the volume of fully utilized media and the establishment of an effective mass transfer zone (MTZ). This section focuses on minimizing underutilized media through underdrain design. Establishing an effective MTZ is accomplished by optimizing hydraulic performance and plugged flow, as discussed in the previous section.

Minimizing Underutilized Media
Making the most of the media from an initial fill goes a long way in delivering operational savings. Underdrain design plays an important role in minimizing underutilized media in a system. When plugged flow is achieved as the MTZ migrates linearly down through the bed, the first detection of contaminated water during the bed life occurs when the saturated media reaches the top of any nozzle where the screens allow water to filter through. This means any media sitting under the nozzles will not be 100% saturated before a change out is required. The image on the following page illustrates the media volume in the underdrain area for typical 12-foot-diameter vessels and how some designs underutilize a larger volume of media than others.

For a 12-foot-diameter system operating for 25 years, minimizing the underutilized media volume can save millions. The table below outlines lifecycle costs associated with the media volume contained below the underdrain, exclusive of future media price increases.

	External Ring Header	Internal Cone	Header-Lateral
GAC	$144,900	$252,395	$395,000
IX	$600,700	$1,050,000	$1,650,000



Corrosion Management
When using carbon steel, pressure vessel corrosion is certain. The design phase is an opportunity to anticipate and deter premature vessel corrosion. Engineers can ensure their solutions last with manageable operations costs by considering vessel materials, strong coating specifications, and underdrain design.

Material Selection
The anodic (most active) and cathodic (least active) metals used to build pressure vessels will inevitably interact. Accounting for this, a critical aspect of corrosion control is choosing materials that are close within the galvanic series, to decelerate the exchange of electrons between the two metals.

Linings and Coatings
Coatings are another important consideration of corrosion control. Some vessel specifications exclusively call for the coating of the anodic member, as this is the electron donor that erodes. However, NACE (now AMPP) recommends coating both cathodic and anodic metals to reduce the interaction between them.

Surface Preparation
Approximately 70% of coating failures are due to inadequate surface preparation. By utilizing industry best practices generated from the Society of Protective Coatings, SSPC SP-5, or NACE Standard RP0178-2007, as well as coating manufacturer recommendations, engineers can ensure that vessel materials are free of contaminants that affect mechanical adhesion of the coating or lining system. Welding specifications also lay the groundwork for long-term life and reduced corrosion rates, like NACE RP0178, which requires welds and sharp edges be ground down to create a smooth surface to build proper dry film thickness and mitigate voids.

Underdrain Design
A properly designed underdrain can prevent electrolyte build-up that corrodes vessel outlets. Per the welding specifications, avoiding unintentional crevices within the vessel will prevent water and media stagnation, which wears coatings and vessel materials.

1. Header-lateral: The internal structure of this design challenges the lining and can cause corrosion with dissimilar metals, crevasses, and welds.

2. Internal cone: Because of its shape, welding seams, and sharp edge hydrospheres, this design has lining challenges and can be prone to corrosion.

3. External ring header: This features one homogenous lining to avoid corrosive crevices and is fully rated to the ASME VIII design criteria.

Long-Term Operation & Maintenance
The final tenet of pressure vessel design considers how the vessel will be operated and maintained. The design choices made earlier in the process dictate the standard operating procedures required, particularly for the underdrains.

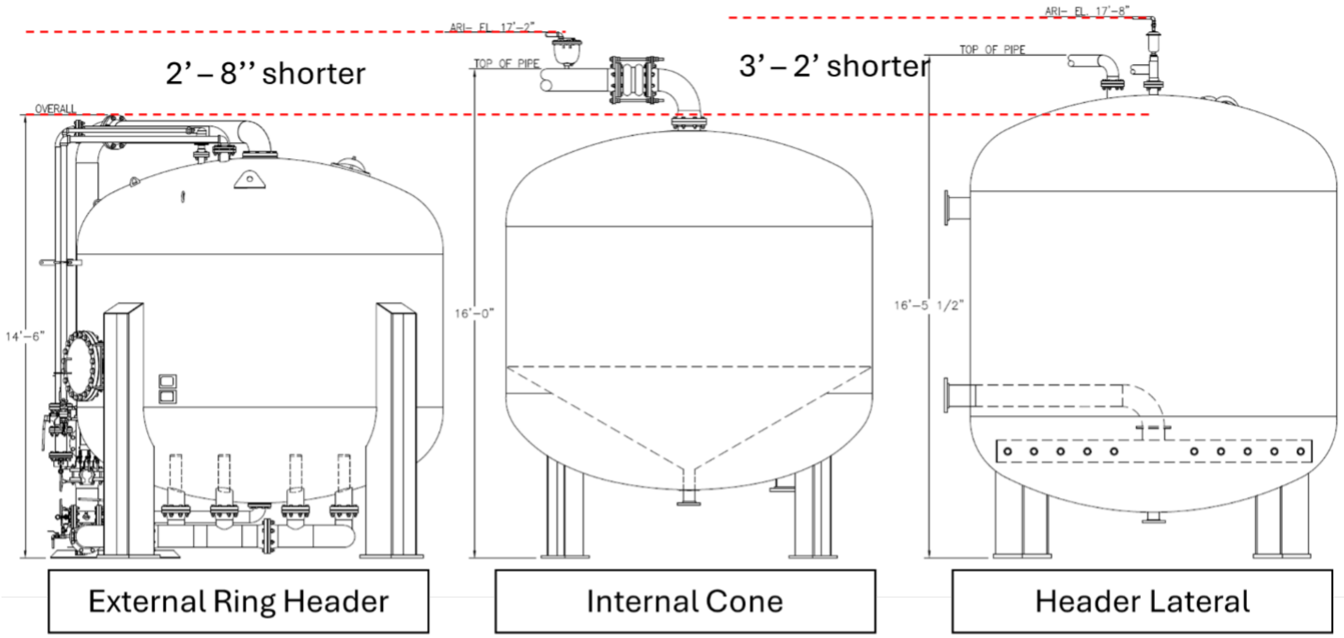
Ease of Maintenance
When vessel professionals discuss simpler designs, they're typically referring to ease of inspection during service events. Especially during media exchange, accessibility and lack of confined space protocol simplifies upkeep for operators.

1. Header-lateral: Media must be removed from the vessel for any underdrain maintenance and requires confined space protocol.

2. Internal cone: To gauge lining integrity, confined space entry is required both above and below the internal cone. The false bottom is not fully rated to the pressure vessel rating in upflow and downflow.

3. External ring header: This doesn't require carbon removal for maintenance, and it uses a simple forklift to remove the ring header for any potential maintenance.

For all designs, a 2:1 elliptical head should be designed to



Description	External Ring Header	Internal Cone	Header Lateral
NACE Standard #RP0178-2007 Compliant	✓	X	✓
Design Mitigates Risk of Corrosion	✓	X	✓
One Homogenous Lining	✓	X	✓
Underdrain Fully Pressure Rated to the Vessel	✓	X	✓
Media Optimized Design Volume Beneath Top Nozzle	✓	X	X
Optimizes Pressure Drop & Pumping Costs	✓	X	X
Prevents Confined Space entry	✓	X	X

create a circular bottom to allow the easy flow of media to the bottom center for removal without any flat areas where media can accumulate.

System Footprint

Pressure vessel systems often operate inside a building to protect them from the elements and to prevent them from becoming eyesores in the community. Considering height during design can affect the facility's broader operational costs. The annual electric costs related to HVAC and pumping water to the overdrain are directly affected by vessel height. Using the external ring header saves nearly three feet of height when compared to the internal cone design and just over three feet when compared to the header-lateral, as shown in the image above for a 12-foot-diameter, five-foot side shell external ring header system.

As discussed, there are several important factors that must be considered in the design of media filtration systems, many of which are associated with underdrain design. The table above highlights the key mechanical impacts of underdrain design.

With the EPA's announcement of regulatory actions regarding PFAS, considering the tenets of pressure vessel design is crucial to providing quality and cost-effective treatments. Thousands of systems are due to come on-line in the coming years, and working with a vendor that can provide support from concept to commission is critical for ensuring the long-term success of these systems. ■

About The Author

As Manager of Strategic Initiatives, Conrad Hopp supports the AqueoUS Vets CEO in four main capacities: planning and alignment, strategic partnerships and corporate development, strategic projects, and direct support. Conrad brings a deep understanding of the emerging contaminants market to the position and has a proven record of success leading the Advisory Services team at BlueTech Research, a global provider of water technology market intelligence.

How Transparency And Collaboration Delivered Millions In Savings For Wichita's Newest Water Treatment Plant

The **Northwest Water Facility** project illuminates the many benefits of the progressive design-build process.

By David Kinchen

A new water treatment facility that will deliver clean water to Wichita, Kansas, and the surrounding region for decades to come serves as an illustration of how collaborative project delivery through a two-step progressive design-build process can keep costs reined in even with a demanding schedule, a worldwide pandemic, labor shortages, record inflation, cost escalation, and general uncertainty.

When it begins operations in early 2025, the Northwest Water Facility's $500 million price tag will stand as the single largest capital investment in Wichita's history. While it is a substantial sum, it nonetheless represents a big win for the city. Not only does it represent significant savings over early budget projections, but also the schedule discipline maintained over the duration of this multiyear project will result in an estimated $93 million in interest and cost escalation savings for water ratepayers. These savings have been calculated by the U.S. EPA, based on the combination of early cost certainty and a 1.17% interest rate that was obtained under a federal financing program for municipal infrastructure improvements.

Critical Milestones

Delivering water at an affordable cost could be considered one of the most pressing responsibilities of any municipality. Yet, the costs of replacing aging systems needed to deliver clean and safe water often exceed the means of many communities. By 2018, those pressures were building for the city of Wichita.

Early in 2018, Wichita officials turned to Burns & McDonnell for a study to evaluate the current state of the city's water infrastructure, including the city's existing 80-year-old treatment plant. The study was finalized in May 2018 and confirmed that the plant was at the end of its useful life.

With that conclusion in hand, a budget for a new treatment facility began to be developed. Based on a conceptual design representing approximately 5% of the total engineering that would be required, a $524 million budget was set as a not-to-exceed design-plus-capital cost ceiling.

For the balance of 2018, crucial milestones were set for project development, including a formal procurement process by the city of Wichita to select a contractor to serve as design-builder for the project. The process concluded in February 2019 with the selection of Wichita Water Partners, a joint venture partnership of Burns & McDonnell and Alberici to begin the Phase 1 preliminary design and preconstruction for the project. More than 77% of all contracted dollars have stayed local to Wichita and more than 12% of contracted dollars have gone to emerging, disadvantaged, minority-owned, and/or woman-owned businesses.

The city's procurement process had left an extremely compressed timeline to comply with a series of tasks that had to be completed during Phase 1, with a hard milestone of October 31, 2019, the deadline to apply for federal funding available under the Water Infrastructure Finance and Innovation Act (WIFIA). Administered by the EPA, the program provides low-interest loans for up to 49% of the total budgeted cost of water facilities.

With a hard budget cap of $524 million, the team set to work identifying savings that could reduce the project's costs to be submitted for WIFIA funding while meeting the hard budget established more than one year earlier. The collaboration and communication enabled by the design-build process were critical at this juncture, as over 20 value engineering and optimization innovations were vetted for positive cost and schedule impact. These value engineering elements saved the city approximately $14 million when compared to the initial budget and scope, including an additional $10 million when the city elected to work with Evergy to self-perform design and construction of an electrical substation that would serve the new treatment plant.

All these savings rolled up to a final Phase 2 contract price of $494.2 million for the final design and construction of the new facility.

Tight Schedule

With a final contract value approved and other requirements met, the WIFIA application was submitted on time and was approved by early November 2019.

If that deadline had not been met, the WIFIA process would have started over, resulting in a delay of at least one year. Because interest rates were extremely low in late 2019, the city was able to lock in substantial interest cost savings over the life of the loan. Had the city been forced to wait until late 2020 to reapply, the interest rates under the WIFIA program would have been at least a percentage point higher.

WIFIA loans must be coupled with other funding mechanisms, and in Wichita's case that meant applying for funding through the Kansas State Revolving Fund (SRF). This source of funding represented approximately 48% of the project's costs, with the remaining amount of funding coming through local revenues.

Both loan applications were successful, thanks to the fact that the project was shovel-ready by the time documents were submitted as a result of the progressive design-build approach. This cost and schedule certainty was particularly important in securing the Kansas SRF funding, because draws against the loan must be done annually from funding allocated for that year by the Kansas Legislature. The city and the design-builder worked collaboratively to quickly develop a detailed schedule of values for the project and create cash flow projections based on a detailed design and construction schedule. These actions provided accurate costs measured over time. The resulting evaluation demonstrated that the monthly capital costs by the city and the cash flow necessary for the design-builder could be synchronized and support the SRF's funding limitations, while still meeting the schedule demands of the project for successful completion.

Added Complications

With financing checked off the list, the next big milestone was to complete site preparation and other steps so construction could commence no later than February 2020. The start date was a key requirement under WIFIA because payments are deferred for five years from the date of loan approval.

As a further complication, COVID was emerging as a global pandemic by February 2020, just as construction teams were mobilizing at the site. Given that the price and schedule were set, the project team utilized the full flexibility of the progressive design-build process by right-sizing design flows and prioritizing deliverables to support the various strategies needed to successfully navigate supply chain disruption, escalation, and labor shortages. Working with the state's regulatory agency, the team was able to break down the work packages through collaboration with the various regulatory agencies over design deliverables that were necessary to secure permit approvals within time frames that would not hold up construction.

Material and equipment costs were also carefully evaluated. Thanks to close collaboration and communication with the city, decisions were made to procure longer-lead-time items to minimize risk of delays in an already tight schedule.

This proactive procurement strategy was a key to success in staying on schedule and within the fixed price established for the contract. Because several key parts of the treatment facility required expensive equipment that would take significant time to manufacture and ship, those items were specified and ordered early. Once they arrived on-site, they were stored in a temporary warehouse built specifically for process-related equipment. Proper protected storage on the project site allows required maintenance to be performed until commissioning, start-up, and handover of the equipment to the owner, an event that starts the two-year warranty period.

Wants And Needs

The collaboration enabled by the progressive design-build process enabled the project team to accommodate several design adjustments to add significant redundancy to certain operational areas. Even with those adjustments, budget discipline was maintained, due to cost offsets achieved through an economical design of less critical plant features.

Some of those savings were realized through the types of material selected. For example, some of the large piping within the plant called for installation of expensive ductile iron pipe (DIP), but careful review of the design showed that some sections could be respecified for steel pipe, reducing the delay impact of the fabrication process of DIP. The steel fabricator also qualified as an Emerging Business Enterprise (EBE) under the City of Wichita's program, thus expanding the EBE program to new vendors and growing the local capabilities of the program.

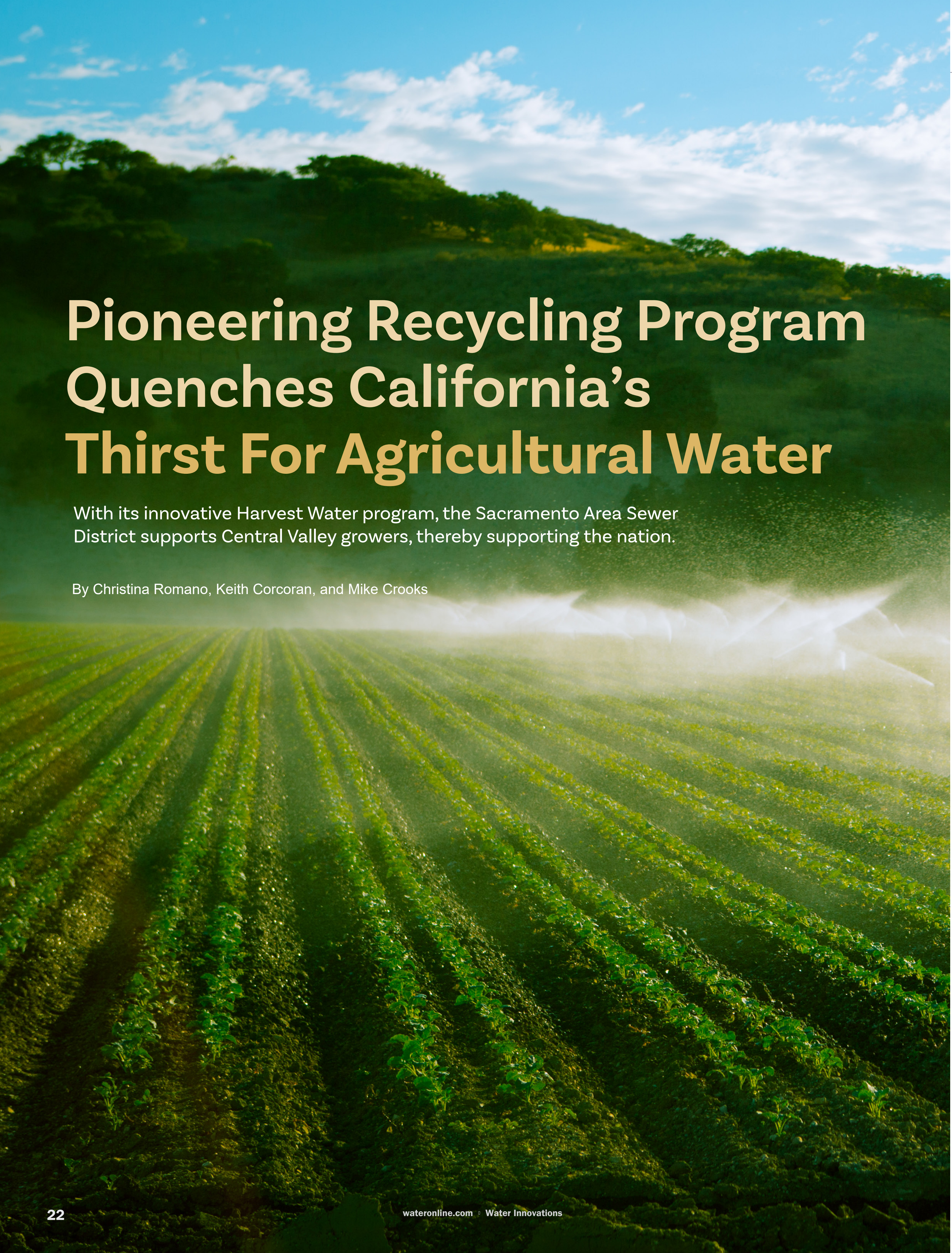
Right On Target

By the third quarter of 2024, the project had hit all scheduled milestones and stood at about 98.5% completion. Meeting scheduled milestones on this highly complex, four-year construction project is a noteworthy accomplishment, particularly because hiccups (i.e., unexpected issues) are commonplace. Thanks to the ability to stage elements of the project with adequate procurement lead times and schedule flexibility resulting from close collaboration with the city and our partners, we have maintained schedule discipline for the entire project duration.

Following performance acceptance testing beginning this fall, the keys to the facility are set to be turned over to the city by April 2025. This complex and highly critical infrastructure improvement will then stand as an illustration of what can be achieved through the power of partnership. ■

About The Author

David Kinchen is national construction director at Burns & McDonnell. Throughout a career spanning more than 35 years, Kinchen has led multidisciplinary teams on critical water, wastewater, power, aviation, healthcare, and government projects. He has become widely known for his industry experience with nearly every collaborative delivery method currently utilized in the construction industry.



Pioneering Recycling Program Quenches California's Thirst For Agricultural Water

With its innovative Harvest Water program, the Sacramento Area Sewer District supports Central Valley growers, thereby supporting the nation.

By Christina Romano, Keith Corcoran, and Mike Crooks

In the heart of California's Central Valley, a significant project is creating a blueprint for sustainable water management and collaboration in agriculture. The Sacramento Area Sewer District (SacSewer) is implementing what may be California's most ambitious agricultural water recycling program to date: Harvest Water.

Declining groundwater levels have impacted water sustainability in the region. This program will allow the use of recycled water instead of pumped groundwater for irrigation, raise local groundwater levels by up to 35 feet over 15 years, and increase groundwater storage by approximately 370,000 acre-feet.

Turning A Vision Into Reality

The story of Harvest Water began in 2004, when SacSewer set a long-term goal to increase recycled water deliveries by up to 40 MGD. A recycled water opportunities study completed in 2007 identified an agricultural use option originally known as the South County Ag Project, which eventually evolved into the Harvest Water program.

Bringing this visionary program to life requires more than just technical expertise — it demands collaboration and financial support. SacSewer worked with Woodard and Curran and the Freshwater Trust as part of the Administrative Program Management Office to plan, permit, and fund the program. This included securing a $291.8 million Proposition 1 grant through the Water Storage and Investment Program (WSIP) and a $30 million grant from the U.S. Bureau of Reclamation Title XVI Water Reclamation and Reuse Program.

A Rising Tide Lifts All Boats

The benefits of Harvest Water extend across the ecosystem:

- More than 5,000 acres of riparian and wetland habitat will be enhanced.
- Threatened species, like the Swainson's hawk, sandhill crane, and giant garter snake, will find new sanctuaries.
- The Consumnes River will see an increased duration of instream flows due to restored groundwater connectivity, supporting fall-run Chinook salmon.

A Drop Of Hope In A Dry Land

When complete, this $597 million program will supply up to 50,000 acre-feet per year — approximately 16 billion gallons of water — of drought-resistant, recycled water to local growers to irrigate more than 16,000 acres of agricultural lands.

The journey of this recycled water begins at the recently upgraded EchoWater Resource Recovery Facility, the second-largest tertiary treatment facility of its kind in the country. Thanks to the $1.7 billion upgrade, including $500 million in construction projects designed by Carollo, this facility now produces disinfected tertiary recycled water suitable for unrestricted use.

In 2020, SacSewer hired a joint venture team of Carollo, and Brown and Caldwell to provide capital program management services. This team, part of SacSewer's Capital Program Management Office (C-PMO), is overseeing the design and construction of Harvest Water's capital projects, including:

- A high-capacity, 105-MGD pump station.
- 42 miles of pipelines ranging from 12 to 66 inches in diameter.
- More than 100 on-farm connection assemblies.

Building Bridges, Not Just Pipelines

What sets Harvest Water apart isn't just its scale or innovation — it's the partnerships forged along the way. More than 100 growers have already signed letters of intent to receive water from the program — a testament to SacSewer's community-focused approach.

Scott Parker, a senior vice president at Carollo and a local grower, has been instrumental in bridging the gap between the growers' needs and the engineers' recommendations. Scott has worked with public relations liaisons to meet with every grower and discuss specifics, including details such as exactly where water will enter each customer's property. This dedication to personally connecting with each grower has been critical to gaining consensus from the agricultural community. Said Parker: "We're not just managing water. We're cultivating trust."

Construction is now in full swing, with five of the eight capital projects already awarded to contractors. Pipelines are currently being laid, and the pump station construction team has mobilized on site. SacSewer anticipates that the first drop of water will be delivered in early 2027.

Further information on the Harvest Water program can be found at www.SacHarvestWater.org.

About The Authors

Christina Romano is a vice president and professional engineer with Carollo Engineers. She is currently the program controls lead for the Harvest Water program and has been on the program management team since the capital program started in April 2020.

Keith Corcoran, PE, is a vice president with Carollo Engineers and leads its Northern California construction management group. He is currently the project manager for two Harvest Water pipeline projects and the construction management lead for the capital program team.

Mike Crooks is a licensed civil engineer with SacSewer and deputy director of operations at the EchoWater Resource Recovery Facility in Elk Grove, CA. In this role, he oversees the EchoWater Facility's engineering section and manages the EchoWater and Harvest Water capital improvement programs.