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EDITOR'S LETTER

By Kevin Westerling
Chief Editor, editor@wateronline.com

New President,
New Vision For Water

In the midst of this U.S. presidential race, a thought about Ronald Reagan (apolitical, I promise): Known as the "Great Communicator," it's certainly no coincidence that Reagan was an actor before becoming president; and honed communication skills, especially in times of trouble, are vital to effective leadership.

But this space is not reserved for talk of national presidential proceedings, thankfully. As it happens, the American Water Works Association (AWWA) has its own great communicator, Jeanne Bennett-Bailey, to be named president at the culmination of the organization's Annual Conference and Exhibition (ACE) — and not a moment too soon.

With the lead contamination of Flint, MI, and its fallout grabbing national headlines, water utilities are suddenly in the position of defending their longstanding, exceptional record of service. Add that to the existing storyline where water and wastewater utilities have, for years, struggled to convey the "value of water" — to obtain financing for infrastructure renewal — and it's clear that effective consumer outreach is more essential right now than ever before.

It's fortunate, then, that Bennett-Bailey is stepping in as president for AWWA. Even better than actor-turned-president, the 30-year industry veteran comes into the role having recently been public affairs officer at Virginia's largest drinking water utility, Fairfax Water, which serves nearly 2 million people in the Washington, D.C., metro area. Her focus, however, just got much bigger.

How will Bennett-Bailey allay fears and inspire progress in these tough times? Here are her thoughts — moreover, her words (an important distinction for communicators) — on four of the industry's biggest challenges.

On Flint: Restoring Confidence, Removing Lead

Water professionals understand that confidence is earned over many decades and can be damaged very quickly. They strive to produce safe water 24/7, and, in the vast majority of cases, they deliver on that goal. In many ways, water, like politics, is local. If a utility has good relationships with its customers, it's unlikely that what happens elsewhere will have lasting damage.

> *"It's difficult to say something good will come out of what happened in Flint, but if we fast-forward a few years, hopefully we'll see some positive outcomes.*
>
> **Jeanne Bennett-Bailey, president-elect, American Water Works Association (AWWA)**

An AP poll in the middle of the Flint crisis showed about half the population was either extremely confident or very confident in tap water. Two in 10 said they were not confident, so there's always more work that can be done. We need to continue to find ways for people to get to know their water. … It's difficult to say something good will come out of what happened in Flint, but if we fast-forward a few years, hopefully we'll see some positive outcomes. First, families will be more aware of all lead risks, including those from water, and they will be inspired to take steps to reduce exposure. And second, as a society, we'll have taken more purposeful steps to get the lead out altogether — lead service lines and home plumbing included. AWWA published a study in March that showed some 6.1 million lead service lines remain in the U.S. alone. That suggests there has been progress over the past couple decades, but there's a long way to go.

On Communication: Earning Positive Press

Generating positive media stories sometimes takes more work and planning, but it can be done and is being done by utilities every day. We can look for calendar moments such as Drinking Water

Water Innovations

101 Gibraltar Road, Suite 100
Horsham, PA 19044
PH: (215) 675-1800
FX: (215) 675-4880
Email: info@wateronline.com
Website: www.wateronline.com

CHIEF EDITOR
Kevin Westerling
(215) 675-1800 ext. 120
kwesterling@vertmarkets.com

ASSOCIATE EDITOR
Peter Chawaga
(215) 675-1800 ext. 124
pchawaga@vertmarkets.com

PUBLISHER
Travis Kennedy
(215) 675-1800 ext. 122
tkennedy@vertmarkets.com

ASSOCIATE PUBLISHER
Patrick Gallagher
(215) 675-1800 ext. 129
pgallagher@vertmarkets.com

PRODUCT MANAGER
Bill King
(215) 675-1800 ext. 100
bking@vertmarkets.com

MANAGING EDITOR
Michael Thiemann
(814) 897-9000, ext. 340
mthiemann@vertmarkets.com

DIGITAL PUBLISHING DESIGNER
William Pompilii
(215) 675-1800, ext. 115
bpompilii@vertmarkets.com

PRODUCTION DIRECTOR
Lynn Netkowicz
(814) 897-9000, ext. 205
lnetkowicz@vertmarkets.com

PRODUCTION MANAGER
Susan Day
(215) 675-1800, ext. 101
sday@vertmarkets.com

DIRECTOR OF AUDIENCE DEVELOPMENT
Martin Zapolski
(814) 897-7700, ext. 337
mzapolski@vertmarkets.com

DIRECTOR OF ONLINE DEVELOPMENT
Art Glenn
aglenn@vertmarkets.com

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Week or World Water Day to talk about the importance of water in all facets of our lives. We can engineer stories about water infrastructure, where we take media below ground to make the case for water infrastructure funding. We can show off innovative technologies that demonstrate how water professionals are forward-thinking and stewards of the environment. There's plenty we can do. It begins with building relationships with media before there's a crisis.

I think one of the most important things to remember is that we are often part of the community we serve. Our family, neighbors, and friends are also those that we serve. There are as many opportunities for us to share about the importance of water in our own backyard BBQs as there are for media stories.

On Infrastructure Financing: WIFIA And Washington

The U.S. Congress enacted the Water Infrastructure Finance and Innovation Act in 2014 as an innovative, cost-effective mechanism to help the nation renew, improve, and rehabilitate its aging water and wastewater infrastructures. But WIFIA came with some unnecessary budgetary red tape, specifically a ban on the use of tax-exempt debt in combination with WIFIA loans.

About a year ago, AWWA initiated a "free WIFIA" campaign to encourage Congress to lift that restriction. Thanks to the hard work of many members and partner organizations, Congress removed the ban in December of last year. That makes WIFIA a much more attractive financing tool. Still, in the fiscal years 2015 and 2016 omnibus spending bills, Congress provided only $2.2 million for the EPA to stand up the WIFIA program — no money for actual loans. It's time to appropriate money for WIFIA to do its important work.

Today, WIFIA loans can only support 49 percent of a project's costs — 100 percent would be better. We're asking Congress to remove that restriction, and we'll continue our longstanding support for funding State Revolving Funds.

… One proposal in the Senate related to Flint would actually direct $70 million in funding to WIFIA, which would leverage into at least $700 million in financing for water projects both there and elsewhere. So it's good to see Congress recognizing WIFIA's potential.

> *"… if we fail to expand our water portfolios by taking advantage of new technologies, we are in real trouble.*
>
> **Jeanne Bennett-Bailey, president-elect, American Water Works Association (AWWA)**

On Water Security: The Biggest Threat … And Promise For The Future

I believe that if we do not make efficient use of the water we have and that if we fail to expand our water portfolios by taking advantage of new technologies, we are in real trouble.

We can avoid these pitfalls in a number of ways. For instance, this past March AWWA announced a challenge to its member water utilities and others across the globe to complete 1,000 water audits over the next two years using AWWA's newest Water Audit Software. Simply gaining an understanding of where our water is going will go a long way toward eliminating waste.

We also need to begin taking a serious look at new technologies like desalination and reuse. They are expensive and difficult to implement, but I believe they are both critical to long-term sustainability. … As water sector solutions become more complex, water professionals won't be able to easily fall into drinking water or wastewater categories. Instead, I believe utilities will begin to view water more holistically. In many cases they will need to be looking for new sources and new treatment solutions. It's an exciting time, and I'm looking forward to seeing how it all works out.

A new vision indeed, communicated quite well. Great, even.

The Cure For Membrane Biofouling

After reviewing multiple methods, engineers and operators at a Pennsylvania water reclamation facility discover a winning pretreatment formula for reverse osmosis biofouling control.

By Michele Braas and Jason Wert

As more organizations, municipalities, and companies turn to water reuse as a means to decrease their water and energy footprints and reduce costs, these groups implement technologies that often involve low- and high-pressure membrane filtration. A common challenge of membrane filtration is biofouling, which is the colonization of the membranes by bacteriological growth, resulting in decreased performance of the membrane system. Biofouling particularly concerns municipal wastewater operators in their reclamation processes. These operators must consider the cost-effective application of technology to control biofouling while ensuring the technology provides other benefits such as advanced oxidation.

At the University Area Joint Authority (UAJA), serving an area in central Pennsylvania, leaders have implemented an advanced oxidation process (AOP) to control biofouling of its reverse osmosis (RO) system. The additional system simultaneously improves the Authority's ability to remove contaminants of concern.

The University Area Joint Authority

Surrounding Pennsylvania State University and the Borough of State College, UAJA provides wastewater collection, treatment, and water reuse to more than 80,000 residents. While not providing wastewater services to the university's entire campus, the Authority manages the surrounding growing community's need for long-term sustainability and watershed protection. Nearby flow the headwaters of Spring Creek, a high-quality, cold-water fishery. Because of its designation as "high quality" and the potential for temperature impacts from the heat within wastewater discharge, the Pennsylvania Department of Environmental Protection (PADEP) places strict limitations on both the quality and volume of treated effluent discharge allowed from the Authority.

Chemical	Use	Approximate Costs
Sodium Hydroxide	pH Adjustment	$34,000
Salt	Sodium Hypochlorite Production	$14,000
Reverse Osmosis Chemicals	Clean in Place	$10,000
Biological Control	Chlorination/ Dechlorination and Biocide	$262,000

Table 1. CY 2012 Costs For Chemicals Associated With RO

The UAJA facility meets tertiary effluence standards with some of the most stringent discharge limits in the state, including a 0.13 mg/L total dissolved phosphorus standard. First constructed in 1969 with a hydraulic design capacity of 3.84 MGD, the Authority upgraded its facility first in 1992 and again in 2002. The PADEP also granted re-ratings in 1993 and 2013. Today, the site is rated for a maximum monthly flow of 10.56 MGD and 50,000 pounds per day of organic loading.

To meet the PADEP's regulatory restrictions, the Authority implemented an award-winning water reuse program in 2002 and began operations with its new facility in 2005. It now reclaims a portion of its treated wastewater effluent to Spring Creek with water quality exceeding state and federal limits for drinking water.

The Authority also provides 1.0 MGD of beneficial reuse water to the community for swimming pools, laundromats, car washes, turf grass irrigation, heating and cooling supplies, and stream augmentation. This not only reduces the volume headed to Spring Creek but also offsets the potable water requirements within the community.

Advanced Water Treatment

The UAJA Beneficial Reuse Project Advanced Water Treatment Building houses a series of processes that transform secondary clarifier effluent into a water supply that meets all federal and state requirements for drinking water. Originally, the processes consisted of microfiltration, RO, pH stabilization, UV disinfection, and chlorination for distribution residual. After the most recent system update began operating, the Authority discovered the planned intermittent biocide treatment for water prior to its entry into RO did not sufficiently control biofouling. To stabilize pressure gains, the Authority installed a combination of chlorination and dechlorination steps prior to RO, with supplemental biocide application every few weeks.

During a periodic performance review in 2013, the Authority noted elevated salt passage and nitrogen concentrations in its reuse water. The resulting discharge was still within the required limits; however, the RO membranes had exceeded their usable life. The Authority elected to replace those membranes in 2015. With new membranes as part of the process, the organization decided to review all of its costs associated with the membrane operations, finding that its biofouling costs had risen dramatically throughout the years. Additionally, the Authority found that its equipment for on-site generation of sodium hypochlorite was worn and likely in need of a significant capital upgrade.

As part of its planning process, the Authority retained RETTEW, a firm specializing in environmental engineering, to evaluate, design, permit, and bid a cost-effective disinfection process upgrade featuring better control of biofouling, along with other water treatment advantages. Together, the partners selected a new disinfection process to reduce operational costs, improve disinfection performance, and replace the membranes.

The previously existing biofouling control method consisted primarily of injecting chlorine followed by dechlorination, as well as the periodic application of a biocide in the water stream prior to entry into RO. Operational costs for the previous planning year are shown in Table 1.

Advanced Oxidation Processes

One method to control biofouling is AOP, which destroys contaminants by oxidation using reactions with hydroxyl radicals. These radicals are one of the strongest oxidants that can be applied in water and are 200 percent more effective in oxidation than sodium hypochlorite. Hydroxyl radicals can oxidize most compounds present in water, including organic compounds, trichloroethylene (TCE), endocrine disrupting compounds (EDCs), N-Nitrosodimethylamine (NDMA), pesticides, and pharmaceuticals.

Hydroxyl radicals are generally produced using an oxidant with an energy source, such as the combination of ozone or hydrogen peroxide (H2O2) with UV light to produce highly reactive hydroxyl radicals. However, research indicates that ozone alone can provide AOP treatment when applied to secondary wastewater effluent. The ozone reacts with the organic matter in the secondary effluent, resulting in hydroxyl radicals. This reaction eliminates the need for the additional energy from UV light typically required to produce the hydroxyl radicals.

AOP Alternatives Evaluation

As part of the review of technologies for biofouling control, UAJA and RETTEW contacted various manufacturers that provide ozonation, UV disinfection, chlorine dioxide, or hydrogen peroxide for technical and economic considerations.

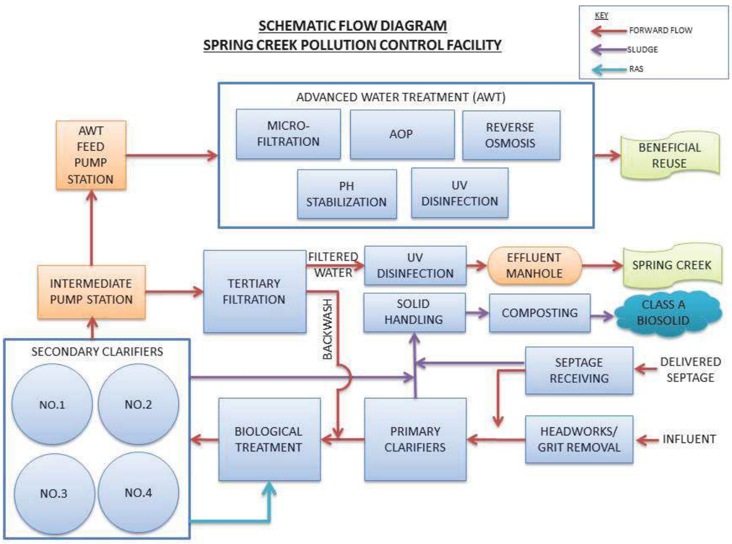
RETTEW took samples from the microfiltration effluent and provided them to various manufacturers to test for effectiveness of each manufacturer's systems and to determine key performance indicators to dictate operational economics. As the primary goal was to provide pretreatment for RO, the limited application of hydrogen peroxide in this location did not provide sufficient experience to merit further consideration and was not included in the bench-scale testing. The process used heterotrophic plate counts removal as the key indicator of biofouling control. The bench-scale testing indicated that UV, ozone, and chlorine dioxide performed equivalent to the Authority's existing biofouling controls and could reduce the plate counts to nondetect.

RETTEW then reviewed each alternative for implementation and economic impacts (see Table 2). All options were determined to be more cost-effective than the current treatment system.

The Authority and RETTEW also considered the potential benefits of applying technologies that could also be modified to an AOP. While the PADEP currently does not require AOP for indirect potable reuse, national trends indicate it could be dictated in the future, as the method is quickly becoming a required technology in water reuse applications similar to the Authority's reuse system. Additionally, the U.S. EPA Water Reuse Guidance Manual suggests AOP for implementation on indirect potable reuse applications, which the Authority would ultimately pursue in later phases of its Beneficial Reuse Project. As AOP could provide this subsidiary benefit consistent with

Parameter	Baseline Conditions	UV	Ozone (A)	Ozone (B)	Chlorine Dioxide
Equipment Capital Cost	$275,000	$105,000	$405,000	$520,000	$143,000
Installation Cost	$55,000	$124,000	$162,000	$162,000	$8,200
Total Capital Cost	$330,000	$229,000	$567,000	$682,000	$152,000
Sodium Hydroxide (pH) Annual Cost	$34,000	$34,000	$34,000	$34,000	$34,000
Salt (Dis) Annual Cost	$14,000	-	-	-	-
Reverse Osmosis Clean-In-Place Annual Cost	$10,000	$10,000	$10,000	$10,000	$10,000
Biological Control Annual Cost	$262,000	$10,000	$10,000	$10,000	$10,000
Electricity Annual Cost	$19,000	$4,800	$7,800	$8,000	$4,000
Other Consumables Annual Cost	-	-	$10,500	$24,000	$6,000
Maintenance Annual Cost	$9,100	$3,000	$8,500	$8,500	$29,000
Total Annual Cost	$348,100	$61,800	$80,800	$94,500	$93,000
Total 20-Year Cost	$7,292,000	$1,465,000	$2,183,000	$2,572,000	$2,012,000
Savings Over Baseline (Total)	-	$5,827,000	$5,109,000	$4,720,000	$5,280,000
Savings Over Baseline (Annualized)	-	$291,350	$255,450	$236,000	$264,000

Table 2. Opinion Of Probable Costs



national regulatory trends and guidelines, preference was given to these technologies. Of the alternatives tested, ozone could provide the additional advantage of AOP disinfection per EPA water reuse guidelines.

While UV disinfection provided the greatest economic savings to the Authority, the potential long-term benefits of AOP by ozonation led the Authority to select ozone disinfection as the preferred method. RETTEW designed the system to allow for future higher dosages, complying with recommended AOP methodologies and providing biofouling control.

The AOP System At UAJA

The AOP process consists of an ozone gas generation system combined with support processes to inject the ozone gas into the RO feed and secondary safety structure. System requirements include the following:

- Liquid oxygen (LOX) supply
- Ozone generator
- Gas cooling and chiller
- Sidestream gas injection system
- Ozone contactor
- Ozone quench injection system
- Off-gas collection and destruction system

A third-party vendor supplies the oxygen, which is stored in an exterior cryotank specially made for that use. When required for the process, a vaporizer converts liquid oxygen to high-purity gaseous oxygen and conveys the substance, under pressure, into the AOP system. To improve operation performance, the Authority chills its oxygen gas to a minimum of minus 60 degrees Fahrenheit dew point.

The ozone generator converts chilled gaseous oxygen into ozone gas, with a maximum capacity of 53 pounds per day of ozone at a 5 percent concentration. Additional capacity could be gained in the future by increasing the concentration of ozone in the gas. The ozone gas is first applied to a sidestream water feed through a venturi injector, and then mixed with the RO feed to the ozone contactor.

The ozone contactor is a 4,200-gallon stainless steel baffled tank designed to provide the minimum contact time for reaction. Based on the treatability study conducted, the design contact time is five minutes at a dose of 4.0 mg/L of ozone. Off-gassing is controlled through the removal of headspace gases in the ozone contactor, through an ozone destruction skid. The gas is then discharged into the atmosphere outside the building. The Authority monitors the off-gas for ozone concentration, ensuring an ozone-free discharge.

As an aggressive oxidant that would damage thin-film composite RO membranes, the Authority must quench residual ozone in the water. RETTEW adapted a portion of the existing chemical dosing system to feed liquid sodium bisulfite into the water before the RO feed, which provides sufficient removal and protection.

Construction

The Authority initiated construction in the summer of 2014 and began operations in early 2015. Equipment costs were lower than anticipated during the AOP evaluation, resulting in an additional $100,000 in capital cost savings to the Authority. Total project costs related to the AOP portion were approximately $800,000.

To date, power and oxygen consumption have been lower than predicted. The energy savings from the project were enough for the Authority to receive a rebate from the local electrical utility, further enhancing project returns and payback.

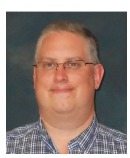
Operational monitoring is underway to characterize the reduction in total organic carbon (TOC) and contaminants of concern to document removal efficiencies and their impact on the RO system operations. System operations are thus far stable, not showing any performance decrease with the use of ozone for AOP, as opposed to the previous chlorination/dechlorination scheme.

Conclusions

Proper biofouling control is critical to the cost-effective operation of an RO system; however, the economic merits of any biofouling control require periodic evaluation and modifications. While AOP is not necessary for the UAJA to meet its current regulatory limits for water reuse, its application has proved to be a cost-effective means for controlling membrane biofouling. Coupled with the removal of contaminants of concern, AOP proved to be an effective alternative to traditional biofouling control strategies. ■

About The Authors

Braas is an environmental engineer and the firm's water reuse expert, engaged in projects across the U.S. She has more than 20 years of experience in designing wastewater systems and drinking water distribution systems, including coordinating design, evaluations, and implementing industrial pretreatment programs. She also manages grant applications, permitting, operation analysis, and construction-related activities.



Jason Wert is a senior technical engineer responsible for the development and technical evaluation of traditional and renewable energy projects throughout the U.S. With more than two decades of experience, he brings a practical project knowledge in financing, development, and structuring of public and private energy projects. He is a national expert in the planning, development, design, construction, and operation of membrane treatment, anaerobic digestion, and renewable energy projects.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Two Powerful Sidestream Treatment Technologies Battle To Be The Best

A comparison of post-aerobic digestion (PAD) and anaerobic ammonium oxidation (anammox) for sidestream nutrient removal at wastewater facilities

By Heidi Bauer, Bruce Johnson, and Tom Johnson

A sidestream is any flow stream resulting from the treatment of biosolids that is returned to the liquid treatment train. Sidestream flow streams at facilities with anaerobic digestion are targeted for nutrient removal because they exhibit relatively small flow with concentrated nutrient loading back to the liquid treatment train. Post-aerobic digestion (PAD) and anaerobic ammonium oxidation (anammox) are two sidestream treatment technologies that are beneficial for the reduction of nitrogen recycled back to the liquid stream without the need for supplemental carbon or alkalinity. However, because the two treatment options differ greatly, careful evaluation will help determine which is the most beneficial and cost-effective option for wastewater treatment facilities.

Post-Aerobic Digestion

PAD is a recently developed, advanced digestion process, where aerobic digestion is designed to follow anaerobic digestion. The most significant reason for implementing PAD is the reduction of nitrogen recycled back to the liquid stream without a need to supplement with carbon or alkalinity. Other benefits include volatile solids reduction, odor reduction, and struvite stabilization. Challenges, which have been overcome by operational controls and engineered solutions, include significant biological heat generated by the process and foam.

Spokane County Regional Water Reclamation Facility (SCRWRF) implemented a full-scale PAD facility in late 2011 to help achieve strict nutrient removal, including a maximum monthly effluent limitation of 10 mg/L total nitrogen. (Figure 1)

Denver Metro Wastewater Reclamation District's (MWRD) Northern Treatment Plant is also implementing PAD technology, which will be placed into service in the fall of 2016. The MWRD selected PAD as a cost-effective way to help achieve strict nutrient removal criteria, including a maximum daily nitrate value of approximately 10 mg/L total nitrogen, while also reducing biosolids hauling costs. Typically, MWRD hauls biosolids for 30 to 60 miles to both private and District-owned land application sites.

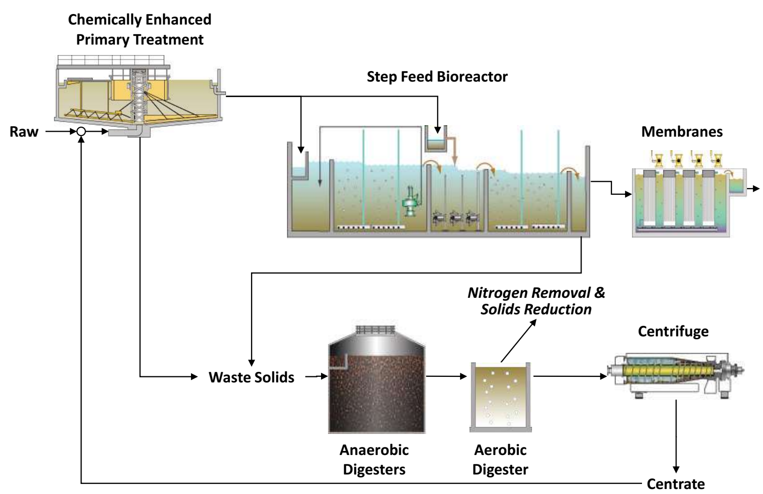
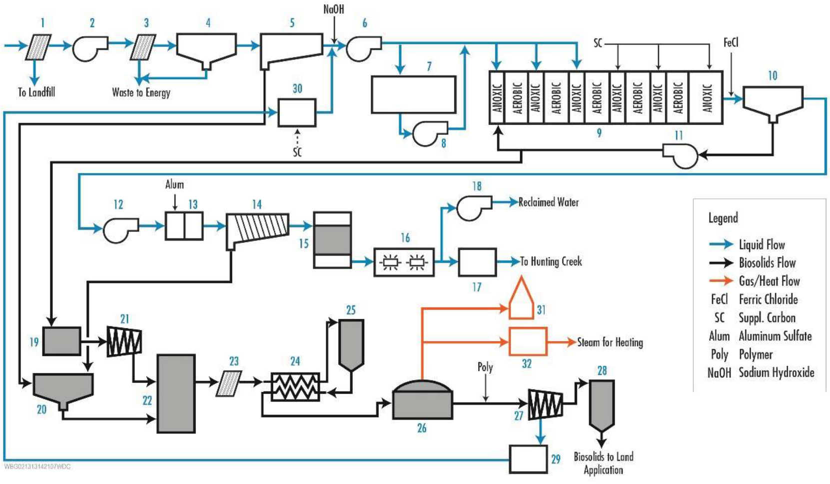


Figure 1. SCRWRF process flow diagram with post-aerobic digestion

Anammox

Anammox harnesses a specific species of autotrophic bacteria that can achieve partial nitritation-deammonification (or, the conversion of ammonia and nitrite to nitrogen gas) under anoxic conditions. Anammox bacteria work alongside ammonia-oxidizing bacteria under partial aerobic/partial anoxic conditions to ultimately convert ammonia to nitrogen gas without fully nitrifying and denitrifying. Like PAD, one of the key benefits of anammox is the reduction of nitrogen recycled back to the liquid stream without supplemental carbon or alkalinity. Other benefits include lower energy consumption and less oxygen compared to conventional nitrification. Challenges to overcome include the slow growth of the anammox bacteria, as well as its competition with nitrite-oxidizing bacteria.

Alexandria Renew Enterprises (AlexRenew) Water Resources Recovery



Unit Processes							
1	Coarse Screens	9	Biological Reactor Basins	17	Post-Aeration Channels	25	Pasteurization Tanks
2	Raw Sewage Pumps	10	Secondary Settling Tanks	18	Reclaimed Water Pumps	26	Anaerobic Digesters
3	Fine Screens	11	Return Activated Sludge Pumps	19	Raw Sludge Blending Tanks	27	Dewatering Centrifuges
4	Vortex Grit Chambers	12	Intermediate Pumps	20	Gravity Thickeners	28	Biosolids Silos
5	Primary Settling Tanks	13	Rapid Mix/Floc.Tanks	21	Thickening Centrifuges	29	Centrate Storage Tanks
6	Primary Effluent Pumps	14	Tertiary Settling Tanks	22	Thickened Sludge Eq. Tanks	30	Centrate Pre-Treat. Reactors
7	Nutrient Mgmt. Facility	15	Gravity Filters	23	Sludge Screenings Presses	31	Gas Flares
8	Nutrient Mgmt. Pumps	16	UV Disinfection	24	Heat Exchangers	32	Biogas Boilers

Figure 2. AlexRenew WRRF process flow diagram with sidestream anammox

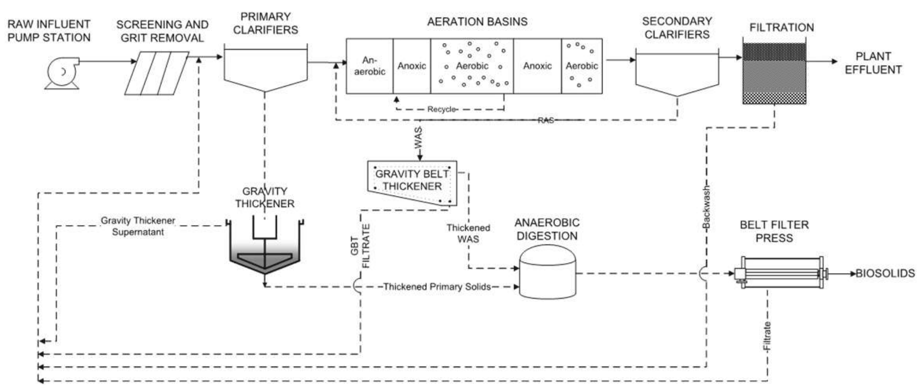


Figure 3. Process flow diagram for the baseline wastewater treatment facility (no sidestream treatment)

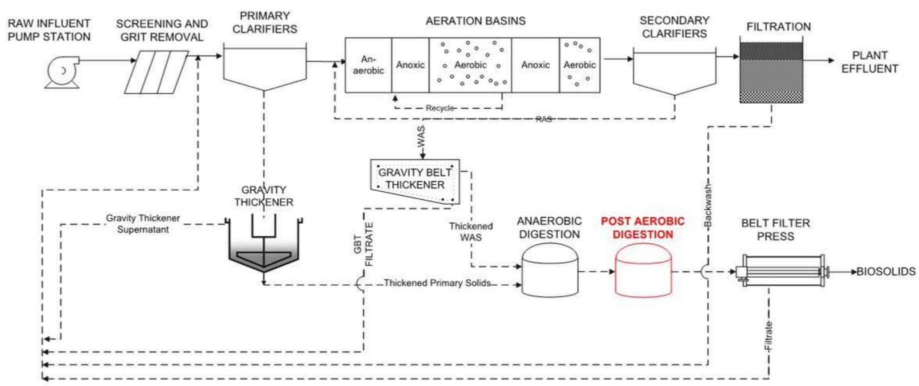


Figure 4. Process flow diagram for sidestream treatment with PAD

Facility in Alexandria, VA, is currently implementing a full-scale sidestream anammox system to help address Virginia's state regulatory requirement to remove 62 percent of 2005 levels of effluent nitrogen by 2011. AlexRenew selected anammox technology because it can achieve significant nitrogen removal with reduced supplemental chemical addition and energy. (Figure 2)

Methodology

Using CH2M's proprietary Pro2D2 whole plant simulator tool, sidestream treatment with PAD, sidestream treatment with anammox, and a baseline (no sidestream treatment) at three hypothetical wastewater treatment facilities were compared to evaluate the respective benefits and cost-effectiveness of implementing these two treatment technologies.

As shown in the process flow diagrams for the three models illustrated in Figures 3, 4, and 5, respectively, the PAD and anammox technologies target different sidestream flow streams; PAD targets digester effluent, while anammox targets the filtrate or centrate produced from dewatering.

Each model assumed a flow of 20 MGD, a greenfield site, and the same raw influent characteristics and effluent limitations, including 1 mg/L ammonia-nitrogen, 5.0 mg/L total nitrogen, and 1.0 mg/L total phosphorus.

Results

- The baseline model could not achieve the effluent limitations without supplemental carbon (1,715 pounds per day), but no supplemental alkalinity or carbon was needed for either sidestream treatment model to achieve these limitations.
- Both sidestream treatment technologies can remove a significant amount of

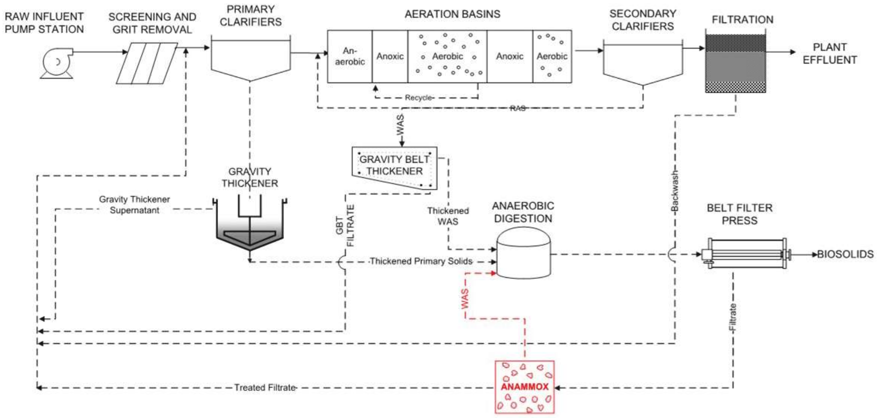


Figure 5. Process flow diagram for sidestream treatment with anammox

nitrogen from the filtrate compared to the baseline (90 percent and 99 percent removal of ammonia-nitrogen with anammox and PAD, respectively) and can achieve similar effluent quality.

- Energy invested in either sidestream treatment technology results in less energy required for nutrient removal in the aeration basins (by approximately 7 percent). For sidestream treatment with anammox, the energy saved in the aeration basins overcomes the energy required for sidestream treatment.

PAD targets digester effluent, while anammox targets the filtrate or centrate produced from dewatering.

- Considering energy use, chemical use, and biosolids production together, sidestream treatment with PAD demonstrates a net annual energy cost savings of 5.1 percent relative to sidestream treatment with anammox and a net annual energy costs savings of 19.1 percent relative to the baseline. These savings are attributed to significantly lower biosolids hauling and disposal costs due to the volatile solids destruction associated with PAD. The baseline (no sidestream treatment) offers the lowest capital cost because construction of a sidestream treatment facility costs more than the construction of a methanol feed and storage facility.
- Sidestream treatment with PAD offers the lowest annual cost primarily due to the significant savings in biosolids hauling and disposal.
- The lowest 20-year net present value is equivalent for the baseline (no sidestream treatment), sidestream treatment with PAD, and sidestream treatment with anammox alternatives.

Conclusions

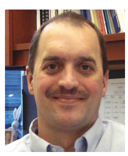
Both PAD and anammox offer nitrogen removal without the need for supplemental carbon or alkalinity, but PAD should be considered when there is also a desire for additional volatile solids destruction. PAD would be ideal for facilities with high and/or volatile biosolids disposal costs or a long haul distance.

Anammox should be considered when the additional desire is energy minimization. Anammox would be ideal for facilities with high energy rates, volatile energy rates, or a desire to achieve net zero energy.

This evaluation made reasonable assumptions; however, every site is different, and different assumptions would affect the cost evaluation. For example, the assumption for a greenfield site was made in order to produce an apples-to-apples comparison, but a retrofit installation would significantly affect the cost evaluation. Moreover, if a spare tank is available, blowers, diffusers, and controls could be cost-effectively incorporated to create a PAD facility. ■

About The Authors

Heidi Bauer, PE, joined CH2M in 2008 and has enjoyed working on wastewater modeling, master planning, and design projects for wastewater and biosolids treatment. Prior to joining CH2M, Heidi worked as a contract operator and currently holds Colorado certifications for Class A water and wastewater, Class 3 collections and distribution, and Biosolids Land Appliers.



Bruce Johnson, global technology leader for wastewater simulation, joined CH2M in 1995 and brings more than 26 years of experience operating, troubleshooting, and designing water and wastewater treatment plants and equipment. He is seen as an expert in modeling and designing wastewater treatment facilities and has made a lasting impact on the wastewater profession through the high-end application of wastewater simulation to advanced waste treatment design. He holds five patents in wastewater technologies and has authored/co-authored more than 25 technical papers on the subject. He was recently named an IWA Fellow by the International Water Association.

Tom Johnson joined CH2M as a Senior Technologist in 2005. With more than 17 years of experience working in the water industry, Tom specializes in wastewater process analysis, modeling and design, wastewater collection and conveyance, as well as wastewater treatment plant optimization and efficiency.

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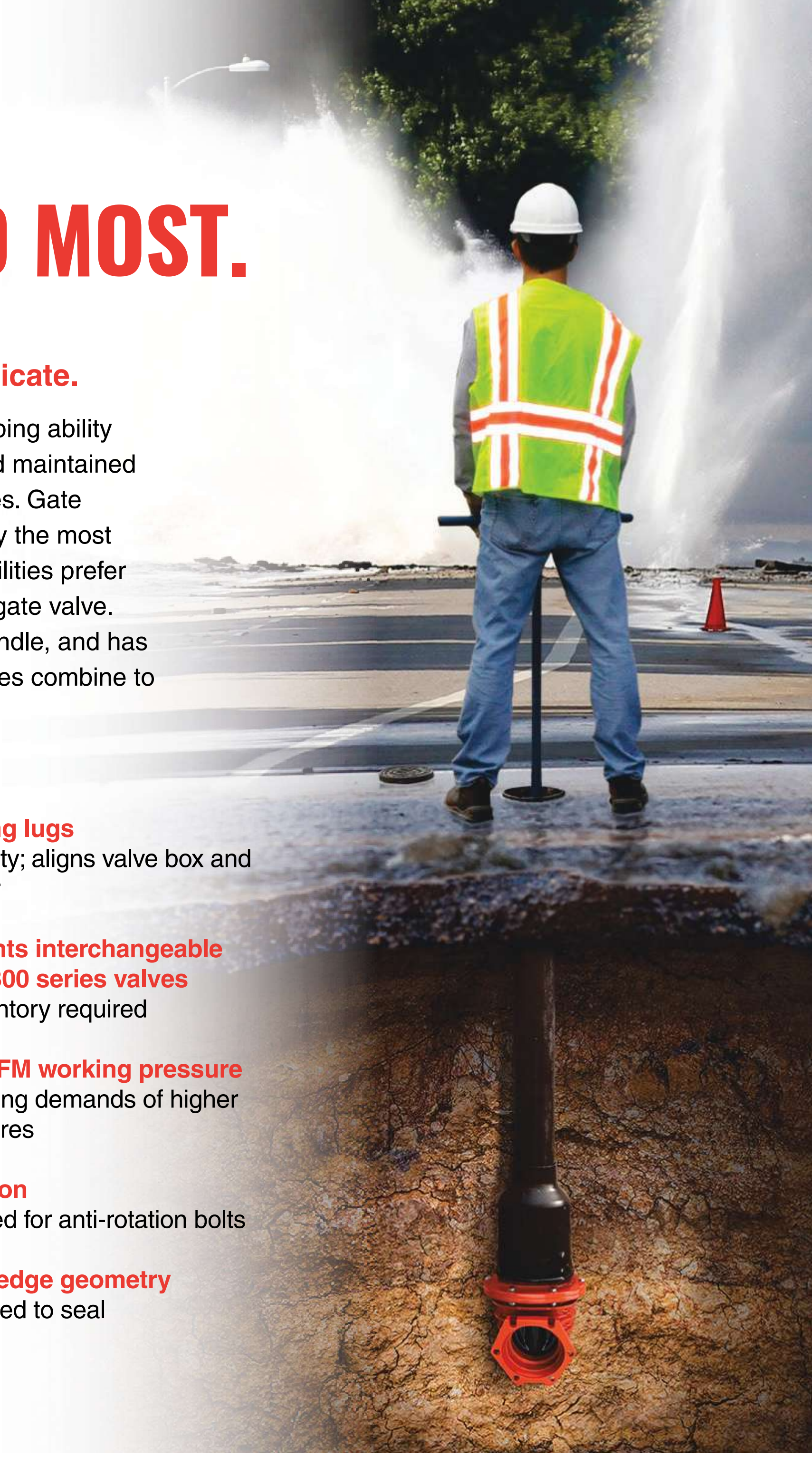

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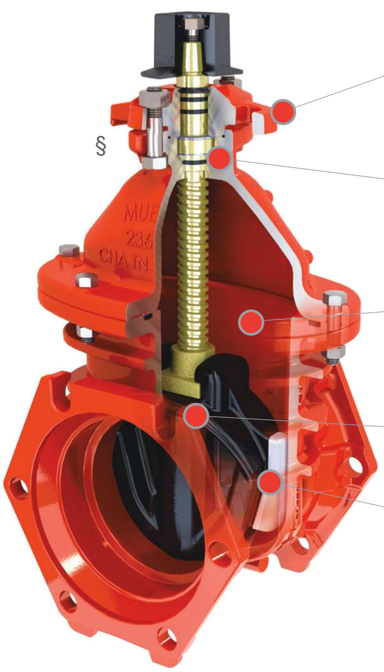

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Protecting Against Doomsday Contaminants

New tools are being developed for worst-case drinking water scenarios: chemical, biological, radiological, and nuclear (CBRN)-related contamination.

By Thomas Bernard

The security of drinking water is increasingly recognized as a major challenge for municipalities and water utilities. The safety and/or security of drinking water can be threatened by natural disasters, accidents, or malevolent attacks (Gleik, 2006). In the event of a contamination, the material can spread within the water rapidly and extensively before the problem is detected. Contaminated drinking water can induce widespread illness or death, disrupt economic life, and create mass panic. First-generation software packages and sensors are available — such as Guardian Blue from Hach Lange and Canary from the U.S. EPA — for managing drinking water safety and security and, in particular, for detecting incidents. These allow for an overall management of water security, including the systematic collection and interpretation of information by online sensors. However, this first generation of tools suffers from a range of serious shortcomings:

1. Real-time detection and alarm capabilities are insufficient or nonexisting;
2. Current limitations of propagation models make the effective situation assessment of potentially contaminated zones very difficult;
3. There exists no generic approach for the online calibration of the hydraulic and transport model;
4. Models for response, mitigation, and recovery are almost nonexistent for real-world systems at present;
5. The set of available CBRN sensors, which can be used to detect contamination threats to water drinking quality in the distribution system, is very limited.

Real-time detection and alarm capabilities are insufficient or nonexisting.

The aim of several international projects that have been recently finished or are still in progress is the development of comprehensive event detection and event management solutions for drinking water security management and mitigation against major deliberate, accidental, or natural CBRN-related contaminations. The aims and results of three projects are briefly presented herein.

Project SMaRT-Online^{WDN}

Online security management and reliability toolkit for water distribution networks

The main objective of the project SMaRT-Online^{WDN} (duration: 2012 – 2105; see SMaRT Online^{WDN} (2015)) was the development of an online security management toolkit for water distribution networks (WDN) that is based on sensor measurements of water quality as well as water quantity. The French-German cooperative research project consists of end users (BWB in Germany, CUS Strasbourg, and Veolia Eau d'Ile de France), technical and socio-economic research institutions (Fraunhofer IOSB, TZW, Irstea, ENGEES), and industrial partners on both French and German sides (Veolia, 3S Consult). In this project, the technical research work was completed with a sociological, economical, and management analysis. SMaRT-Online^{WDN} combines applied mathematics, civil and environmental engineering, fluid mechanics research, and social science and economics in a multidisciplinary approach.

The general system concept is sketched in Figure 2. The software solution relies on data treatment and assimilation from a sensor network of water quantity values (pressure, flow rate) and water quality values (e.g., chlorine residue, pH, conductivity, turbidity, and temperature). The core of the online security management toolkit consists of a grid of smart sensors in combination with an online simulation model. The boundary conditions of the network model are regularly updated by measurement data guaranteeing the compliance of the model with the observations. With this information, the online security management toolkit is able to reflect the current hydraulic state of the entire system. In addition, monitoring of water quality parameters supports the detection of biochemical contamination of the drinking water.

The functionality of the SMaRT-Online^{WDN} software modules can be summarized as follows:

- *Event detection and alarm generation:* Enables a robust

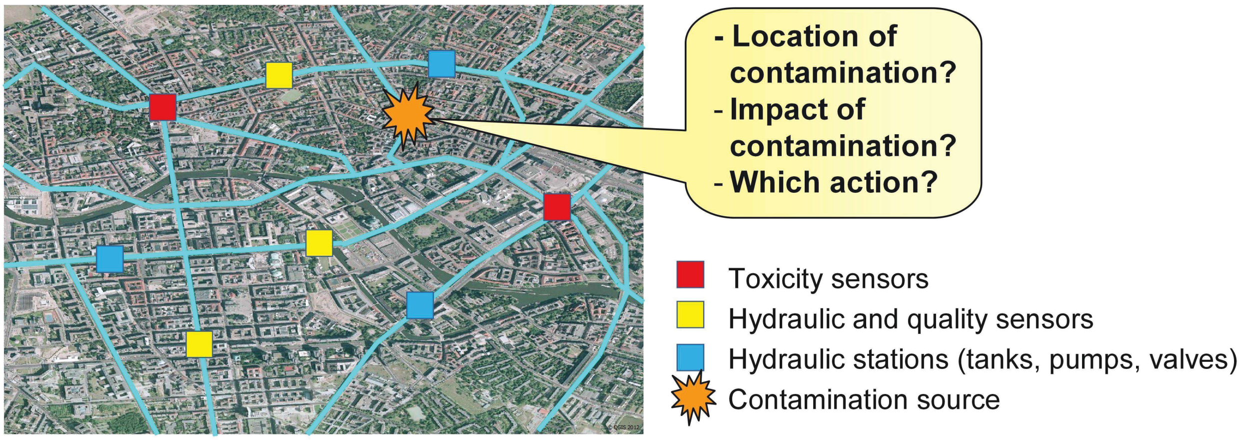

Figure 1. In case of a toxic contamination of the water distribution network, the water suppliers will be supported by the SMaRT-Online^{WDN} security management toolkit.

detection of changes in the water quality. A sensor data fusion module evaluates the data of water quality sensors. The module learns the normal water quality ranges and patterns from historical data. The online simulation model is used for plausibility, check-of-the-event detection.

- *Optimal sensor placement:* Enables the optimal placement of a defined number of quality sensors in a real-world network (hydraulic state, physical/chemical parameters). It enables the user (e.g., WDN operators) to find optimal locations for early warning detection systems (Propato and Piller, 2006; Deuerlein et al., 2010).
- *Online simulator:* Provides real-time, reliable flow, pressure, and water quality parameter values of the whole water network. The calculations are based on the available online measurement data of hydraulic parameters (e.g., inflow in the network, demand, flow, and pressure values) and water quality parameters.
- *Enhanced water quality simulator:* Provides more reliable water quality simulation results. In most of the actual available WDN simulation software tools (e.g., EPANET), a complete mixing of substances at junctions is assumed. Detailed experimental and simulation-based study of the transport of conservative substances in real-world water drinking networks showed that under various flow conditions the complete mixing assumption does not hold (Shen 2008, Braun 2105). The water quality models PORTEAU (Irstea) and EPANET-MSX has been enhanced so that the non-ideal mixing at junctions is considered.
- *Online contaminant source identification and mitigation of risks:* Provides the location (or at least candidates) of a contamination source. A backtracking algorithm that uses the data of historical measurements has been implemented. The merit of offline methods (e.g., Propato et al., 2007) and pseudo real-time ones (Preis and Ostfeld, 2011) has been studied and compared to the developed online solution method. As a result of water quality sensor alarms, the possible localizations of the intrusion of contaminant can be calculated.
- *Risk analysis and impact assessment:* Risk analysis and impact evaluation (real impacts and perceived ones) will be performed for the three aspects of sustainability: environmental, social, and economical, combined with technical innovation.

The SMaRT-Online^{WDN} toolkit improves the observability of water quality and quantity in the distribution network in near real time. It acts as an early warning system as well as decision-support system in case of contamination events. Furthermore, it supports a better understanding of the physical and biochemical processes in the pipe systems — e.g., it is possible to use it offline for training of staff by use of simulation.

Project SAFEWATER

Innovative tools for the detection and mitigation of CBRN-related contamination of drinking water events

Similar to the aims of the project SMaRT Online^{WDN}, the European FP7 ("Seventh Framework Programme for Research and Technological Development") project SAFEWATER (Oct. 2013 to Dec. 2016) aims at developing a comprehensive event detection and event management solution for drinking water security management and mitigation against major deliberate, accidental, or natural CBRN-related contaminations (see SAFEWATER (2016)). The comprehensive SAFEWATER solution, comprising enhanced near-real-time sensors, an advanced decision support system, online hydraulic propagation models, and an all-encompassing event management system

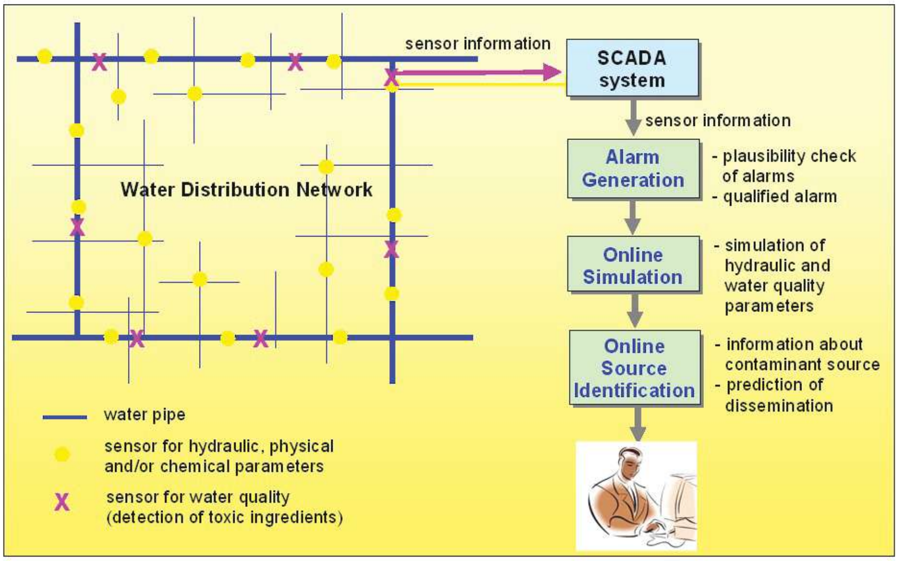

Figure 2. System concept of SMaRT-Online^{WDN}

are tested against several true-to-life usage cases (e.g., contamination of a municipal storage tank, contamination of a major water trunk line, contamination of a local supply line) using several families of contaminants such as organic compounds, toxic waste, and radioactive material. Trials and measurements of individual components of the system as well as the entire completed system are performed in special hydraulic test networks set up in three different water utilities.

Applying the SAFEWATER system or any component thereof will enhance a water utility's ability to rapidly detect a contamination event, analyze its repercussions using real-time hydraulic models, mitigate the damage using simulation tools and swift operating procedures, and deal more effectively with the event using a comprehensive event management tool.

Figure 3 provides an overview of the structure of the SAFEWATER system. The key module is the *Event Management System* (EMS), which handles incoming events and provides decision support in case of a crisis (as well as for routine operations). The *Event Detection System* (EDS) breaks ground by detecting potentially dangerous constellations of water quality parameters currently undetectable. These constellations may indicate a contamination of the drinking water network, or a so-far-unknown operational effect. In case of an event, it is important to quickly provide decision support regarding the best mitigation measures (e.g., opening/closing of valves). In the SAFEWATER system the hydraulic and water quality state of the network is simulated in real time. In case of an event, online response tools can predict the spread of the contamination and calculate optimal measures to minimize the impact of the contamination. The simulators can also be used in an offline context in order to train the operational staff. Furthermore, the simulators are used in order to train the event detection system. Within the SAFEWATER project, enhanced CBRN sensors are also being developed to provide the ability for early detection of CBRN contaminations.

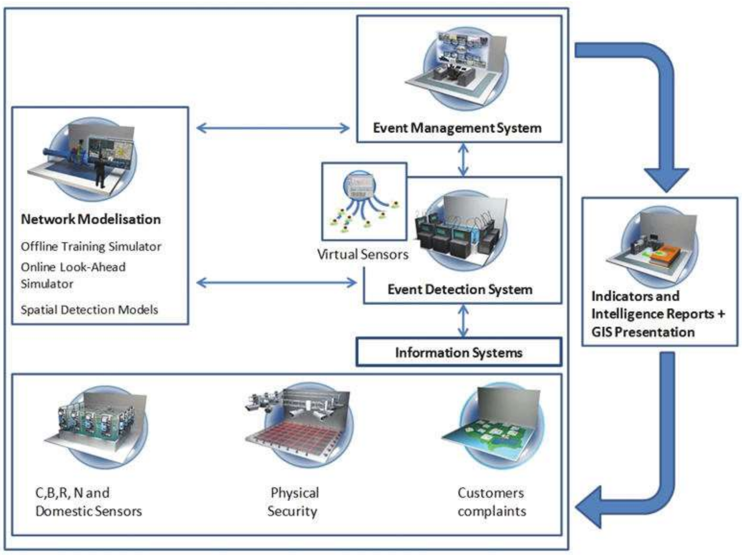

Figure 3. Structure of the SAFEWATER system

Project ResiWater

Innovative secure sensor networks and model-based assessment tools for increased resilience of water infrastructures

The German-French project ResiWater (2015 to 2018) aims to develop tools to prepare water utilities for crisis management and enhance their resilience with regard to three specific case studies: (1) collapse of water distribution systems, (2) water quality deterioration, and (3) cascade effects among water, energy, and IT infrastructures. The aim of this project is to develop enhanced sensors and secure sensor networks, self-learning monitoring tools, robust simulation models, and vulnerability and resilience assessment tools for improving the security and the resilience of water infrastructures against major threats. The new developments will be investigated and evaluated by means of real-world use cases. The specific threats are defined by the partner water utilities Berliner Wasserbetriebe (Germany), EMS (Strasbourg, France), and VEDIF - Veolia Eau d'Ile de France (France). Additionally, experiments will be conducted at TZW (Dresden, Germany) with test platform facilities and also on the private water network at CEA/DAM (Gramat, France). The R&D work will be accompanied by socioeconomic studies ensuring, among other considerations, that the privacy and the freedom of the citizens are not compromised. ■

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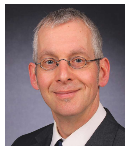
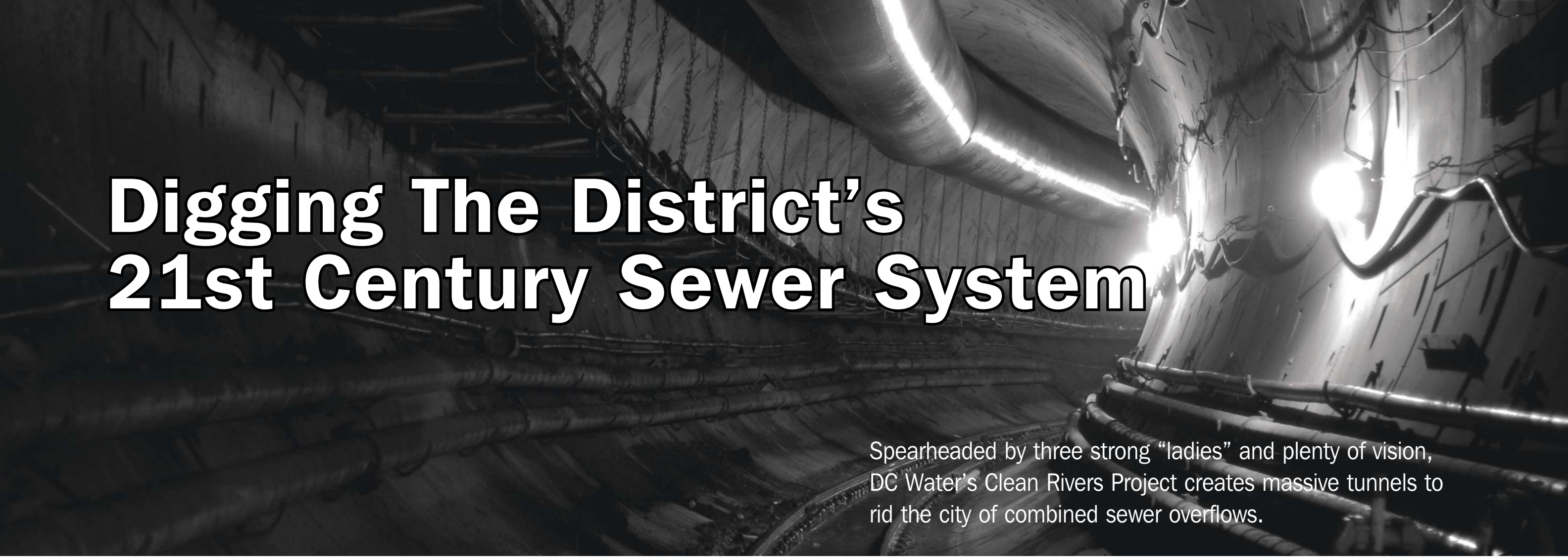
About The Author



Dr. Thomas Bernard is a physicist with a Ph.D. from the University Karlsruhe (TH). Since 1996 he has been a scientific assistant at Fraunhofer Institute of Optronics, System Technologies and Image Exploitation (IOSB) in Karlsruhe, Germany. Since 2007 he has led the research group Process Control and Data Analysis at IOSB. His main research areas consist of modeling, simulation, control, optimization, and data analysis of environmental processes, water infrastructures, and industrial processes.



Digging The District's 21st Century Sewer System

Spearheaded by three strong "ladies" and plenty of vision, DC Water's Clean Rivers Project creates massive tunnels to rid the city of combined sewer overflows.

By Carlton M. Ray

Over the course of the past 10 years, the District of Columbia Water and Sewer Authority (DC Water) has been planning, designing, and constructing the DC Clean Rivers (DCCR) Project to reduce combined sewer overflows (CSOs) to the District's receiving waters and to mitigate chronic flooding in its historic neighborhoods. The DCCR Project consists of a series of large underground storage and conveyance tunnels, drop shafts, diversion sewers and chambers, overflow structures, and a tunnel dewatering pumping station located at DC Water's Blue Plains Advanced Wastewater Treatment Plant. The backbone of the project is a 23-foot-diameter tunnel system that spans the length of Washington, D.C., from the southwest to northeast quadrants of the city. The tunnels, constructed in soft ground, will total over 13 miles in length and be located approximately 100 feet underground. The project is anticipated to be complete by 2022, three years before its associated consent decree deadline.

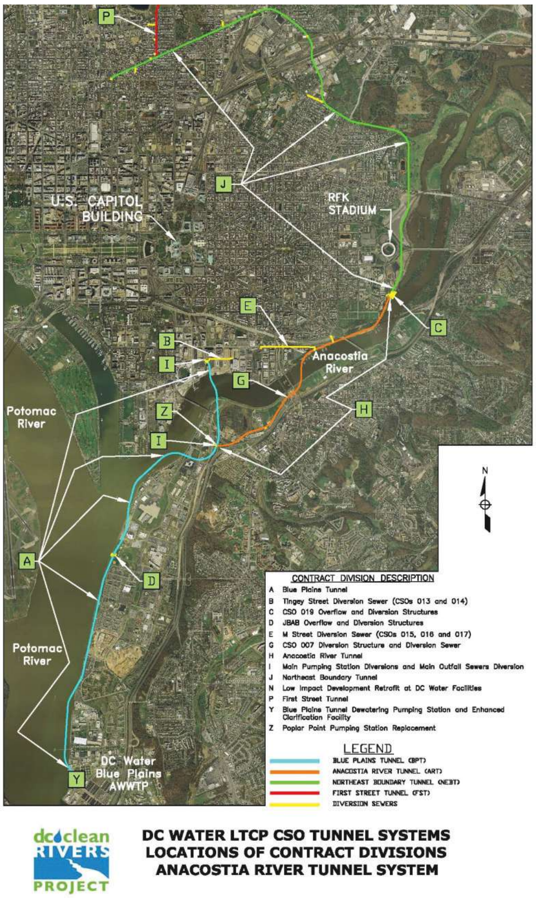


Figure 1. DC Clean Rivers Project tunnel system

DC Water's Tunnel Boring Machines

Since the entire tunnel system is being constructed in soft ground, DC Water is employing state-of-the-art earth pressure balance tunnel boring machines, or TBMs, to build the reinforced concrete tunnel. The tunnels are being constructed in geologic stratigraphy consisting of 65-million-year-old clays and sands, referred to locally as the "Potomac Group Soils." To date, DC Water contractors have procured three TBMs, which have been diligently digging under the nation's capital since 2013 and are named after prominent District women (see sidebars). These machines are, in essence, underground factories that are approximately 26 feet in diameter and longer than a football field. The 80-ton cutting wheel is driven by a dozen motors. Behind the cutting wheel, the 1.3 million pound TBM shield is backed up by over 300 feet of support equipment — "the trailing gear" that provides the electrical power, hydraulics, ventilation, pumping, grout, instrumentation, and ground conditioning necessary to keep the TBM mining.

The 24,243-foot-long Blue Plains Tunnel was excavated by a TBM named Lady Bird. The 12,483-foot-long Anacostia River Tunnel is currently being excavated by a TBM named Nannie. The Blue Plains and Anacostia Tunnels are primarily storage tunnels that will provide approximately 115 million gallons of the system's 157 million gallons of total CSO storage volume. The 2,722-foot-long First Street Tunnel was recently completed by Lucy just prior to Christmas, 2015. The First Street Tunnel and the future Northeast Boundary Tunnel will increase the capacity of the existing sewer system in the District to current design standards, significantly

Lady Bird was named after "Lady Bird" Johnson (wife of President Lyndon B. Johnson). When her husband became president in 1964, she made it her mission to preserve and protect the environment. She encouraged her husband to declare the Potomac River "a national disgrace," which drew attention to the declining health of America's waterways and was a catalyst for the eventual Clean Water Act of 1972.

Nannie is named after Nannie Helen Burroughs, who was an African-American educator and civil rights activist in the District.

Lucy was named after Howard University's first dean of women.

Figure 2. TOP: The 23-foot cutting wheels of Lady Bird, Lucy, and Nannie (left to right) are designed for each contract's specific requirements and ground conditions. BOTTOM: The shield sections handle the excavated ground, provide hydraulic thrust for advancing, steer the machines, and erect the final concrete lining.

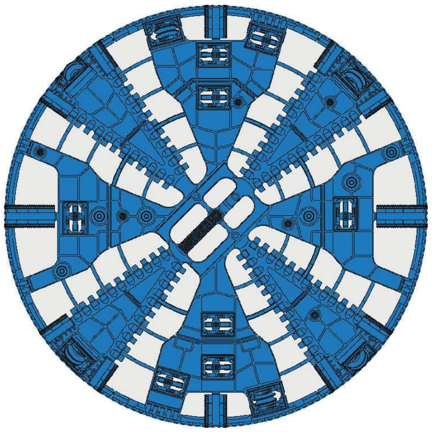
mitigating the frequency, magnitude, and duration of sewer flooding and basement backups, and thus address chronic sewer flooding in one of the District's largest drainage areas that have been plagued by flooding since the early 1900s.

How Do The Tunnel Boring Machines Work?

The TBMs provide an effective method of constructing tunnels in soft ground by actively supporting the ground during excavation, providing continuous ground support, and constructing behind itself a watertight final lining with a 100-year design life in a single pass. The TBMs excavate the dense sands and hard clays encountered along the tunnel alignment with a cutterhead or cutting wheel that resembles a pinwheel. The arms of the wheel are lined with ripping teeth and, depending on the ground conditions, the faces of the arms can include disc cutters. The ripping teeth, or drag bits, are effective at removing clayey and sandy soils whereas the disc cutters engage when harder materials, such as the concrete walls at shaft penetrations, cemented soils, ground improvement zones (jet grout, frozen ground), and rock, are encountered. The combination of drag teeth and disc cutters allows the TBM to handle the variety of soils and materials that are encountered along the alignment.

The cutterhead is also designed to support the soil during excavation, distribute and mix ground conditioning agents, and convey the excavated ground to the extraction point at the auger. Conditioning agents (foams, polymers, or bentonite) are added during excavation to turn the soil into a cohesive mass with a consistency similar to toothpaste. This consistency helps maintain and evenly distribute ground support (face pressures) during excavation and allows the auger to efficiently extract the excavated spoil in a controlled manner. The auger is the one point where excavated ground is removed from the face; the rate and direction of auger rotation controls the face pressure, which supports the unexcavated ground to control ground movements around the tunnel.

The TBM advances through the ground by pushing off the lining system with the use of hydraulic jacks. As it does so, undisturbed ground passes over the shield, which is a few inches smaller in diameter than the cutting wheel. The ground is supported by conditioning



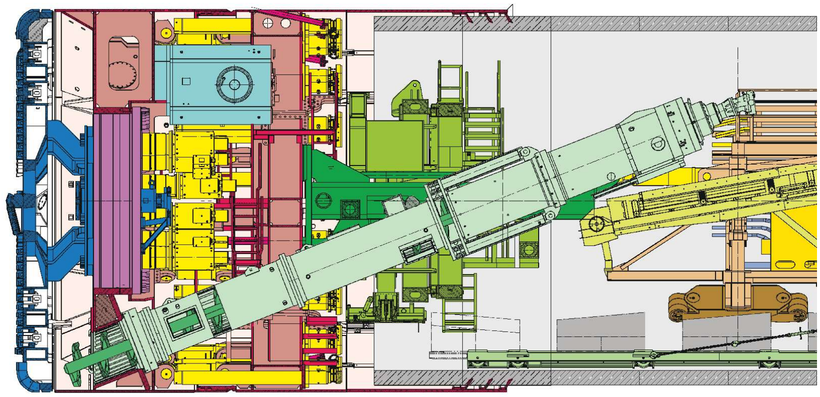


Figure 3. Tunnel boring machine cutting wheel (left) and shield components

agents that are injected through the shield. At the end of the shield, about 30 to 50 feet behind the cutting wheel, precast concrete segmental rings are assembled and extruded behind the machine. The ring passes through brush seals, and annular grout is injected between the concrete rings and the ground. The wire brush seals prevent ground, grout, and water from entering the shield in the gap between the segments and shield. The annular grout, typically a two-part grout, gels quickly after injection and prevents movement of the segments and surrounding ground.

The precast concrete segmental rings are typically 4 to 6 feet wide, and 5 to 7 segments make up a complete ring. During assembly, the ring segments are bolted together for temporary support and are connected to the previous complete ring with locking dowels. Each ring is tapered such that, depending on the rotation of a set of rings, any vertical or horizontal curve greater than about 800-foot radius can be navigated. Ethylene propylene diene monomer (EPDM) gaskets are used between the segments to prevent water ingress at the joints between segments and between rings. The combination of high-quality, high-strength, precast concrete segments and durable gaskets allows the tunnel to achieve a 100-year design life and a leakage rate less than 5 gpm per mile of completed tunnel.

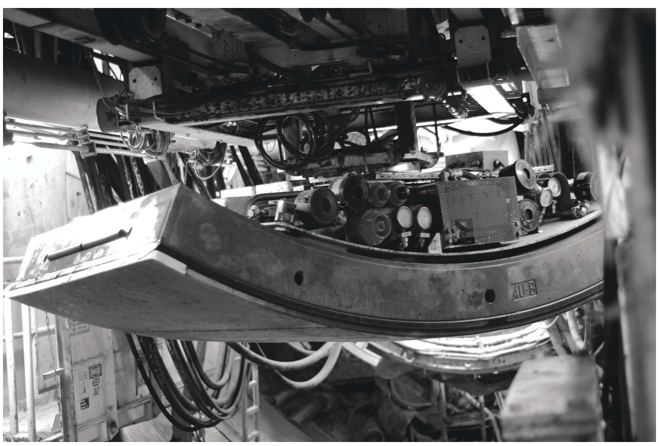


Figure 4. The segment handler of Lady Bird easily manipulates the 11-foot-long, 6-foot-wide, 6-ton segment prior to ring assembly.

Within the tunnel, the work environment is generally clean and dry. Water and ground ingress into the tunnel is limited and spoils removed through the auger at the face are directly conveyed into either muck cars on rails or a continuous conveyor belt that runs back to the mining shaft. Materials and precast concrete segments are delivered by locomotive along rails that are assembled behind the machine as it advances. The initial 500 to 1,000 feet of tunnel is considered part of the learning curve, and advance rates are typically reduced due to equipment assembly, troubleshooting, and downtime to install additional support equipment. After the learning curve phase, the TBM can consistently advance 50 to 100 feet a day, with scheduled downtime during the graveyard shift and on weekends to perform maintenance. Toward the end of her run, Lady Bird had a personal best 150-feet-per-day production rate. At the surface, the ground movements have been imperceptible, less than 1/10th of 1 inch on average, as measured by geotechnical instrumentation placed along the alignment.

Tunnel Safety

Safety is an important consideration in any construction project. Safety in a tunnel environment has many different elements from above-ground construction: a long supply line, congested work area, multiple activities at the face, and special equipment. The job safety analysis must include an evaluation of tunnel access and egress, flood control, ventilation and air quality, illumination, and fire/explosion prevention. Site-specific incident response plans are also prepared in conjunction with local emergency responders, which include periodic tunnel rescue training.

Conclusion

DC Water's TBMs have been instrumental in meeting project goals and the strict milestones associated with DC Water's consent decree. Without this technology, the project would not be possible. These high-production machines have been quietly constructing a new 21st century sewer system in the District with little to no disturbance of the ground surface. Once completed, the tunnel system will reduce CSO volume to the Anacostia River in an average year of rainfall by 98 percent. ■

About The Author

Carlton Ray is the director for DC Water's Combined Sewer Overflow Long Term Control Plan called the DC Clean Rivers Project, responsible for implementing DC Water's 25-year, $2.7 billion federally mandated consent decree to control combined sewer overflows (CSOs). Previously, he worked at the Department of Public Works in Indianapolis, IN, as chief engineer, deputy director, and CSO program lead. Ray has more than 25 years of engineering and leadership experience in both public and private civil engineering sectors, and holds a Bachelor of Science degree in Civil Engineering from Auburn University.

Saving Oil And Gas: Improving Profit Margins In Down Times With Innovative Water Management

With oil prices depressed, exploration and production companies unearth the money-saving opportunities in water management planning.

By Jeffrey A. Anderson, William H. Fronczak, and Stephen A. Goodwin

Unconventional oil and gas (UCOG) exploration and production (E&P) companies traditionally have not planned oilfield development with total water management solutions and costs in mind because past oil prices have resulted in high margins wherein water solutions and associated variances in water costs were insignificant (typically less than 10 percent with oil prices at $100/barrel). However, with the current downward spiral in oil and gas (O&G) prices, total water costs are now a significant factor for operators to improve their margins in U.S. basins/plays where they are able to operate. While operators have been successful in improving drilling and completion efficiencies and reducing the costs associated with both, overall water costs and efficiencies have not followed suit. Complicating the matter are regulatory changes and the challenges associated with securing reliable water resources in arid areas, the logistics of moving water from the source to locations, handling flowback and produced water, and evaluating the total cost of water matters in the oil patch — for example, water purchase, water transfer, water hauling, water storage, flowback and produced water treatment, and disposal (see Figure 1). To address these total water management issues, which in turn will result in significant cost savings and improved margins, is to engage in upfront water planning and use decision support tools and preliminary engineering to quickly and accurately evaluate various water solutions strategies. Operators need to spend a little now on planning and the use of technology/engineering to significantly save capital in the near term and have known costs for the future.

New Perspective

Traditionally, water management and associated costs have been separated between the drilling and completion (D&C) and production business units. Because of this "siloed" approach to handling water management costs, most E&P companies do not know total life cycle water management costs. For example, D&C operations are concerned only with the water management costs associated with drilling and completing wells, much of which is temporary or transitory in nature.

The D&C water management costs are associated with pre-flowback operations and typically include:

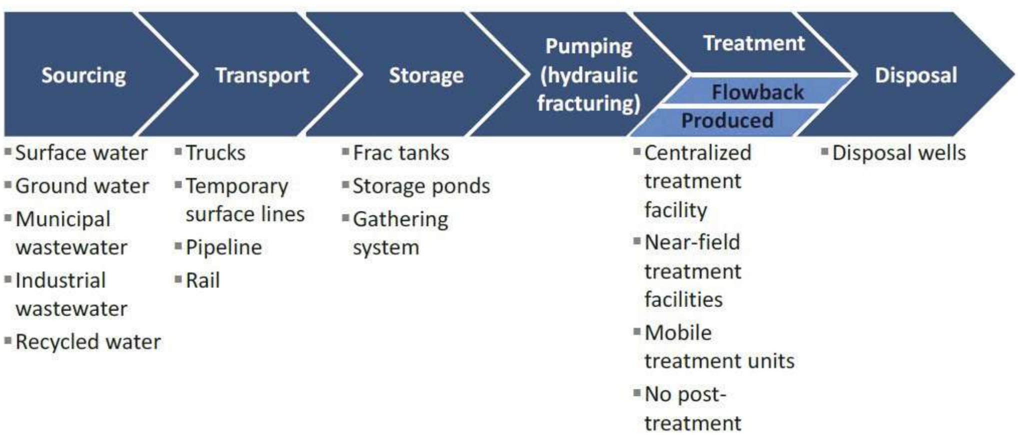


Figure 1. Oilfield water management life cycle (PacWest 2012)

- *Water supply* — obtaining the necessary water pursuant to the approved D&C plan.
- *Transportation* — getting water to the pad either by pipeline or trucking.
- *Storage* — above-ground tanks or in-ground impoundments for storing water to be used in D&C operations.
- *Treat and reuse* — oilfield water treatment in mobile or fixed-based plants for reuse in completions.
- *Other costs* — right-of-ways, easements, or other land access agreements required to run transfer lines or permanent water supply pipelines and to construct water storage facilities required to support D&C operations.

Water management costs associated with D&C operations are usually incorporated in the well authorized for expenditure (AFE), which is a capital expense (CAPEX). By contrast, the production teams are focused on water management costs associated with permanent facilities for storing and handling fluids and long-term management of produced water. Typical O&G production-related water management costs include:

- *Separation and storage facilities* — permanent facilities for separation of oil, gas, and water from the production stream and storage of fluids.
- *Transportation* — gathering systems and pipelines or trucking to transport long-term produced water to its final disposition.
- *Treat and reuse* — oilfield water treatment in mobile or fixed-based facilities for reuse in completions.
- *Disposal* – deep well injection into properly permitted and constructed Class II underground injection control (UIC) wells.

Although the produced water facilities costs are capitalized, the long-term handling of produced water is an operating expense (OPEX). Since water management costs touch many different business units and types of expense, total water-related costs are many times uncertain or unknown by E&P companies. Total water costs can vary from 5 to 15 percent of the well D&C cost and were not a major concern during UCOG development with $100/barrel (bbl) oil prices. However, in the present low commodity price environment, it is critical for E&P companies to know total life cycle water management cost in order to improve operating margins.

Oilfield water management decision making is challenging and has many associated considerations and components (see Figure 2).

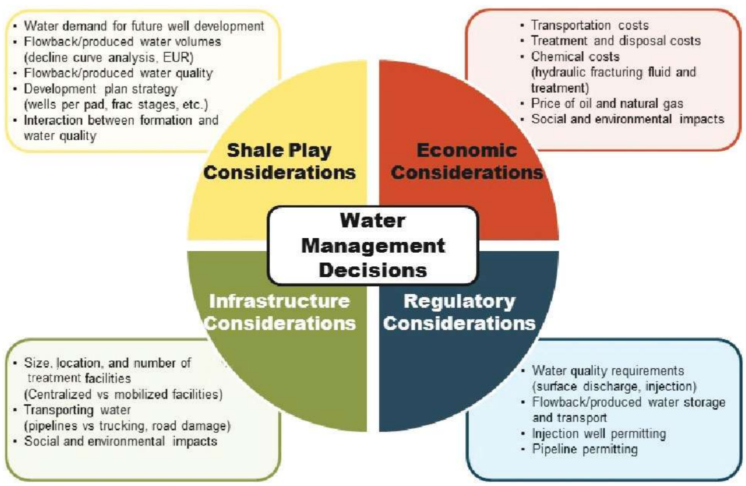


Figure 2. Oilfield water management decision diagram[1,2]

Improved water management in UCOG has been discussed in various forums ranging from the use of infrastructure to reduce costs and increase margins to managing, treating, and reusing flowback and produced water to reduce total water-related costs. However, a key component missing from these discussions is the use of decision support tools and strategic planning to focus front-end engineering and design (FEED) and the total water solutions costs. These discussions, as mentioned above, continue to separate the analysis of water management into the D&C business units and the production business units. However, to minimize total water costs and maximize margins, decision support tools that quickly and accurately analyze costs associated with the complete water cycle in UCOG development should be implemented in the early planning phase of play development. These tools, along with water engineering expertise, can greatly reduce the time and money required to evaluate total water solutions from traditional methods, which require significant time commitments and money. Moreover, these tools allow E&P companies to view their overall water costs (both D&C and production water) to improve efficiencies and reduce cost, thereby improving margins.

By utilizing decision support tools, the operator can analyze and compare multiple water management scenarios quickly and accurately. An example of an oilfield water management decision support tool that MWH has developed is included via the schematic displayed in Figure 3. Furthermore, by coupling this analysis with preliminary engineering, the operator can quickly evaluate water management costs associated with water supply, water infrastructure, treatment/reuse, and disposal alternatives, thereby eliminating risky investments and ensuring that the water solution is suited to the overall development goals. Small investments in such decision support tools can quickly and accurately accomplish these tasks and focus field planning and preliminary engineering, which is essential to continued operation in an environment of depressed and volatile oil prices.

Economic analysis, including a financial model which builds on the preliminary engineering, is essential for quantifying

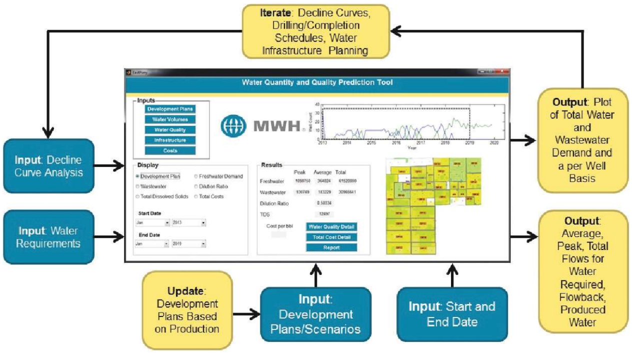


Figure 3. Water management decision support tool, MWH mFlowPlan 2015[1]

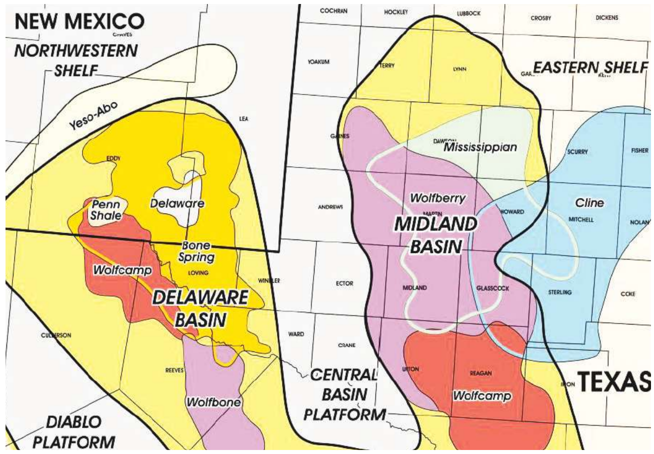


Figure 4. Permian Basin project

total water management cost savings for E&P for both CAPEX and OPEX. However, any model is only as good as the input and assumptions that it is based on. MWH decision support tool results, preliminary engineering analyses, and business economic assumptions are uploaded into a financial model to evaluate the proposed holistic water management solution compared to the status quo. The status quo is the E&P current water management costs. These are important and must be collected to be able to compare existing water management costs of the proposed solutions with the current operations to analyze the total cost savings for the E&P company. At the end of the day, with the current low commodity price environment that appears to be in place for the longer term, it is critical that water management solutions achieve a significant reduction in overall water costs to be effective. It is our experience that cost savings must be in the 30 to 70 percent range to be interesting to E&P companies in the current volatile commodities price market.

True Savings

Utilizing the aforementioned approach, MWH has developed integrated approaches to overall water management and has analyzed water supply and conveyance infrastructure solutions in two unconventional oil and gas plays — Delaware Basin (Permian) and Greater Wattenberg (Niobrara). These examples demonstrate that through proper planning, the use of decision support tools, and preliminary engineering, E&P companies can save significantly in their water management for a minimal cost.

Example 1: Delaware Basin water supply and conveyance infrastructure solution

MWH is working on a confidential project with a water rights owner in the Delaware Basin (Figure 4) to develop a groundwater resource on the owner's property and design and build a water conveyance system to provide D&C water to E&P companies that are currently assessing a multiple horizon UCOG play adjacent to this property. In this arid region of West Texas, the E&P companies currently use a combination of trucking fresh water from small water depots, shallow wells that produce at low rates (10 to 100 gpm), or treatment and reuse flowback and produced water. These water sources are used to fill a frac pit (100 to 300,000 bbls) and once the frac pit is filled a single well can be completed. While this approach allows maximum flexibility, it is costly, inefficient, and not sustainable during field delineation or development operations, as it cannot keep up with water volumes required in the time frame needed for multiwell completions on a pad. Water supply and transportation costs associated with this current industry water solution approach were estimated at $2.68/bbl, exclusive of transfer from the frac pit to blender and on pad water management costs (IHS Vantage analysis Nov 2015[3]).

MWH's proposed solution is to develop the groundwater resources on our client's property by (1) installing the desired number of deeper, larger diameter wells that are able to produce 500 to 1,000 gpm, sustained and (2) designing and building an infrastructure system consisting of permanent, buried pipelines and in-ground pits to convey the groundwater at rates of 50 to 200,000 bbls/day to E&P companies in the area. MWH analyzed numerous configurations. On the basis of the initial engineering design and construction cost estimates, MWH determined that the groundwater resource can be developed on the property and a 24-mile pipeline and 600,000 bbls of storage designed and installed for a cost ranging from $1.50 to $0.70/bbl, depending on volume and term commitment that the operator is willing to agree to. With these costs, when compared to the above-cited IHS current industry average water supply and transportation costs, the operators in the area will save between $1.18 and $1.98/bbl, or 44 to 74 percent and have a reliable, large-volume water supply for D&C operations. Moreover, MWH evaluated the use of private capital to fund the project, which allows the E&P company to preserve its capital for core operations.

Example 2: Niobrara water supply and conveyance infrastructure solution

In the Niobrara, MWH evaluated fresh water supply and conveyance infrastructure solutions for an operator east of Greeley, CO. The focus of MWH's evaluation was to demonstrate that through strategic planning and cost-effective preliminary engineering, the operator could reduce its current water-related completion costs by over 50 percent. MWH evaluated numerous options for water acquisition and water infrastructure design to meet the anticipated E&P development activity. In this area of the Niobrara, operators have recently had access to inexpensive surface water as a result of overly wet conditions. However, Colorado is typically arid, and as a result reliance on current water supplies is risky, in terms of both supply and cost, for continued development. Moreover, during wintertime operations traditional water transfer can be risky because long transfers are subject to freezing.

MWH's solution included developing a plan to secure water rights for use by the operator and to convey this water via pipeline to strategic locations within the operator's acreage. Utilizing strategic storage of water and placement of pipelines, MWH was able to provide a "screening level" analysis of the water system for evaluation by the E&P company. MWH initial engineering design and construction cost estimates for an approximate 23-mile pipeline, 600,000 bbls of in-ground storage, and groundwater wells to supply between 25 and 100,000 bbls/day ranged from $1.00 to $0.30/bbl, depending on volume and term commitment. Costs did not include transfer off the pipeline or from the in-ground storage to the pad or water costs. Comparing these costs to costs for traditional conveyance and storage methods in the greater Wattenberg area of $1.65/bbl, MWH was able to demonstrate to the E&P company that it would save between $0.65 and $1.35/bbl, or 40 to 80 percent. Moreover, as with the Delaware project, MWH evaluated the use of private capital to fund the project so the client could preserve its capital for core operations and incorporate the costs for the water solution in its drilling and completion costs.

At the end of the day, with the current low commodity price environment that appears to be in place for the longer term, it is critical that water management solutions achieve a significant reduction in overall water costs to be effective.

Conclusion

In the current market of continued low commodity prices, it is critical that costs are reduced to improve operating margins and profitability for E&P companies. One innovative avenue for those companies to achieve improved profitability is by reducing total water management costs associated with UCOG development. Total water management cost reduction was not a driver 18 months ago when oil prices were in the $100/bbl range, as operating margins were being driven by the revenue side of the equation and water management costs were a smaller percentage of the total well D&C costs. By employing holistic water management solutions that include decision support tools, such as MWH has developed, to better plan and forecast E&P life cycle water management costs, provide preliminary engineering analysis, and perform financial modeling, E&P companies can greatly reduce water-related costs associated with UCOG development. On the basis of current U.S. UCOG water management projects that we are pursuing, MWH has demonstrated cost savings of 30 to 70-plus percent on D&C water management costs. In addition, future acceptance by E&P companies of treatment and reuse of flowback and produced water has the potential to provide reduced water management costs for both D&C (water supply) and production (water disposal) operations. This technique has not been widely used due to treatment costs and availability of fresh water for fracs. Less than 5 percent of flowback and produced water is treated for reuse in the industry. If this practice becomes accepted by operators, it could reduce total water management costs (completions and production) and provide sustainable frac water during full field development and the "well factory" approach. ■

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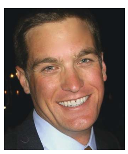
About The Authors

Jeffrey A. Anderson, PG, has more than 30 years' experience solving oilfield water management problems and developing petroleum hydrocarbons. As MWH Global' s Upstream O&G Sector leader, he provides holistic water management solutions for oil and gas operators across the globe.

William H. Fronczak, Esq., PE, has over 25 years of experience involving water matters, including eight years as an attorney and seven years as the chief of water supply for the State of Colorado Division of Water Resources. As MWH Global's Oil and Gas Business Development Director, he provides the company strategic leadership to successfully develop total water solutions for the oil and gas industry.



Stephen A. Goodwin, PhD, specializes in water management and reuse for unconventional oil and gas development. At MWH he developed mFlowPlan, a water management software tool that allows operators to better plan water management and reuse strategies to reduce cost and increase planning efficiency.

A Better Way To Back Up SCADA

How server architecture can automatically back up your whole supervisory control and data acquisition (SCADA) system

By Christopher Little

Modern SCADA software systems carry a heavy burden. They help to ensure uptime, contain a wealth of recorded history, and represent a significant investment of development time. Despite this, backing up applications and their data remains a comparatively low priority. Standard backup strategies have limitations. Offline backups leave your system blind, while online backups can interfere with your process. Both leave gaps in your history when restoring backups, and both require specialized training. Advances in networking provide a more elegant solution. If your application includes one or more networked servers, you can build automatic real-time backups for history, configuration, alarms, and input/output (I/O) tags right into your server architecture. If those servers are in separate locations, you also have an off-site disaster backup of your whole application with no extra effort. If you are without a plan or fear the day you will need to put yours into motion, this article is for you.

Traditional SCADA Backup Strategies

Manual offline (cold) backups — This process is common for smaller SCADA systems. First, someone manually shuts down the system. Then, they save the whole application (or just the historical and configuration data) to a secure location like a tape device, hard drive, or network folder. When this is complete, they restart the application. Though relatively simple, this is a time-consuming process that usually takes place outside of regular business hours. For this reason, backups can be irregular or dropped entirely.

Time-based offline (cold) backups — At regularly scheduled times, usually in the middle of the night, the SCADA application shuts down automatically and its data is exported to an SQL-based database format. This database is then recorded and archived as outlined above. Backing up offline ensures that files will not be corrupted if they are read while being updated by the running system. However, depending on the size and age of the application, this process can take anywhere from a couple of minutes to a couple of hours. All the while, operators cannot see their process displays. Alarms cannot be viewed, disseminated, or acknowledged. Thin client remote access is unavailable. Worst of all, process readings collected during this period will be permanently lost. Should the system fail and need to be restored, all process data and configuration changes logged since the last backup will also be lost.

Time-based online (hot) backups — Online backups are useful for mission-critical systems where downtime is not an option. In this scenario, the monitoring and control process remains active while the application is being saved. This ensures that alarms are managed and operators are not left in the dark. However, this runs the risk of reading files while they are being written which can affect performance and corrupt the backup database. As with cold backups, restored databases will not include process or configuration data recorded since the last backup.

Change-based online (hot) backups — Rather than updating the whole running application at once, the system backs up each change as it occurs. This eliminates the risk of losing data between backups but, like time-based hot backups, there is a risk of impeded performance and corruption as the backup process effectively "steps on the toes" of the running SCADA system.

Other Issues With Traditional Backups

Long-term compatibility of backup utilities — Though some SCADA software platforms include built-in tools for backing up historical and configuration data, others require third-party utilities. As these components are individually upgraded over time, they can cease to function together, which results in dropped backups or lost data.

Specialized technical knowledge — Most backup methodologies require an SQL-based database format. SQL (structured query language) requires specialized knowledge to configure, backup, and restore. This means an investment of time and money for the system integrator or the internal IT department at each point of the process.

A Better Way: Real-Time, Full-System Backup

Simplified SCADA Redundancy

Until recently, the cost of setting up and maintaining redundant servers with automatic failover was prohibitively expensive for most SCADA users. Modern monitoring and control software products not only make it easier to designate hot backups for fallen servers,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they can also greatly simplify the process of synchronizing historical databases across networks in real time. SCADA manufacturers are even starting to incorporate configuration management into their products.

In addition to increasing system uptime, these innovations provide an opportunity to build real-time, full-system backups right into your server architecture while simplifying the entire process. The key to this approach is using a software platform where the history, configuration log, tags, and alarms are integrated into the software itself.

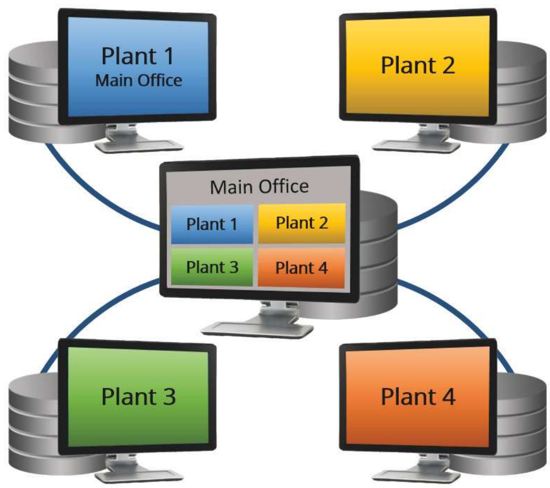
Configuration — Set up two or more SCADA servers on a shared network. Then, configure a server list to designate the primary server, as well as the order of failover to the other computers. At any given point, only one server should be responsible for polling remote monitoring and control devices. The ease of synchronizing servers will vary from product to product. Once completed, each server should contain an up-to-date copy of the historian and the change log, as well as the tag, alarm, and event databases. In effect, each server is a real-time backup of the whole application — no third-party utilities or databases required. Activities such as trending, reporting, and alarm analysis typically take place on the local server, minimizing network traffic.

Disaster backup — If one or more synced servers are located at geographically separate locations, then there is effectively a complete off-site backup in case the primary server or the building where it resides is destroyed. Restored or replaced servers should be able to pull a copy of the running application from any surviving server. Failover scenario – If the primary should go offline for any reason, the next designated server will take over polling and any other duties associated with the primary, such as acting as the thin client server. Configuration changes to displays, settings, and tags will be disseminated to all available computers on the server list. When the primary server resumes its duties, all missed historical and configuration data is bi-directionally backfilled over the network.

Example: Municipality of Colchester, Nova Scotia

The Municipality of Colchester in Nova Scotia, Canada, uses this approach at four of its sewage treatment plants that collectively service approximately 45,000 residents. Originally, each plant had its own autonomous monitoring and control system. They decided to transition to a single SCADA software platform that would allow them to monitor all four plants and make configuration changes from the main office in Colchester (Plant 1). In the process, they also managed to address long-standing issues with remote data backup and automatic failover.

Colchester standardized with software that could communicate with all the various remote programmable logic controllers (PLCs) used at each plant. It also features an integrated historian, change list, alarm manager, and tag database.



The Colchester team took this idea a step further. Each plant has its own SCADA application with a local primary server and a synchronized backup at the main office. All four backup applications run concurrently on the same computer.

In addition to providing centralized configuration, monitoring, and alarm management, this approach also provides a complete real-time backup of the entire application and its historical data. Should any local server fail, the office backup will take over logging from PLCs at the site. When restored or replaced, the primary is automatically backfilled over the network from the backup.

Never Forget Another Backup

SCADA backup strategies need to be scalable, comprehensive, and automatic. By building your backup right into your server architecture, you can ensure that you are capturing every part of your system and leaving no gaps in your historical data. ■

About The Author

Christopher Little is a member of the marketing team at Trihedral Engineering Limited. He has authored numerous HMI and SCADA articles for print and web-based publications including, *Water Online, Everything About Water,* and *Automation.com.* He has also produced a variety of videos discussing different aspects of monitoring and control systems.

Setting The Record Straight On Investor-Owned Water Utilities

Facts, figures, and case studies are presented to quell concerns over water and wastewater utility privatization.

By Mark Strauss

All across America, communities are faced with massive challenges to replace critical water and wastewater infrastructure, with limited access to the capital needed to make these upgrades on an increasingly urgent timeline. When we talk about the aging infrastructure in our country, it's important to keep in mind that upgrading the vast and complex systems is not the sole responsibility of any one group, organization, or entity.

With an estimated 650 water main breaks occurring every day, and 2 trillion gallons of treated water lost every year at a projected cost of $2.6 billion, aging and deteriorating public water systems threaten economic vitality and public health. The need to reverse years of underinvestment in infrastructure, despite tighter budgets at every level of government, calls for us to rethink how we pay for and manage infrastructure investment.

There has been a longstanding debate over the role of investor ownership in the water utility sector, which some say — as an essential resource — should be in the hands of government entities. However, this argument is commonly grounded on misconceptions about how investor-owned utilities operate. In reality, investor-owned water and wastewater providers have a long history of financial and technical capabilities to address challenges for communities.

In reality, investor-owned water and wastewater providers have a long history of financial and technical capabilities to address challenges for communities.

Government-owned systems make up approximately 84 percent of our nation's water systems, and more than 97 percent of our nation's wastewater systems, but many municipalities are challenged by limited budgets, inability to raise capital, and competing priorities. In fully owning, managing, and operating a water or wastewater system or in working with municipalities via public-private partnership (PPP) agreements, investor-owned utilities can meet local needs and ensure communities receive high-quality, reliable water as well as reliable and environmentally sound wastewater service now and in the future.

The Question Of Rates

First, it is important to understand what drives increases in rates. Capital investment needs are the primary drivers of rate requests. This allows for the provision of reliable services — including repairs, upgrades, treatment upgrades, and new sources of supply. Rates are set by state regulators staffed with experts in utility regulation. All expenses of investor-owned utilities are disclosed to and reviewed by the economic commission staff and state ratepayer or consumer advocacy groups. The cost of providing water and sewer service is then billed to customers through their water rates only and is not partially funded by other taxes.

Government-owned utilities have a limited taxpayer and revenue base that must service all the municipalities needs, not just water and wastewater services. As a result, many municipalities, particularly medium to smaller systems, find themselves with significant constraints in their ability to attract capital to maintain reliable service and comply with increasing quality requirements.

A case in point: In June 2015, New Jersey American Water acquired the borough of Haddonfield's water and wastewater system, which faced significant challenges. The company worked with the borough to identify the most critical system needs to be addressed and has an aggressive plan to make upgrades. Over the next five years, New Jersey American Water will spend more than $16 million on system renewal and modernization.

If the sale hadn't gone through, the borough of Haddonfield Board of Commissioners, which recently raised the rates 25 percent, announced that rates would continue to rise to pay for much-needed capital improvements and would actually exceed New Jersey American Water's rates. As part of the sale agreement, New Jersey American Water committed to leaving the water rates unchanged for three years. And, because New Jersey American Water is regulated by the New Jersey Board of Public Utilities, any

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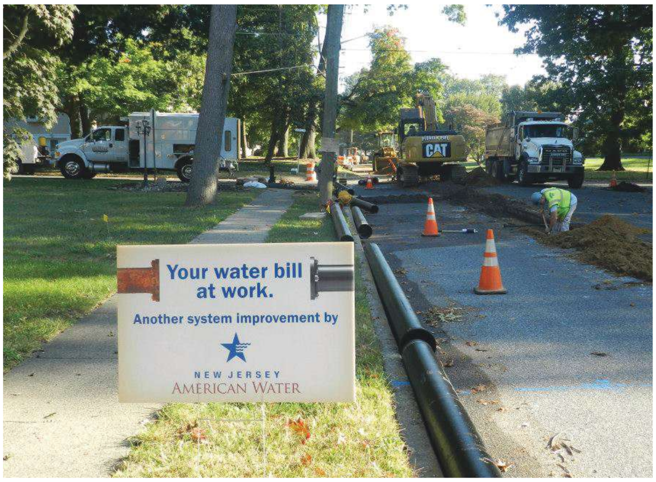
future proposed changes in water and/or wastewater rates would be subject to extensive governmental review and approval.

Bigger Can Be Better

Public systems serving a small population have little bargaining power when it comes to paying for equipment, tools, chemicals, and a host of other requirements needed to support high-quality, reliable systems. Despite their tax base, they still must provide the same basic services such as billing, customer service, and water testing as a larger utility, meaning water and wastewater service management and maintenance comes at a much higher price. As operations become increasingly complex and costly, many small systems could find it difficult to meet performance standards and sustain operations.



Economies of scale brought by larger entities like American Water can benefit communities.

By operating on a larger scope and serving multiple communities, investor-owned water utilities can take advantage of economies of scale and bargain to keep down construction and operation costs. Investor-owned utilities are able to procure materials such as pipe, hydrants, and fleet vehicles for less than smaller systems and also manage systems more effectively.

Even with the willingness to spend the money, many communities lack the in-depth experience to design and/or implement infrastructure upgrades on their own or to operate and maintain systems that are becoming more complex due to increasing water quality requirements. With deep water industry experience, investor-owned water utilities can provide tailored, innovative solutions to meet a community's specific needs. For American Water, this includes local pipe maintenance, leak detection, water reuse technology, and much more.

Along with managing and operating systems, because a primary aspect of a larger water company business is upgrading infrastructure, they accumulate skills based on operating multiple water and wastewater systems in a variety of geographic settings. In terms of resources, these water utilities maintain highly specialized staffs of scientific experts and engineers who can be made available to communities as needed. Through partnerships, municipalities gain affordable access to such expertise.

Real-World Value

For example, the San Clemente Dam Removal & Carmel River Reroute Project is the largest dam-removal project ever to occur in California and one of the largest to occur on the West Coast. An agreement with California American Water (CAW) and federal, state, and local agencies provides a framework to cooperatively remove the dam. It enables CAW to resolve dam safety concerns through the lowest-cost solution for ratepayers. Public agencies, led by the California State Coastal Conservancy and NOAA's (National Oceanic Atmospheric Administration's) National Marine Fisheries Service, will secure additional funds to pay for the dam-removal project. This project demonstrates that when public and private interests work together, benefits are realized far beyond what either could achieve alone. By overcoming numerous political and procedural challenges, the San Clemente Dam Removal Project can be a model for other public-private cooperative efforts.

Whether regulated or market-based, acquisitions or partnerships are about providing water and wastewater solutions. American Water consistently achieves water quality results that are 13 times better than the industry average for meeting all drinking water requirements and has invested almost $1.2 billion in 2015 to improve water and wastewater systems.

In May 2015, Missouri American Water announced the closing of the company's acquisition of the city of Arnold's sanitary sewer system, which added 8,800 sewer customers to Missouri American Water's operations in St. Louis County. Like many municipalities around the country, Arnold was not charging residents what it needed to keep the system up to date, especially with increasingly stringent U.S. EPA and Clean Water Act requirements coming into force. Over the next four years, Missouri American Water will invest approximately $5 million to upgrade and improve the infrastructure of the Arnold sanitary sewer system.

The residents are now benefitting from outstanding customer service, stable rates (which are overseen by the Missouri Public Service Commission), infrastructure investment, and service to the community. In addition, sewer employees, formerly employed by the city of Arnold, continue to provide system operation and field services now as Missouri American Water employees.

Conclusion

Working with investor-owned water providers is a viable solution to a number of serious water industry problems. Investor-owned water companies can help address these challenges by offering access to capital for investment, identifying more cost-effective ways to deliver service, and providing industry expertise and experience. In working together with municipalities, investor-owned utilities can offer clear benefits to communities and remain fully committed to helping communities meet their local water and wastewater needs. ■

About The Author

Mark Strauss is senior vice president of Corporate Strategy and Business Development for American Water, the largest and most geographically diverse publicly traded U.S. water and wastewater utility company. With more than 20 years experience in senior leadership roles for the company, Mr. Strauss oversees strategy and major growth efforts for American Water's regulated and competitive operations.