JOURNAL OF THE NEW ENGLAND WATER ENVIRONMENT ASSOCIATION

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NATIONAL ISSUES OF REGIONAL INTEREST

NEWEA

WORKING FOR WATER QUALITY

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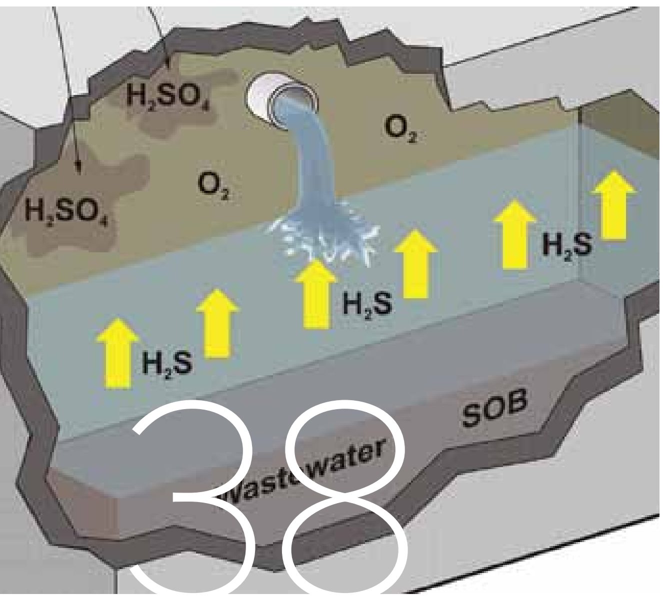

On the cover: Fluidized bed incinerator at the Lynn, Massachusetts, Water & Sewer Commission Regional Water Pollution Control Plant

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NEWEA
WORKING FOR WATER QUALITY

OUR ASSOCIATION WAS ORGANIZED EIGHTY-EIGHT YEARS AGO in Hartford, Connecticut, on April 23, 1929, with the objectives of advancing the knowledge of design, construction, operation and management of waste treatment works and other water pollution control activities, and encouraging a friendly exchange of information and experience. From 40 charter members, the membership has steadily grown to more than 2,000 today. Membership is divided into the following classes:

Professional Member—shall be any individual involved or interested in water quality including any manager or other officer of a private waste treatment works; any person engaged in the design, construction, financing, operation or supervision of pollution control facilities, or in the sale or manufacture of waste treatment equipment.

Executive Member—shall be an upper level manager interested in water quality and who is interested in receiving an expanded suite of WEF products and services.

Corporate Member—shall be a sewerage board, department or commission; sanitary district; or other body, corporation or organization engaged in the design, consultation, operation or management of water quality systems.

Regulatory Member—this membership category is a NEWEA only membership reserved for New England Environmental Regulatory Agencies, including: USEPA Region 1, Connecticut Department of Energy and Environmental Protection, Maine Department of Environmental Protection, Massachusetts Department of Environmental Protection, New Hampshire Department of Environmental Services, Vermont Department of Environmental Conservation, and Rhode Island Department of Environmental Management.

Academic Member—shall be an instructor or professor interested in subjects related to water quality.

Young Professional Member—shall be any individual with five or fewer years of experience in the water quality industry and who is less than 35 years of age.

Professional Wastewater Operations Member (PWO)—shall be any individual who is actively involved on a day-to-day basis with the operation of a wastewater collection, treatment or laboratory facility, or for facilities with a daily flow of <1 million gallons per day. Membership is limited to those actually employed in treatment and collection facilities.

Student Member—shall be a student enrolled for a minimum of six credit hours in an accredited college or university.

WEF Utility Partnership Program (UPP)—NEWEA participates in the WEF Utility Partnership Program (UPP) that supports utilities to join WEF and NEWEA while creating a comprehensive membership package for designated employees. As a UPP a utility can consolidate all members within its organization onto one account and have the flexibility to tailor the appropriate value packages based on the designated employees' needs. Contact WEF for questions & enrollment (703-684-2400 x7213).

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BECOME A NEWEA MEMBER

- Complete and mail the membership application form on pages 87–88
- Download a membership application from **newea.org** by clicking—*How Do I Join?*
- Join online at **wef.org** by clicking—*Become a Member*

2017 RATES

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Legitimate paid and/or requested distribution	Outside county paid/requested mail subscriptions	0	0
	In-county paid/requested mail subscriptions	2,200	2,200
	Sales through dealers & carriers	8	8
	Requested copies distributed by other mail classes	0	0
Total paid and/or requested circulation		2,208	2,208
Total nonrequested distribution		0	0
Total distribution		2,208	2,208
Copies not distributed		292	292
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NEWEA
WORKING FOR WATER QUALITY

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President's Message

We've got time to think of the ones we love, while the miles roll away.
But the only time that seems too short, is the time that we get to play.
– Jackson Browne

One privilege of serving as NEWEA president is traveling the New England highways and byways to participate in our specialty conferences, tradeshows, and legislative events—our most obvious mile markers—to meet with friends and colleagues to celebrate the work we do to protect and enhance our water resources. Late in October, while driving to Burlington, Vermont, for the Northeast Residuals and Biosolids Conference, I avoided I-89 and traveled north on Route 7. I wanted to take my time and enjoy the ride, guided by the music of one of my favorite American bands, Tom Petty and the Heartbreakers, to take pause and reflect on the friendships and connections I have made throughout the year, while viewing the colorful backdrop and splendor of the Green Mountains. As I made my way into Burlington, with majestic Lake Champlain riding along with me to the west, the sun was slowly setting over the peaks of the Adirondacks. The stillness and tranquility of the horizon struck me, signifying not just the end of a great day and road trip but also foreshadowing the curtain closing on my year as president. It truly has been an amazing experience and I thank all of you, my fellow travelers throughout New England, for this opportunity to serve with you. This past year has revealed to me that your focus, diligence, and dedication to water quality excellence is undeniable. Thanks for sharing this ride with me and inspiring me to be a better leader and person. I have truly enjoyed your company. Always have.

In keeping with our traveling theme, these last few months have taken NEWEA members to many exciting places. We ventured to Chicago to attend the annual WEFTEC Conference and kicked it off with our reception on Sunday night at historic Soldier Field with more than 70 members mingling and enjoying the spectacular view of Lake Michigan and the Chicago Bears' home field. We were well represented in the Operations Challenge event with Connecticut's Franken Foggers, Maine's Force Maine, and Rhode Island's Ocean State Alliance competing with more than 40 teams from the United States and Canada. A highlight of the conference was WEF's recognition of Paul Dombrowski of Woodard & Curran as a WEF Fellow at the Awards and Presidential Celebration Ceremony. This prestigious award recognizes the professional achievement, stature, and contributions of WEF members to the preservation and enhancement of the global water environment. At this ceremony, the gavel was passed

The lighthouse in Lake Champlain in the dusk as seen from Burlington, Vermont

to 2017–2018 WEF President Jenny Hartfelder of the Rocky Mountain Water Environment Association. Jenny is energetic and engaging, and we congratulate her and look forward to her leadership of WEF over the coming year.

Back in New England, President-elect Janine Burke-Wells joined the Small Community Committee at its one-day specialty conference on Resiliency Planning: Operator & Engineer Collaboration & Design in Keene, New Hampshire. Attendees included officials of small communities, operators of small wastewater facilities, consulting engineers, and product representatives, with topics discussed including climate adaptation strategies, hazard mitigation, and collection system resiliency. Special thanks to the conference sponsors, exhibitors, presenters, and committee officers, Chair Dan Ottenheimer and Vice Chair Kurt Mailman for their leadership and efforts in planning and coordinating this event.

My travels took me to the Narragansett Bay Commission's Fields Point Wastewater Treatment Plant in Providence, Rhode Island. My good friend Bill Patenaude, principal engineer with the Rhode Island Department of Environmental Management's Office of Water Resources, invited me to join him at his Wastewater Leadership Operator Boot Camp program that was developed in 2007 by the state of Rhode Island together with the Narragansett Water Pollution Control Association (NWPCA), the Narragansett Bay Commission, the New England Interstate Water Pollution Control Commission, and EPA. Attendees are nominated by their employers and participate in a one-year professional development program that provides opportunities to network with colleagues, advance their knowledge of statewide, regional, and national wastewater collection, treatment, and management issues, and enhance their technical and leadership skills. Mr. Patenaude asked me to provide my insights on the importance of professional society involvement and to highlight my experience as NEWEA's president. NWPCA member Peter Connell, a former participant in the program, also spoke and emphasized the value of this program to his professional career growth. I applaud Mr. Patenaude for his leadership in the development and administration of this program, and I salute the participants who play such a vital and essential role operating our treatment facilities and collection systems that serve our communities.

Our Northeast Residuals and Biosolids Specialty Conference showcased emerging technologies, presentations on research initiatives and hot topics, anaerobic digestion, carbon and phosphorus considerations, and a tour of the Essex Junction Water Resource Recovery Facility. We celebrated the 20th anniversary of the Northeast Biosolids & Residuals Association (NEBRA) with keynote speakers Ned Beecher, NEBRA executive director, and Mark Young, NEBRA's outgoing president, providing their perspectives on advancing sustainability through residuals recycling. I acknowledge Chair Natalie Sierra, Vice Chair Eric Spargimino, and the Residuals Management Committee for developing a comprehensive and thought-provoking program for more than 100 attendees.

I especially acknowledge the activities and successes of our recently formed Veterans Workforce Development Committee that is being led by United States Navy veteran and Chair Dustin Price, United States Air Force veteran, Vice Chair Jeremiah Murphy, and New Hampshire Water Pollution Control Association (NHWPCA) Past President Peter Goodwin. Under their leadership, committee members have met with various state agencies throughout New England to develop new programs to directly connect veterans with job opportunities in our water industry. I look forward to NEWEA being a leader in recognizing and serving our veterans who have done so much to serve our nation.

As I bid a fond farewell to this incredible year, I offer my sincere thanks to Mary Barry, Janice Moran, and Linda Austin, the Wonder Women of NEWEA, for their friendship, encouragement, and support throughout the year. I acknowledge the Executive Committee, and current and former members of the senior management team with whom I have served, Past Presidents Ray Willis, Matt Formica, and Brad Moore, Treasurers Priscilla Bloomfield and Frank Occhipinti, President-elect Janine Burke-Wells, and Vice President Ray Vermette. Truly a NEWEA all-star team, and I have been blessed to have such wise colleagues and good friends with me every step of the way. Finally, I thank you, our members, for striving for water quality excellence each day, participating in our activities, and supporting our organization.

This year's theme has been student and young professional outreach, and I leave you with these words to consider. The song *Seven Turns* by the Allman Brothers has a verse that has always resonated with me. "Somebody's calling your name, somebody's waiting for you. Love is all that remains the same, that's what it's all coming to." Challenge yourself to listen for that call and find that person waiting for you, be his or her mentor, make a difference in his or her life, and be a part of his or her journey. Our legacy, and the story that it will tell, is up to you.

From the Editor

Joe Boccadoro, P.E., Senior Project Manager—Water, AECOM

As indicated on the cover, the theme for this edition of the *Journal* is National Issues of Regional Interest. The *Journal* has also featured an overall "throwback" theme throughout 2017 in which we have among other things reprinted past articles, in some cases dating to our inaugural edition in 1967. To close out our throwback theme, I want to compare articles appearing in the 2017 Winter edition to those published in the past to look for any similarities or differences in the issues facing the water industry then versus now, as well as to raise a few more current issues for consideration.

For comparison, I reviewed over 40 years of article titles from our *Journal* archive, from the first edition in 1967 to Winter 2010. I capped my search at 2010, thinking that any period after that would be too current. From there I searched for topics that could be considered a national issue and arranged them by decade.

Era	Selected National Issue
1967–1970	Impact of nuclear power on water quality Nutrient control Waste oil disposal
1971–1980	Land disposal of sludge Spray application of wastewater effluent
1981–1990	Private source inflow removal Emergency response planning Collection system operator certification Water quality preservation without sewers
1991–2000	Odor control Reclaimed water/water reuse
2001-2010	Removal of illicit connections from storm drains Asset management FOG programs Microconstituents Stormwater utilities Greenhouse gas emissions from biosolids Energy recovery from wastewater effluent

This is obviously a subjective exercise; opinions will vary about what constitutes a national issue. Also, time did not permit reading any of the archived articles, so an issue's appearance on the list above was based solely on the title. Lastly, the Winter 2017 *Journal* articles represent a narrow timespan compared to over 40 years of historical *Journal* content. Keeping these points in mind, here are my observations from this research:

- Nuclear power was certainly in the consciousness in the late 1960s, and its potential impact on water quality was important enough to inspire an article. Over the decades similar articles did not appear in the *Journal*, a sign that the topic faded, probably due to the prevalence of wastewater treatment facilities under regional and local authority compared to fewer nuclear power plants under federal control.
- Water quality is obviously as important now as it was in the past, and reuse of water to support these causes remains a key initiative.
- The first article on nutrient control was published in the *Journal* in the 1960s, and then the topic appeared regularly throughout the decades. Nutrient control and innovative ways to accomplish it consistently appear in the national and regional publications.
- Parochialism seemingly has not abated over the years as possibly indicated by the MS4 permitting article and the titles about solving pollution problems without installing sanitary sewers.
- Decades ago security meant fences, gates, and locks. Now it has expanded to include computer security and protection against threat of cyberattack.

In general, the research above leads me to believe that New England has had a good pulse on national issues based on the topics we choose to write about. Following I describe some of these other issues of national or regional interest.

Climate change: I will refrain from commenting about political opinions on climate change. Most in the scientific community likely agree that it is a national and international issue that needs attention and focus. It certainly would have been a worthy topic for the Winter *Journal*.

State of infrastructure and funding gap: In the Fall 2016 *Journal*, I wrote about a $100 billion gap between need and actual spending over the next 10 years that was predicted in an American Society of Civil Engineers publication. No significant government intervention has occurred in the last year to close this gap, and this topic remains an important national issue.

Asbestos cement (AC) pipe: A few months ago I reviewed several of the first *Journal* publications from the late 1960s while doing research for the 50th anniversary edition. Within the first few pages, an advertisement appeared for a major manufacturer of AC pipe. The ad extolled the benefits of this material, including corrosion resistance, strength, and durability. It was shocking to see, given the ever-increasing present-day regulatory focus on the removal, handling, and disposal of previously installed AC pipe. This issue seems to be gaining traction nationally, and certainly has received significant attention regionally and locally.

Future *Journal* themes & submission deadlines
Spring 2018—**Operators** (Dec. 29, 2017)
Summer 2018—**Engineers** (March 30)
Fall 2018—**Public Works/Municipal** (June 29)
Winter 2018—**Young Professionals** (Sept. 28)


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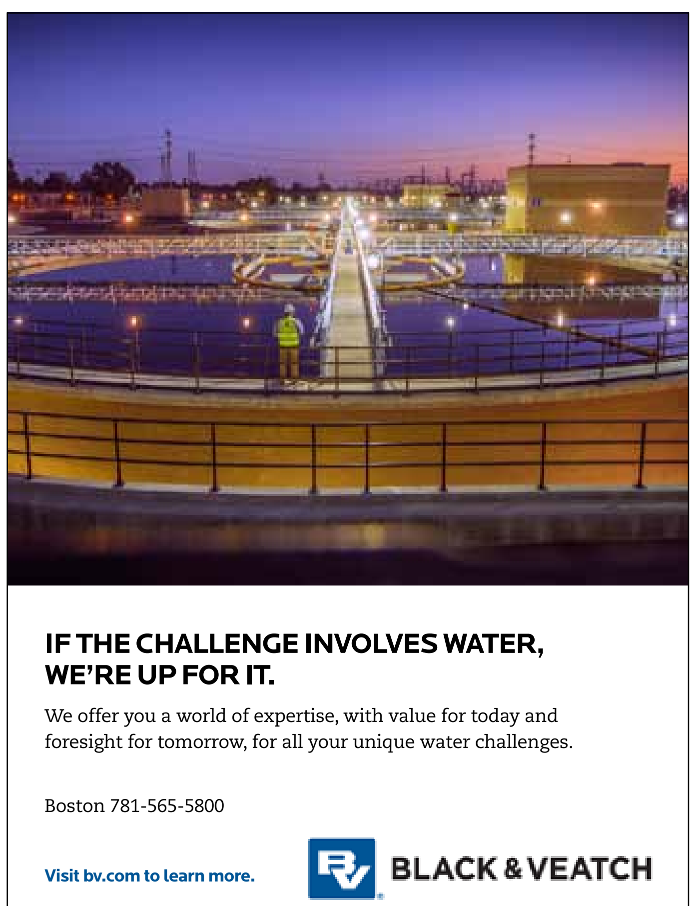
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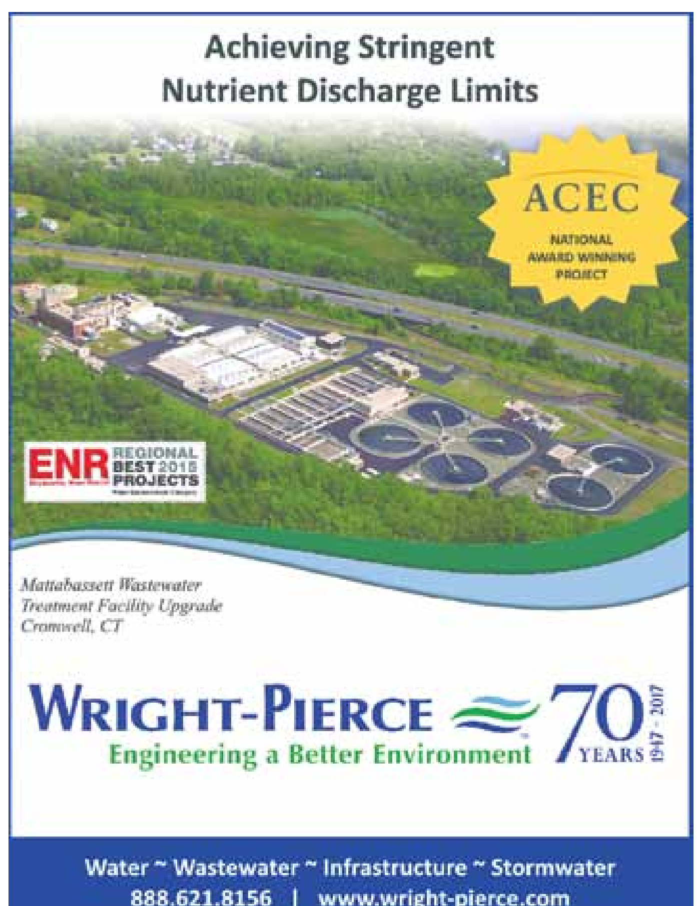
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Industry News

The propylene glycol recovery system at the T.F. Green Airport, in Warwick, Rhode Island, is one of only four de-icer management facilities in the world

EPA Recognizes Rhode Island Project for Excellence and Innovation in Clean Water Infrastructure*

In late October, EPA recognized 28 clean water infrastructure projects for excellence and innovation within the Clean Water State Revolving Fund (CWSRF) program. Honored projects include large wastewater infrastructure projects to small decentralized and agriculture projects. Among the 28 projects by state or local governments, public utilities, and private entities recognized by the 2017 Performance and Innovation in the SRF Creating Environmental Success (PISCES) program was the Rhode Island Airport Corporation (RIAC) glycol recovery system.

The propylene glycol recovery system at the T.F. Green Airport, in Warwick, Rhode Island, is one of only four de-icer management facilities in the world. Funded with $33 million from the Rhode Island Infrastructure Bank, this world-class approach to capturing contamination from plane de-icing chemicals allows the airport to comply with its Rhode Island Pollutant Discharge Elimination System (RIPDES) permit. The system replaces the previous management technique of using vacuum trucks to capture propylene glycol from catch basins that recovered only 20 to 30 percent of the pollutant.

The new collection system achieves a laudable 60 percent collection rate and has been sized to ensure the airport facility can grow and drive economic development. The sophisticated system diverts stormwater runoff to storage tanks, where real-time sensors can detect de-icer contamination and divert, store, and treat the runoff using anaerobic digestion. Leaving no opportunity untouched, the system captures methane produced by the treatment process and uses it to pre-heat the incoming waste stream as well as to heat the treatment facility, reducing operations and maintenance costs by lowering natural gas usage at the facility by 95 percent. This well-considered process prevents propylene glycol (known for lowering dissolved oxygen in waterbodies) from entering Warwick Pond and Buckeye Brook. Buckeye Brook is undammed and, along with Warwick Pond, is a spawning ground for many fish such as alewife and blueback herring that migrate into Narragansett Bay. The project protects the water quality for these fish species essential to the bay's ecosystem and the local fishing industry, and received accolades from local watershed advocates.

EPA News Release
* Emily Bender
**David Deegan

EPA's PISCES program celebrates innovation demonstrated by CWSRF programs and assistance recipients. The CWSRF is a federal–state partnership that provides communities a permanent, independent source of low-cost financing for a wide range of water quality infrastructure projects. Over the past 30 years, CWSRF programs have provided more than $125 billion in financing for water quality infrastructure.

"For decades the Clean Water State Revolving Fund has supported critical water infrastructure projects that help grow the American economy and support our way of life," said Mike Shapiro, acting assistant administrator for EPA's Office of Water. "These projects are a testament to the power of the Clean Water State Revolving Fund in leveraging investment to meet the country's diverse clean water needs."

Three Groups in New England Awarded EPA Grant to Help Air and Water Issues**

Three groups in New England received an EPA Environmental Justice Small Grant award of $30,000 each to address local environmental concerns in local communities. This EPA grant program provides critical support to organizations that otherwise lack the funding and resources to address the environmental challenges in their community, and helps communities understand and address exposure to multiple environmental harms and risks. It funds projects of up to $30,000 a year.

The New England awards went to one program in Connecticut and two in Rhode Island, as follows:

- The New Haven Urban Resources Initiative plans to plant 500 street trees in underserved neighborhoods, engage 300 residents to take care of the trees, and maintain 20 bioswales—landscaped areas that drain silt and pollution from surface water runoff. New Haven suffers from both water and air pollution due to combined sewer overflows and high levels of particulate matter in the air. The Initiative also will provide green job training for nearly 40 residents.
- Groundwork Rhode Island will work closely with the Central Falls High School to develop a youth-based environmental program focused on stormwater management, green infrastructure, public green space, trees, and solid waste disposal.
- Childhood Lead Action's Lead-Safe Blackstone Valley project will work in three of Rhode Island's high-risk communities to reduce the incidence of childhood lead poisoning, improve the safety of rental housing, and increase the capacity of Central Falls, Pawtucket, and Woonsocket residents to address lead issues.

"When the community takes part in protecting the environment, the changes are more sustainable," said Deb Szaro, regional administrator of EPA's New England office. "EPA provides funding so these communities can participate in protecting their own environments."

The 2017 grants will help organizations in 30 states and Puerto Rico carry out projects that will educate residents about environmental issues that may affect their health, collect data about local environmental conditions, and collaborate in addressing environmental justice challenges in their communities. Nationally, 36 non-profit and tribal organizations received nearly $1.2 million for environmental justice projects. Environmental justice means the fair treatment and meaningful involvement of all people, regardless of race or income, in environmental decision-making.

The grants support activities that not only address a range of community concerns but also those that educate and empower youth and the next generation of leaders in STEM (science, technology, engineering, and mathematics)-related job sectors and environmental stewardship. Specific grant projects will focus on reducing exposure to lead and other water pollutants, developing green infrastructure and sustainable agriculture projects, implementing basic energy efficiency measures in low-income households, and increasing overall community resiliency.

Eel grass

EPA Awards Casco Bay with Annual Grant Funding to Improve Water Quality**

EPA has awarded a $630,000 grant to the Casco Bay Estuary Partnership, which is housed at the University of Southern Maine in Portland. The funds will go toward reducing nutrient pollution, protecting and restoring key habitats, and improving resilience and community education around the Casco Bay watershed.

"A healthy Casco Bay is vital to the environmental and economic health of Maine," said EPA Administrator Scott Pruitt. "Promoting and protecting a healthy fishery in Casco Bay is an essential economic foundation for many coastal communities. EPA's National Estuary Program is a place-based program that is helping to protect and restore the water quality and ecological integrity of estuaries of national significance."

Casco Bay is part of EPA's National Estuary Program (NEP) to protect and restore the water quality and ecological integrity of estuaries of national significance. Casco Bay borders Maine's largest metropolitan area. Its watershed represents just three percent of the state's total land mass but holds roughly 18 percent of its population and includes portions of 48 municipalities. It has 575 miles (925 km) of shoreline and 785 islands and ledges. Casco Bay is one of 28 NEPs in the United States and Puerto Rico designated as estuaries of national significance. Each NEP focuses within a study area that includes the estuary and surrounding watershed.

"The health of the Casco Bay estuary is so vitally important to the health of our communities, the regional and state economic climate, and the resilience of the watershed," remarked Dr. Curtis Bohlen, executive director of the Casco Bay Estuary Program. "Thanks to continued support by EPA, the Casco Bay Estuary Program and its partners can continue collaborating to support and protect the health of Casco Bay."

In 2016, the Casco Bay Estuary Partnership, with its partners, finalized a revised Comprehensive Conservation and Management Plan, a five-year plan containing actions to address water quality and living resource challenges and priorities. The Casco Bay Plan is focused on four goals:

- Protect, restore and enhance key habitats such as salt marshes, eelgrass beds, and fish passage
- Reduce nutrient pollution and its impacts, such as coastal acidification
- Increase public engagement with the bay and foster resilient communities as they adapt to climate change
- Mobilize collective knowledge and resources, including convening groups to address problems, such as nutrient pollution

To that end, this grant will help fund the recently convened Nutrient Council, a high-level group that will evaluate options to reduce nutrient loads to the bay. By national standards, Casco Bay is relatively healthy, yet it is far from pristine. Roadways, lawns, wastewater treatment plants, and air pollution contribute excess nutrients and toxics to marine ecosystems. In the last few years, scientists and Casco Bay Estuary Program partners have observed possible signs of increased nutrient enrichment, such as algal blooms on mudflats and negative impacts to eelgrass beds.

EPA Provides State of Vermont $14.7 Million for Water Infrastructure Projects**

EPA has awarded $14.7 million to the state of Vermont to help finance improvements to water infrastructure essential to protecting public health and the environment. The funds will be primarily used to upgrade sewage plants and drinking water systems, as well as replacing aging infrastructure, throughout the state.

The CWSRF program, administrated by the Vermont Department of Environmental Conservation (DEC) and the Vermont Bond Bank, received $6.5 million of the funding. EPA's funding provides low-interest loans for water quality protection projects to make improvements to wastewater treatment systems, control pollution from stormwater runoff, and protect sensitive water bodies.

The Drinking Water State Revolving Fund (DWSRF) program, also administrated by the Vermont DEC and the Vermont Bond Bank, received the remaining $8.2 million. EPA's funding provides low-interest loans to finance improvements to drinking water systems, with a focus on funding small and disadvantaged communities and programs that encourage source protection, oversight of system operations, and training as tools for ensuring safe drinking water.

"EPA's Clean Water and Drinking Water SRF funding provides a critical infusion of money that accelerates the construction of projects to meet communities' water infrastructure needs," Mr. Pruitt said. "These investments empower our states and municipalities to solve real environmental problems in our communities, like the need for clean and safe water."

"This federal funding of Vermont's State Revolving Funds is critical to maintaining and upgrading our water and wastewater infrastructure," noted Emily Boedecker, commissioner of the Vermont DEC. "For example, to address phosphorus pollution to St. Albans Bay, Vermont DEC will invest funds from this award to assist refurbishment of the city of St. Albans wastewater treatment facility. We will also invest in drinking water system upgrades, such as for the Coventry Fire District No. 1, to address arsenic contamination that affects over 100 residents."

Since the beginning of this program, EPA has awarded more than $410 million to Vermont for the construction, expansion, and upgrading of drinking water and clean water infrastructure, resulting in safer drinking water and decreased pollutant loadings to waterbodies throughout the state.

As communities develop and climate patterns shift, water infrastructure needs are expected to grow. Green infrastructure is a cost-effective and resilient approach to water infrastructure needs that provides benefits to communities across the nation.

EPA Announces Grant to Support Safe Beaches in Rhode Island*

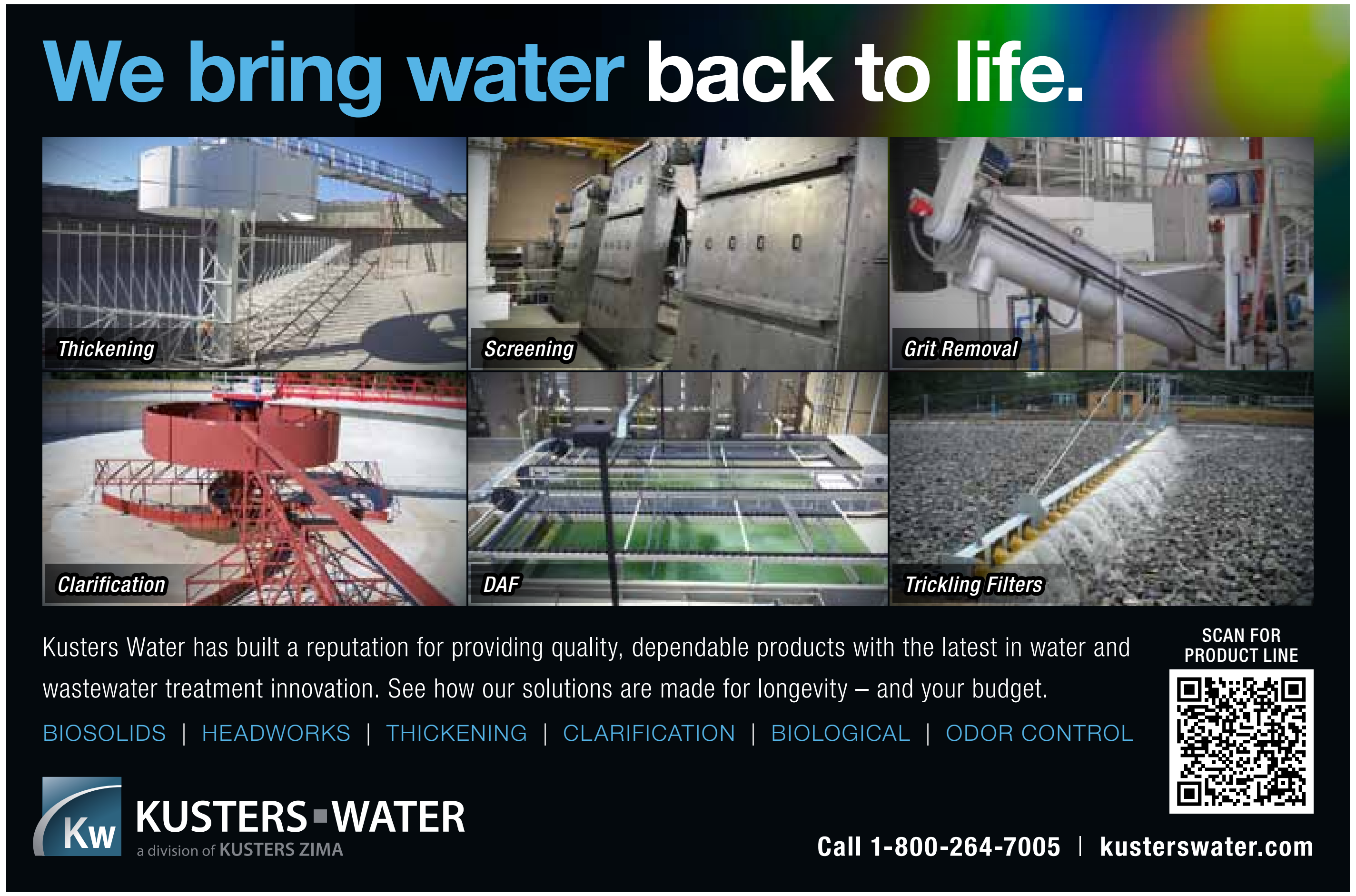
EPA announced a grant of $203,500 to the Rhode Island Department of Health (RIDOH) for its coastal beach monitoring program. Including this grant, Rhode Island has now received $3.4 million since 2001 under the federal Beach Monitoring and Notification Program Development act to implement and support monitoring, assessing, and reporting the condition of a hugely valuable resource for the state's citizens.

"Swimming when bacteria levels are high can be harmful to human health," said Mr. Pruitt. "This funding will help ensure that Rhode Island's beaches are safe and enjoyable."

"Rhode Island's hundreds of miles of coastline are at the economic, environmental, and cultural heart of our state," added Dr. Nicole Alexander-Scott, director of health. "This grant from EPA will allow RIDOH's beach monitoring program and RIDOH's state health laboratories to work together to ensure the safety and accessibility of this invaluable resource for people in every single zip code in Rhode Island."

Rhode Island has more than 400 miles (640 km) of coastline, with some of its beaches seeing up to 10,000 visitors in a single day during the summer. The beach grants are essential to a broader initiative to find and eliminate sources of pollution, particularly stormwater and other nonpoint sources, that contribute to chronic beach closures. Under the beach program, RIDOH monitors 69 licensed saltwater beaches for indicator bacteria; maintains and operates a public notification system; provides technical assistance to communities to assess pollution sources at specific beaches; and reports annually to EPA on the results of its monitoring and notification actions.

In 2016, Rhode Island posted 12 saltwater beach closure events (number of times a beach was closed due to exceedance of water quality standards) and 23 saltwater beach closure days (number of days a beach was closed during an event). These numbers are a major improvement over 2015 when 27 closure events occurred over 54 closure days. Because 2016 was a drier year than 2015, a more telling sign of improved water quality at beaches is that the 2016 decreases occurred under rainfall conditions very similar to those in 2014 that led to almost three times as many closure events (34 versus 12).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FEATURE

Thoughts on the value of water and water rights

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ABSTRACT | How does one begin to value water? Water is valued today more than ever and yet it is still vastly undervalued because it is required to sustain life.[1] Water is critical to the production of energy, and since energy drives economies and industrial production, water is the most powerful commodity in the world. People take clean water and the availability of water for granted. Numerous factors and important considerations determine the value of water, and the rights and responsibilities we have to provide safe, cost-effective, and reliable access to it. This paper will present issues that water professionals are grappling with that affect the water renewal industry and how the industry must lead the discussion to educate the public, and support technology and innovation to ensure that clean and safe water is a resource accessible to all, sustainable, and properly valued.

KEYWORDS | Water, wastewater, renewal, value, natural rights, energy, water indices, natural capital, innovation, technology life cycle, sustainability

VALUE OF WATER FOR ECONOMIC GROWTH

Water is valued today more than ever and yet it is still vastly undervalued because it is required to sustain life.[1] No other natural resource has the power of water or the importance of water. Wars have been fought, economies created, and political and regional boundaries defined by water. Water is critical to the production of energy, and since energy drives economies and industrial production,[2] water is the most powerful commodity in the world. Figure 1 depicts the cumulative water demand for gross domestic product (GDP) by country. This graph is based on data from the International Monetary Fund World Economic Outlook Database with an estimate of 5.8 MG (22 ML) of water for every $1 million in incremental GDP.[3] Water demand and quality to drive industrialization are increasing at a dramatic rate as can be seen in the figure.

The world's increase in water demand for manufacturing, industry, and GDP between 2010 and 2016 is greater than the total daily water withdrawal[4] in the United States. This increase in water withdrawal is simply not sustainable and has depleted groundwater and other high-quality water sources in many developing countries. Figure 2 depicts the projections for water demand increase for GDP by country. As can be seen in the figures, the two largest consumers of water are China and the United States followed by Brazil, Russia, and India.

ENERGY CONSUMPTION AND PRODUCTION

Water supply and treatment consumes large amounts of energy, and the production of energy for the oil and gas industries and electricity production requires vast amounts of water. For example, the energy consumed across the water cycle for a typical water treatment and secondary treatment process is approximately 1,500–2,500 kW/h per million gallons (400–660 kW/h per million liters).[5] Figure 3 shows the water usage by category for several states in the northeastern United States.

As shown in Figure 3, typically 80 percent of water withdrawal in the Northeast is used for energy production. This is synonymous with the energy–water nexus. The U.S. Department of Energy estimates that the water demand for energy generation will increase by approximately 50 percent by 2030.[6] This practice is not sustainable and in fact increases the conflict between water withdrawals for environmental habitat and industry. How will this affect our future and what are the consequences of increasing demand and dwindling supply for water value and water rights?

ENERGY VALUES FOR CLEAN WATER

As pristine natural water quality is dwindling and becoming more difficult to find, water quality can be defined as a function of increasing energy input.[7] An increase in water quality is observed for each unit of energy, although the relationship is often not linear or proportional. Increasing levels of water quality can be characterized by lower levels of turbidity, suspended solids, biochemical oxygen demand, bacterial count, color, total dissolved solids, and taste. Water products that have higher purity are either naturally pristine due to environment or have been transformed from lower quality to higher quality through a man-made treatment system or series of unit processes.

Energy intensity is an energy–time-based relationship and can occur in both natural treatment systems and physical–chemical (man-made) treatment systems. The main difference is that the energy intensity in a natural treatment system is typically much lower than in a physical–chemical system. However, the cycle time needed to obtain a specific water quality is longer in the natural system.

Figure 4 depicts a typical unit process energy and water quality cycle. Water quality varies depending on the location within the cycle. The figure shows that each unit process is additive in that as the cycle progresses, the energy

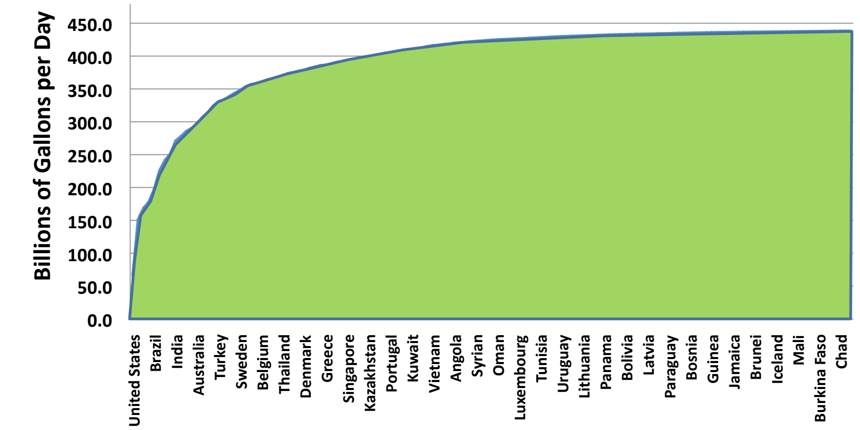

Figure 1. Cumulative water demand increase for gross domestic product 2010–2016

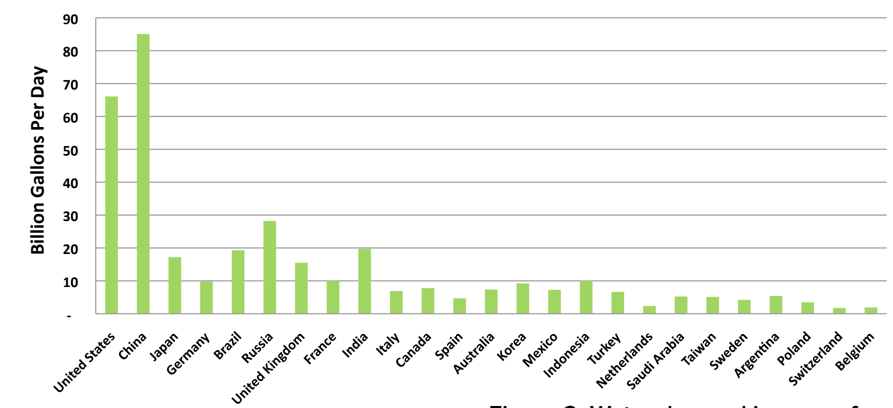

Figure 2. Water demand increase for gross domestic product 2010—2016

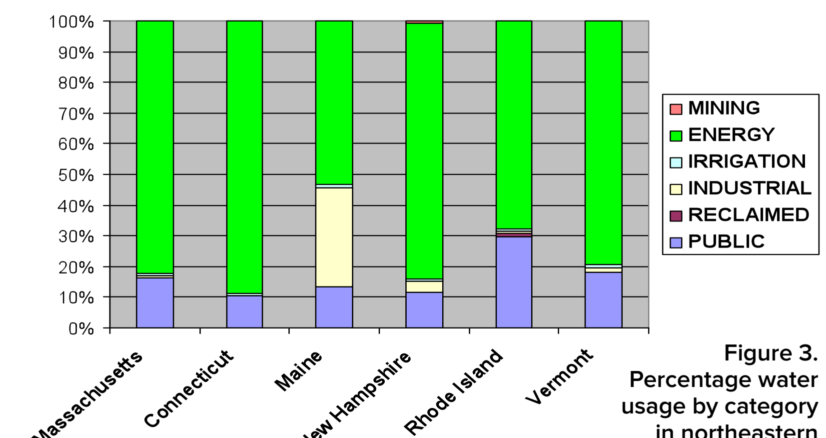

Figure 3. Percentage water usage by category in northeastern United States

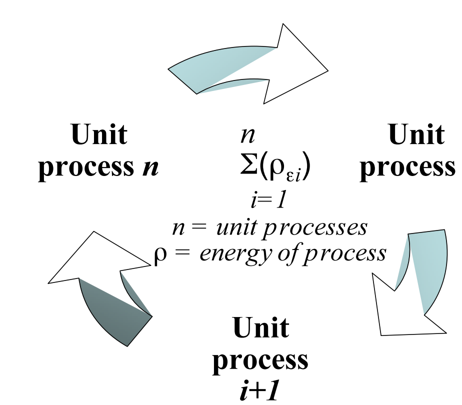

Figure 4. Unit process energy and water quality cycle

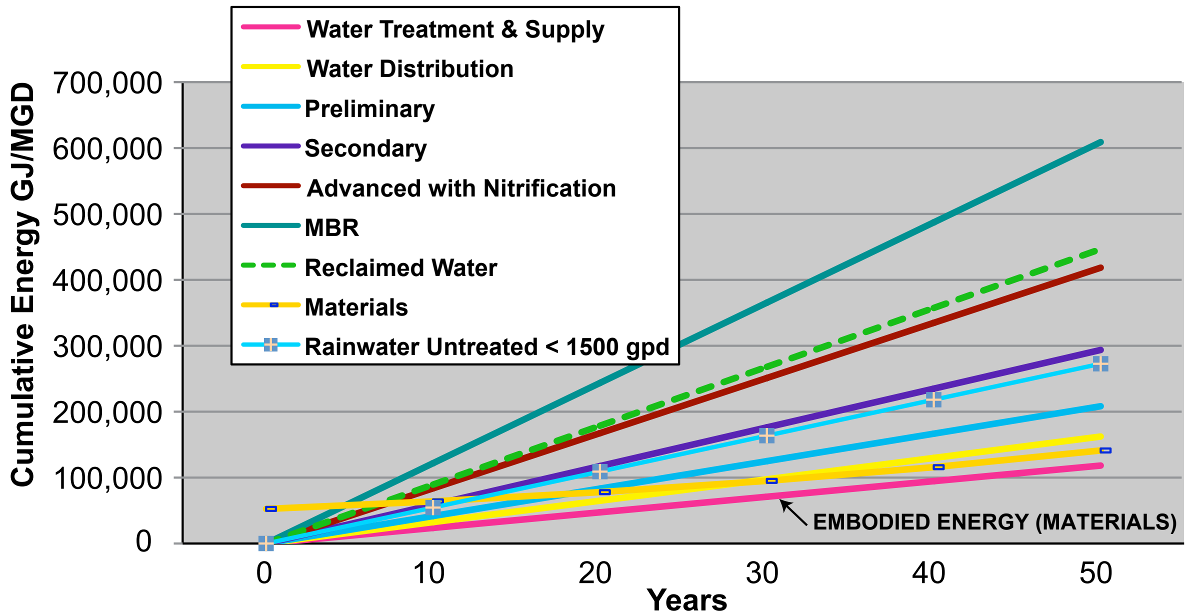

Figure 5. Life cycle energy usage envelope

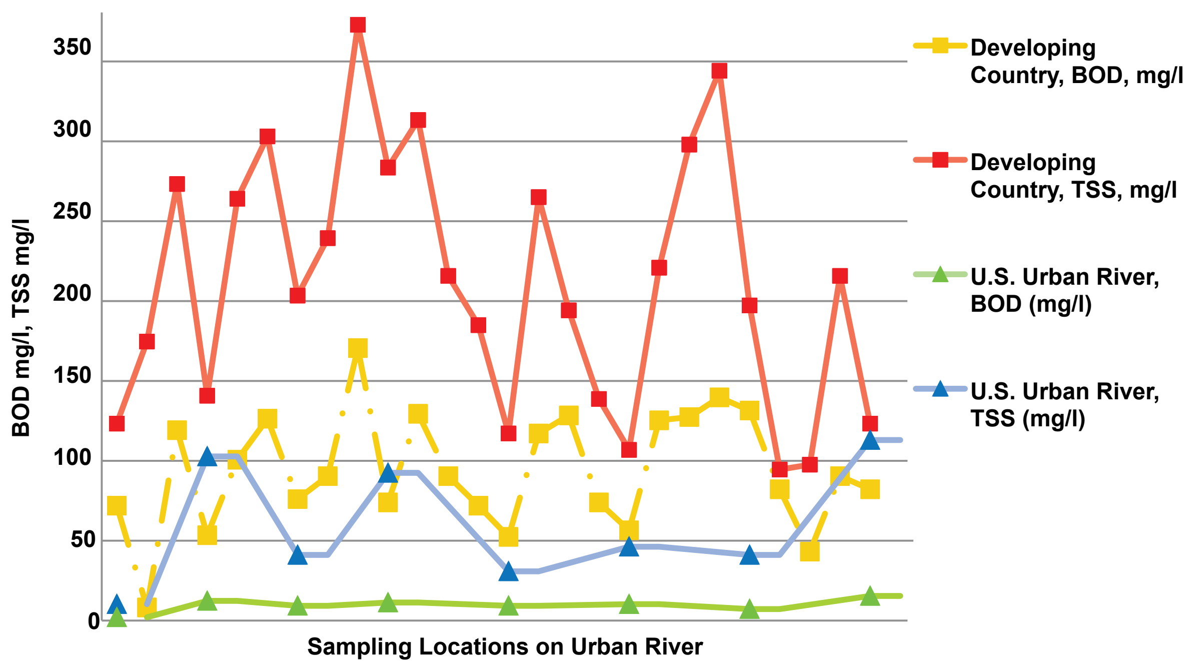

Figure 6. Comparison of urban river water quality in developing economies and the United States

consumed is cumulative. For example, if a surface water treatment plant (Unit process *i*) were pumped from sea level through a distributed conveyance system (Unit process *i*+1) to a reclamation plant (Unit process *n*) at elevation 500 feet (152 m), the tracked pumping energy would be added at the beginning of the subsequent unit process for a cumulative unit process energy consumption. The water quality of the surface water would likely degrade within the distributed conveyance and pumping system, and following reclamation, the water quality would increase. The energy consumed is location-specific and includes many factors such as the quality of the source water, types of unit processes to obtain the desired water quality, topography, and size of the service area.

For example, groundwater treatment requires less energy to achieve a specific water quality since groundwater normally has fewer contaminants than surface water. However, as groundwater levels are reduced through overuse in suburban environments, salt intrusion can occur in coastal areas that can significantly degrade water quality. On the other hand, capture and treatment of stormwater and rainwater harvesting could reduce the energy intensity to achieve a specific water quality by eliminating the added energy intensity of distributed conveyance and pumping systems. In order to achieve this reduced energy demand, maintaining naturally occurring water quality is an increasingly important sustainability issue for overstressed watersheds and is acutely important in low-income areas where treatment is not prevalent.

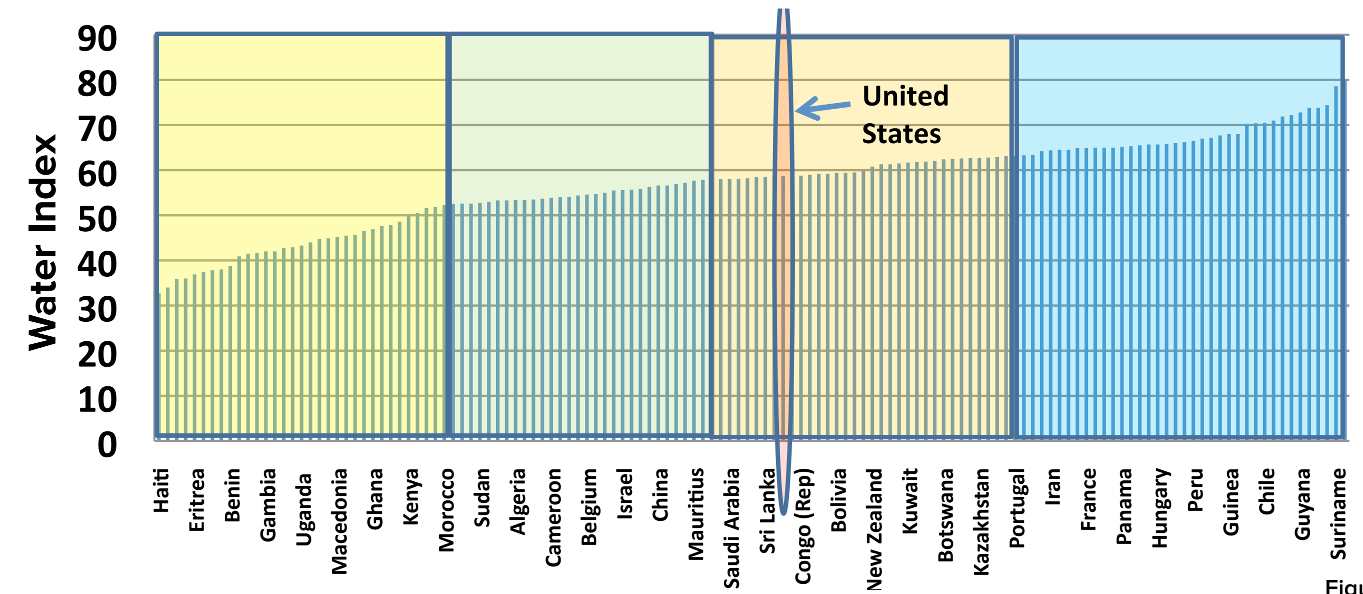

Figure 7. Relative water indices of 130 countries

LIFE CYCLE ENERGY

Figure 5 presents another way of looking at the energy required to produce a water quality product and the valuation of embodied energy in water. The figure depicts the life cycle energy usage envelope based on the cumulative energy for a series of water, wastewater, and reclamation unit processes that create a product. The value of water and water production costs are predominately related to the energy used in treating and moving water. For example, membrane bioreactors (MBRs) use approximately 50 percent more energy in their life cycle than advanced wastewater treatment with nitrification. Reclaimed water quality, on the other hand, can be attained with only about 10 percent more life cycle energy use than advanced wastewater treatment with nitrification. The energy associated with the materials of construction and infrastructure is significant and can approach 100 percent of the energy consumed for water treatment and distribution but less than 20 percent of the energy consumed for the full water reclamation cycle. In contrast, the energy intensity of untreated rainwater can be much greater than the energy intensity of water treatment on a per-volume basis, because the volume of water is significantly greater for a water treatment plant than for a rainwater harvesting facility.

VALUE OR COST

Worth noting is that creation and delivery of a water quality product are not the same as provision of water service to an end-user. When a water product is valued through a block or tariff for water, valuation does not adequately capture the variability in the cost of making the product and delivering the resource. However, water rates in many low-income and poor areas are based on block tariffs without regard to flow, consumption, or cost of the water product.

WATER QUALITY

A significant differentiator between developing economies and urbanized countries is raw water quality in urban rivers.[8] While the use of surface water is limited in many locations, it is often necessary to meet system demands. In those countries where surface water quality is poorest, the water system may not be in service 24 hours a day. When the system is in service, the demand can far exceed the system capacity such that an entire day's water plant production can be consumed or withdrawn from the system in only a few hours. Figure 6 compares typical urban river water quality between a developing country and an urban river in the United States. It shows that raw water quality is much lower in the example of the developing country compared to the United States. Therefore the amount of energy required and the cost of raw water treatment in the developing country is greater due to the poorer quality of the raw water.

WATER INDICES

Several methods and approaches exist for measuring water scarcity and attributing a comparative measurement or index to account for wealth and income in determining water wealth or scarcity.[9] One method uses the combination of five interrelated factors and is also called the water poverty index. The five factors are as follows:

1. Level of access
2. Water quantity and quality
3. Water consumptive use
4. Water management capacity
5. Environmental factors

This approach is not typically that meaningful nationally, and comparisons between countries are complicated because of varying water tariffs and how consumptive use is measured. Figure 7 depicts relative water indices, based on the above

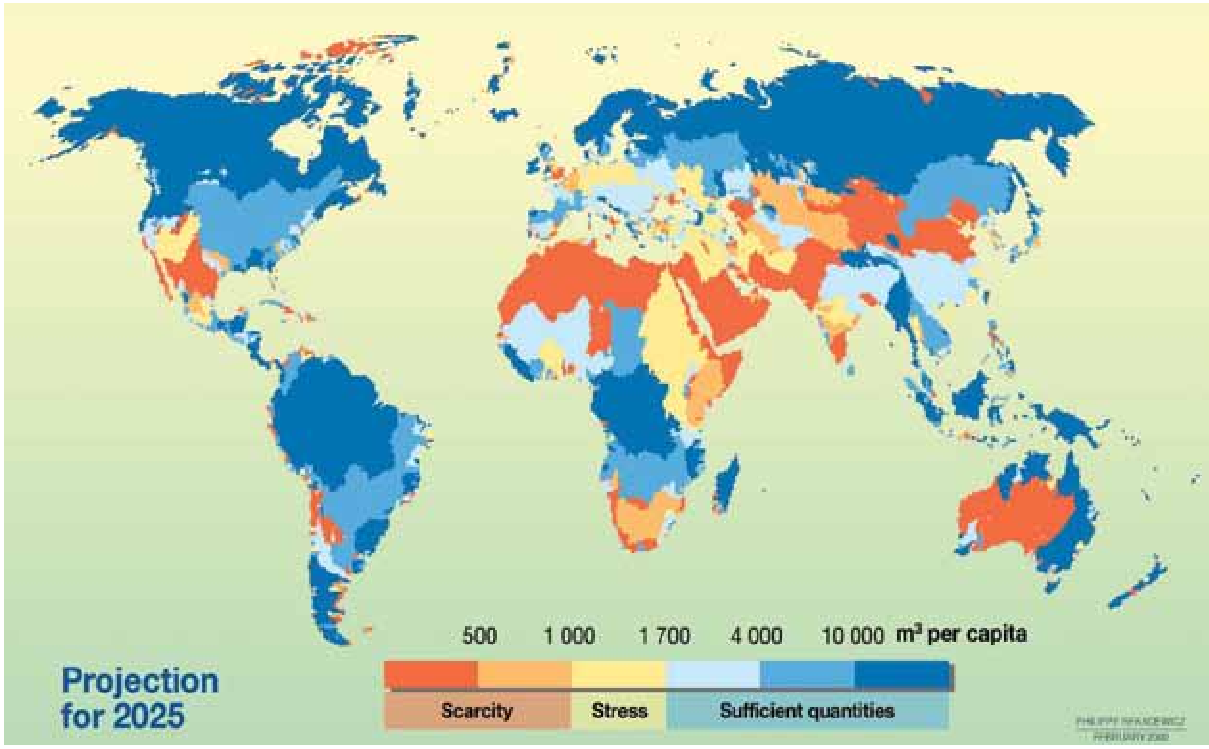

Figure 8. Forecast for water scarcity
Cartographer, Philippe Rekacewicz (www.grida.no/resources/5643)

attributes for 130 countries. As shown in the figure, the United States is near the middle of this graph due to its extremely high consumptive use. While the United States may be considered water-rich, it is not water wealthy since our consumptive use and environmental factors are not as favorable as other countries such as Finland, Canada, Norway, and the Netherlands. Figure 8 depicts the forecast for water scarcity by continent in 2025. The figure shows the greatest stress is forecast for Northern Africa and Australia; however, significant stress is anticipated for the southwestern United States and Central Asia.[10]

SOCIAL, ENVIRONMENTAL, AND FINANCIAL MOVEMENTS

The social, environmental, and financial movements have all converged to define the value of water and to propose that sustainability in water resources is a possibility. Historically the value of water has been "insured and underwritten" by municipalities due to the social construct that there is a natural right to an adequate supply and that it will be made available at a modest and reasonable cost.

In low-income or developing countries the price of an initial block for water is used as a tariff so that the poor can access clean water at a reduced rate or subsidized price. There are a number of significant policy debates over this concept and whether it actually helps the poor. It may be that the social contract for safe, clean water cannot be equally applied. For example, rural areas in West Bengal use a tariff of approximately 3 rupees per month for enhanced water.[11] Assuming that the average annual income for these areas is US$3,500 per year, the cost of clean water is less than about 0.05 percent of this annual income. The average cost of the initial block of water for many African water utilities is about $0.32/m³ ($0.0012/gal), and with average annual incomes of US$11,900 this is about 1.2 percent of a family's typical annual income. In the United States the average cost for water is less than about 2 percent of the annual income. The cost of clean water in developing countries is supplemented to keep prices affordable, but among the poorest it is still a burden. However, the cost of clean water is much less than the cost of waterborne disease in those same countries, estimated to be as much as 5 percent of a family's annual income.[12]

SOCIAL SUSTAINABILITY AND NATURAL RIGHTS

Exploring the philosophy of natural rights and resources will help us better understand where we are in the debate over the value of water. It is important to go back to the political philosophy that originally shaped our country and government to better understand where we came from in order to see where we are going.

John Locke was one of the first writers in the 17th century to provide a basis for natural rights and social contract theories in *The Second Treatise on Government*.[13] He argues that natural rights are those that we have as human beings before government comes into being. This discussion on rights is further summarized and is echoed in the *Declaration of Independence* of the United States in which the term "unalienable rights" was coined. We have a natural right to struggle for our survival and a right to the means to survive. Mr. Locke states that when government is created or formed, people agree to transfer some of their rights to the government, while retaining some of their natural rights. This is the theory of the social contract.

Since water has such an important place in public health and politics it only seems fitting that energy has a similar stature, and yet the access to clean drinking water must be viewed as an inalienable right. People cannot be denied the right to water because they cannot afford it. Said Mr. Locke, "Nobody could consider himself injured by the drinking of another man, though he took a good draught, who had a whole river of the same water left to quench his thirst: and the case of land and water, where there is enough, is perfectly the same."

The power of social media is staggering, and its ability to amplify behavior and reshape the media is just beginning. The ability to access 900 million people in seconds through the internet facilitates the ability to create social change in minutes. Thomas Friedman explains this flattening effect in *The World is Flat*.[14] He also explains and calls for government to develop a geo-green strategy to preserve the environment and our natural world. This affects water rights in a very peculiar way. Behavior modification and management is a new strategy being cleverly hidden within our new social contracts. For instance, if one person says, "I installed a rain barrel in my back yard," that is not a movement, but if 20 of your 25 nearest neighbors install rain barrels would that not suggest that it may be a good thing? Would there possibly be a little social shame if you did not take the hint and get one, and do a good thing for the planet?

ENVIRONMENTAL SUSTAINABILITY

In April 1960, Tiros I transmitted the first television pictures of Earth from space.[15] This single event changed our view of Earth forever. Instead of unlimited resources we saw the limits of our environment for the first time. We mapped global water resources and quantified them. This global view of the earth fueled the environmental movement. Then in 1962 the seminal work, *Silent Spring*, was published and defined the environmental conscience and the foundation for the environmental movement, Earth Day, and later the creation of EPA.

FINANCIAL SUSTAINABILITY

In 1972, the first electronic transfer of funds between Federal Reserve banks occurred through integrated system architecture. This event provided a fundamental change in the way the financial markets distribute and manage funds globally. Water flows through pipes in a network just like electronic funds are transferred between banks. This principal is discussed in *The World is Flat*.

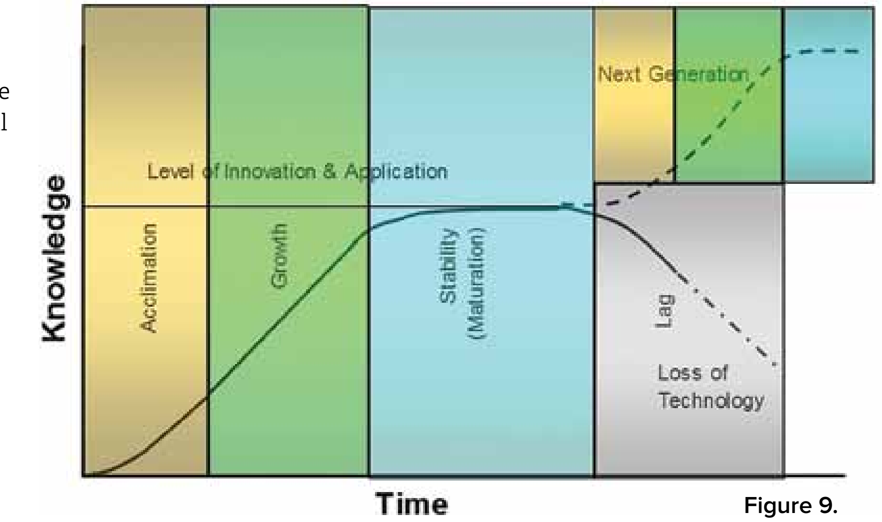

Figure 9. Technology life cycle model

Financially, the funding for the water industry does not have the same urgency as some other mandates such as community development and manufacturing; however to remain sustainable, if there is no reliable water source, or a quality water source, economic development will not occur and communities will literally dry up and move toward other viable water sources.

TECHNOLOGY IN THE WATER INDUSTRY

Technology comes at a cost. Manufacturers that develop new technology do so to sell a product, and the research required to bring a new process or technology to market is expensive. Many new products are developed and patented that do not create a return on investment for a manufacturer, and these products are sometimes offered in a portfolio or suite of other products that do create adequate returns on investment. Also, much emphasis is put on public health and environmental sustainability. Manufacturers are entitled to a fair and reasonable return on the investment in water industry products, but it is also evident that higher water quality comes from increasing energy intensities, in turn increasing the cost of treatment to create a clean and safe water product.

The application of the appropriate level and type of technology is why environmental engineers are needed. No benefit comes to society or to the public or even to the engineering community to design and build a treatment process that is not efficient or cost-effective. Overdesign of technology is just as bad as underdesign. Good engineering practice requires an understanding of the operating and capital costs for a new treatment process. Technology emergence, growth, and development follows a life cycle that may be modeled similarly to a micro-organism life cycle. Figure 9 depicts the technology life cycle model[16] and shows how the phases change with knowledge, experience in the technology, and successful application.

The technology life cycle comprises four phases, each with a unique focus:

1. **Acclimation**
   - Novel, dependent on perception of value added, marketability, and strategic importance, risk-focused
2. **Growth**
   - Understood, well documented applications and signs of transfer success, experience-focused
3. **Stability and Maturation**
   - Growth has been rechecked at the value-added plateau, new generation emerges due to feedback and activity from innovation, cost-focused
4. **Lag Phase**
   - Demise of technology support and life span or emergence of next generation

Critical assets must be designed for redundancy, with the proper attention to technology to allow for maintenance and emergency conditions. These factors need to be included in a robust design process.

There is currently a healthy discussion about technology, water quality, effluent quality, and sustainability. Many utilities are looking beyond permit compliance, even though they may not admit to it with regulators in the room. Just meeting compliance targets does not follow the principles of sustainability. Going beyond permit compliance has several benefits including the ability to create more product and recover more energy from a process. The process of "going beyond permit compliance" helps to drive innovation and technology development.

If there were a move beyond mere permitted compliance and a recognition of utilities of the future that do more than "just meet the permitted values," the impact to water quality for reuse and the environment would be significantly enhanced.

WATER RECLAMATION'S ROLE

Wastewater exists only if we choose to waste the energy value we have put into it to create it. All water has value either in nutrients or carbon, or as a product. If one were to consider the energy input into creating a secondary effluent with a 20/20 permit limit, there is a sunk value within the treatment process, and the incremental cost or "value" to reclaim it is only an additional 20 percent over the cost of creating the secondary effluent. It is wasteful to allow secondary effluent from freshwater sources to be discharged into a river, estuary, or ocean through an outfall.

The water cycle is a fundamental principle that most of the public does not understand or consider important. The paradigm that water does not have a linear presence must be changed, but what goes around comes back around and as such, we need to treat water with respect and recycle it to the maximum extent possible.

GLOBAL ECONOMIC DEVELOPMENT

People take clean water and the availability of water for granted. This does not mean that they do not value water or the services that it provides both to them and for them through the environment. However, they expect it to be available and at a low cost. They expect this because it has historically been the case. They turn on the tap and water is there. They flush the toilet and it goes away. And, their bills are modest compared to other bills such as electricity, cable, and cell phones.

A significant nexus or connection exists among water, sanitation, and the economy. Studies have been done in developing countries on the economic impact of the lack, in these countries, of a modern water and sanitation system. These impacts can be measured because the system is not there. What they generally indicate is that a modern system will cost about 1 percent of national GDP. While this is an interesting way to look at the cost, it also shows that the absence of such a system restricts growth by 2 to 3 percentage points. In other words, an investment of 1 percent of GDP would increase GDP growth by 2 to 3 percent with a net of 1 to 2 percent; consequently, the economic benefit of water and sanitation exceeds the cost. One could conclude that water and sanitation are not a cost but rather an investment that has a return that greatly exceeds the cost. The absence of an effective system would reduce our economic growth by 2 to 3 percentage points; in current economic times this can mean the difference between slight growth and recession.

So, when it comes to the "value" of water, one can make a serious case that it is economic—that society does not truly "pay" for water and sanitation, because the investment provides greater value than it costs. What is necessary is that the investment be adequately funded. This is a fundamental change in mindset, beginning with the establishment of the logic that water and sanitation are economic, and that the issue is not whether society should support it but rather how should society fund it; then the question becomes, how will it be funded? Of course, the answer is that those who benefit should pay; but we all benefit, so we should all pay. The question really boils down to whether individuals pay directly for the furnished service (through utility bills) or as a general good through taxes.

In general, we have a mixed system. Utility charges are levied, but utilities also seek government grants. But government grant funds come from taxes, which also come from people. In addition, many communities fund their infrastructure through property taxes, which come from people. So, the conflict that arises when one says that "water is a right" is the question. Does this mean it should be free? But of course it cannot be free—someone has to pay for it. The United Nations addressed this by saying three things: (1) water and sanitation are rights, (2) government has the responsibility to see that these rights are provided, and (3) the private sector can play a role by providing services but only under the supervision of the government. To say that government is responsible, does not necessarily mean that the service should be paid for through taxes rather than user fees. It means that government must define how it will happen—service fees, taxes, or a combination.

This leads to the next question. If a service fee approach is used, what about those (the indigent) who cannot afford it? The answer is that government must arrange a system where someone else pays for them. This can be accomplished through a governmental subsidy or by adjusting rates for those who can afford a little more to account for those who cannot pay. The bottom line is that those who can pay need to pay enough for both themselves and for those who cannot pay.

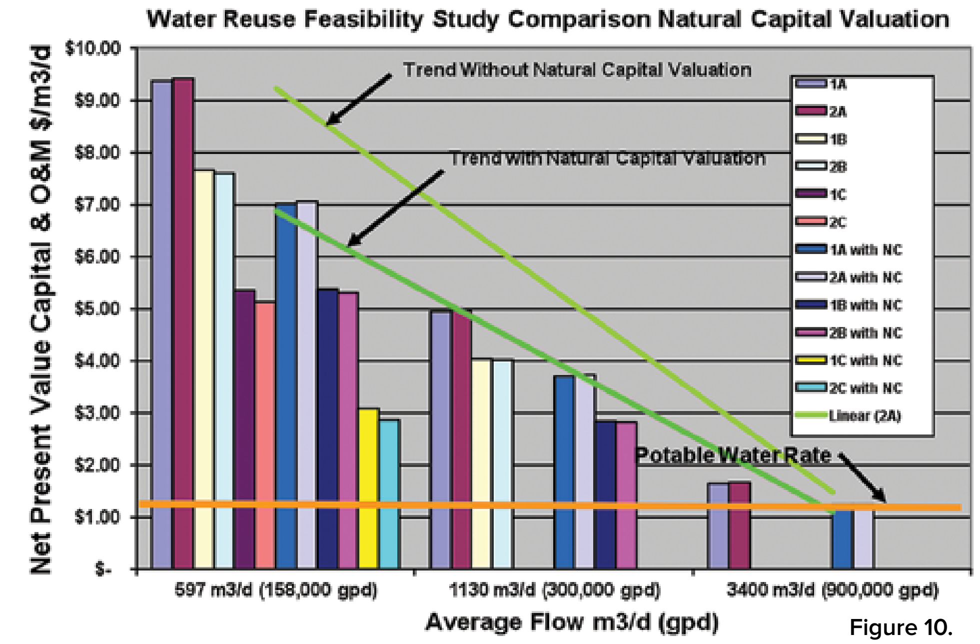

Figure 10. Natural capital comparison of water rates

BUILDING A NEW WORLD WITH WATER AS NATURAL CAPITAL

As described in this paper, several factors and important considerations determine the value of water and the rights and responsibilities we have to provide safe, cost-effective, and reliable access to it. Once this necessity is understood, the remaining question is the beneficial level of service. Service level is not simple to understand and compare between countries, but the use of tariffs has purportedly reduced service interruptions in developing countries.[17] The question is whether the system provided is purely "economic" including only economic benefits that equal or exceed the costs, or does it provide more intangible things such as natural capital and enrichment from water protection and treatment? For example, is funding for a cleaner lake or river valued only because people believe there is economic value to be gained for this or is there value added in protecting unspoiled nature because of its intrinsic value? These discussions are important, because we are talking about how people value water; enforcing funding to maintain that value without human or environmental benefit is not reasonable or sustainable.

Figure 10 provides a natural capital comparison of water rates for a water reclamation district in the northeastern United States.[18] When the value of natural capital is netted from this cost, the net present cost is reduced by 30 percent. The watershed potable water rates ranged from $1.05/m^3 ($2.97/100cf) to $1.91/m^3 ($5.41/100cf) resulting in a net value cost below the range of potable water rates.

We need to learn to use our water more wisely by valuing competing uses of water resources including in-stream uses as well as water withdrawals. Water reclamation is one tool that can play an important role in stretching limited water resources by decreasing total water withdrawals and increasing reuse and return flows, thus contributing to restoring and maintaining flows necessary for supporting healthy aquatic ecosystems, recreation, and potable water uses.

Accounting for natural capital provides a victory for communities, the environment, and water utilities by identifying solutions such as water reclamation that contribute toward sustaining a higher level of economic welfare through preserving highly valued natural capital and applying water rights to other intangibles.

CONCLUSIONS

Our work as water professionals is just beginning. There is a tremendous need to plan for the future. The water renewal industry and all water industry professionals must lead the discussion to educate the public, support technology and innovation, and ensure that water is a resource accessible to all, sustainable, and properly valued for all. Public awareness of the importance of water resources and value of water should be a top priority for water professionals now and in the future.

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Regional and national NPDES Phase II small MS4 permitting

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ABSTRACT | Massachusetts is one of four states that has the Phase II Small Municipal Separate Storm Sewer System (MS4) General Permits issued by EPA rather than the state Department of Environmental Protection. MS4 permits are issued under the National Pollutant Discharge Elimination System (NPDES) program. Stormwater permitting requirements vary from state to state and by EPA region. The history and status of the Massachusetts MS4 permit will be presented, along with information related to two of the other states under EPA jurisdiction and one state with primacy. In Massachusetts, coordinated efforts were launched by stormwater coalitions, municipalities, and other stakeholder groups to oppose the most recent MS4 permit conditions, with the goal of initiating discussions with EPA to promote more reasonable, practical, and affordable regulation. Currently, several lawsuits are pending with respect to the MS4 permit. Massachusetts is also working toward applying to EPA for primacy of the MS4 program. This effort has support from municipalities and the state but is opposed by environmental groups.

KEYWORDS | MS4, Phase II, stormwater, EPA, MassDEP, litigation, primacy, Maximum Extent Practicable (MEP)

INTRODUCTION

The Phase II Small Municipal Separate Storm Sewer System (MS4) General Permit program covers stormwater permitting in urbanized areas (UAs) for municipalities and other entities (e.g., universities, Departments of Transportation) throughout the country. Forty-six states administer their own MS4 permits under the National Pollutant Discharge Elimination System (NPDES) program, while four states and the District of Columbia have MS4 programs administered by EPA. The four states under EPA jurisdiction are Massachusetts, New Hampshire, Idaho, and New Mexico. The states that administer their own MS4 permits are said to have “primacy.” Interpretation and application of the MS4 regulations vary among states with primacy. Permit requirements also vary by EPA regions for the four states under EPA jurisdiction. Idaho's MS4 program and application for primacy will be discussed and a comparison of stormwater standards around the country will be presented. California's MS4 program will be discussed as an example of a state with primacy. The MS4 programs in New Hampshire and Massachusetts will be discussed, as they are very similar and have been put on the same implementation schedule by EPA Region 1 due to appeals in both states.

The Massachusetts permit is being appealed by several organizations, for differing reasons. One of the biggest concerns with the permit language is the requirement of specific numeric pollutant reduction goals, as opposed to the performance standard of Maximum Extent Practicable (MEP). MEP helps to ensure that permittees address stormwater quality issues without chasing an unobtainable (or unaffordable) goal. Another concern of the municipalities impacted is how to fund the work required by the permit. Cost estimates vary, but the implication is that all communities would see a marked increase in their stormwater budgets, at a time when most municipalities struggle to fund basic services such as public safety, schools, roads, and other critical infrastructure.

It has long been acknowledged that stormwater runoff carries pollutants such as sediments, oils, bacteria, and nutrients. Discharge of these pollutants to water bodies can affect water quality and the environment. The basis for the MS4 permits is the Clean Water Act (CWA), Section 402. The regulations governing municipal MS4s are found at Title 40 (Protection of Environment), Chapter I (EPA), Subchapter D (Water Programs), Part 122 of the Code of Federal Regulations (i.e. 40 CFR Part 122). The rule-making authority for MS4 NPDES permits is Title 33 U.S.Code § 1342(p)(3)(B), which states that MS4 permits must:

1. *effectively prohibit non-precipitation related flows from entering the MS4, and*
2. *require controls necessary to reduce pollutants in municipal storm water discharges to the MEP, including management practices, control techniques, and system design and engineering methods, and/or other such provisions determined to be appropriate by the NPDES permitting authority.*

Figure 1. National map of regulated MS4s

NATIONAL PERSPECTIVE

The Draft *Summary of State Stormwater Standards* was published by EPA in 2011. It is an overview of stormwater management requirements around the country. Note that this is an overview of stormwater standards, not the MS4 permits. However, as most states administer their own MS4 permits, this information indicates the differences from state to state. In summary:

- Twenty percent of states require application of the stormwater standards statewide, and most of the other 80 percent require them only in MS4 areas.
- Most states use the 1 ac (0.4 ha) of disturbance threshold for when to apply the standards. A few states have a lower disturbance threshold.
- Forty percent of states defer to the Narrative Standard for volume control, retention, and treatment. Of the remaining 60 percent, the standards for retention and treatment vary from capture of 0.5 in. (2.5 cm) of rain to 100 percent of post-development runoff.
- Forty percent of states require the same retention and treatment standards for redevelopment as for new development. Thirty-eight percent do not have specific redevelopment standards, and the rest have varying requirements. Only Virginia has a removal standard for phosphorous for redevelopment [20 percent removal of pre-existing load for more than 1 ac (0.4 ha)].

Figure 1 shows the areas regulated by the MS4 permits. Only 4 percent of United States land area is subject to MS4 permits; however, this covers approximately 80 percent of the population. This review of stormwater standards by states demonstrates that, overall, there appears to be a minimum standard for stormwater management, with a few states imposing stricter standards.

California

California is one of the states with primacy, and the MS4 permit program is administered by the State Water Board. The current MS4 permit became effective on July 1, 2013, and will expire in 2018. Regional water boards oversee the administration of permits in their jurisdictional areas. California has long been regarded as an early adopter of environmental regulations and a state with some of the strictest environmental regulations. However, a review of the Fact Sheet for the California MS4 program

Table 1. Changes in the 2013 California MS4 Permit

Strengthened	Modified	Eliminated
Total Maximum Daily Load (TMDL) implementation	Reduced post-construction requirements	Annual cost analysis
Requirements for ASBS discharges	Reduced effort for community-based social marketing	Mandatory citizens advisory group
Assessment of water quality monitoring and Best Management Practices (BMPs)	Extended compliance deadlines	System-wide Illicit Discharge Detection and Elimination (IDDE) monitoring (incident only)
	Added water quality monitoring tiers	Mandatory construction inspection frequency

indicated a more moderate approach to stormwater permitting.

The 2013 California MS4 permit focuses on four priorities:

1. Discharges to areas of special biological significance (ASBS)
2. Discharges to water bodies listed as impaired on the 303[d] list
3. Post-construction requirements
4. Water quality monitoring requirements

In the writing of the 2013 permit, certain areas of water quality protection were strengthened; however, the Fact Sheet discusses at length the effort to not increase the cost of compliance for the new permit. Therefore, some requirements were either reduced or eliminated to balance costs. Table 1 summarizes some of those changes.

The 2013 permit maintains flexibility for implementation, employs the iterative Best Management Practice (BMP) process, and states that the performance standard is the MEP. The Fact Sheet states:

Under 40 CFR Section 122.44(k)(2)&(3), the State Water Board may impose BMPs for control of storm water discharges in lieu of numeric effluent limitations.

The state water board estimated that the annual cost per household to implement the MS4 program is $32. However, this number assumes that only 38 percent of stormwater management costs for the MS4 are due to the new permit. That is, it assumes the MS4 was already incurring costs for street sweeping, leaf collection, staffing, equipment, etc. Therefore, the cost per household is closer to $84 annually.

Idaho

The draft permit for Idaho was issued by EPA Region 10 on April 8, 2016, but as of this writing it has not been finalized. The draft permit requires a Stormwater Management Plan that includes the six minimum control measures, effluent limitations, requirements for discharges to impaired waters, and monitoring and reporting requirements. Section 2.3.4 of the Idaho Draft MS4 permit specifically states that the Performance Standard for the reduction of pollutants in stormwater effluent shall be MEP. The Idaho Department of Environmental Quality (DEQ) reported that they do not plan to include additional requirements over the typical MS4 permit requirements if it assumes primacy for the program.

In August 2016, DEQ petitioned EPA for primacy of the NPDES permit. EPA is accepting public comments on the primacy application. The scope of the MS4 program in Idaho is much smaller than in Massachusetts, largely due to a difference in the UAs. The Phase II MS4s are made up of highway districts (four), municipalities/urban areas (five), colleges and universities (one), and a combination of those types of entities (four). The last round of Phase II MS4 permits expired in 2014. DEQ reported that the Phase II stakeholders petitioned for primacy, because they thought DEQ would better understand Idaho's unique issues and be able to keep the permits current. No outside groups (e.g., conservation groups, business groups) have voiced objection to the state's application for primacy (as of this writing, the public comments have not been released by EPA). The estimated cost to the state to assume primacy for the full NPDES program is $3.1 million, including adding 29 staff. Two-thirds of this cost will be financed through the General Fund and one-third will be generated through fees. Fees will not be levied on Phase II MS4s. The only stormwater fees will apply to construction projects. EPA Region 10 stated that the goal is to issue a new MS4 permit prior to handing over primacy to DEQ and transferring responsibility of the program to the state of Idaho in 2020.

Unique issues faced in Idaho that will need to be addressed by DEQ once it assumes primacy include:

- Most waters in Idaho are regulated under the Endangered Species Act (ESA). Currently, MS4 permits for areas with ESA waters are required to go through lengthy U.S. Fish and Wildlife Service and National Oceanic and Atmospheric Administration review. If the state takes over the MS4 program, this review will be simplified.
- Approximately half of the MS4s are highway districts. The regulated area is limited to the right of way. Because of this, EPA considers the UA as "serving" a population of less than 1,000, allowing an exemption from complying with waste load allocations for waters that have Total Maximum Daily Loads (TMDLs) for any pollutants, including nutrients. In other words, the highway districts are not held to as high a standard as the other permittees.
- There is a law in Idaho that prohibits stormwater utilities, based on a court ruling that stormwater fees are a tax. The municipal MS4s are responsible for the costs of compliance and will not have this mechanism for funding available to them.
- Likewise, highway district MS4s have no legal authority to generate revenue to pay for stormwater compliance.

New Hampshire

New Hampshire has 60 traditional MS4s. The New Hampshire permit went through a significant review and comment process. The original draft permit was released for public comment on February 12, 2013. After many extensions for the comment period and revisions to Section 2 (Non-Numeric Effluent Limitations) and Appendices F (Requirements for NH Small MS4s Subject to Approved TMDLs) and H (Requirements Related to Discharges to Certain Impaired Waterbodies), the final comment period closed on November 20, 2015. EPA received 615 comments during the last public comment period. Most of the comments are related to the high costs of compliance, lack of flexibility, and lack of practicality in meeting specific water quality goals.

The final Response to Comments and the MS4 permit were released on January 18, 2017, with an effective date of July 1, 2018. Beyond the baseline MS4 requirements, the New Hampshire permit identifies communities that will have additional requirements due to impairments of particular pollutants. Appendix H outlines the requirements for source identification and enhanced BMPs for water bodies with water quality impairments (i.e., no TMDL) due to nitrogen, phosphorous, bacteria and pathogens, chloride, and solids, hydrocarbons, or metals. Appendix F outlines compliance with TMDLs for chloride, bacteria, phosphorous (lakes and ponds only), and mercury. The permit goals are based on the water quality standards established by the New Hampshire Code of Administrative Rules, Chapter Env-Wq 1700 Surface Water Quality Regulations. The performance standard is the MEP. The permit also has a detailed Illicit Discharge Detection and Elimination (IDDE) program, with a strict timetable.

The New Hampshire Stormwater Coalition (NHSWC) filed an appeal against the EPA New Hampshire permit. NHSWC is made up of 38 towns and cities, two academic institutions, and four consulting companies. The municipal members represent the Manchester area, Nashua Area, and the New Hampshire seacoast communities. Appeals were also filed by the Center for Regulatory Reasonableness (Case 17-1060), the Home Builders Association (Case 17-1138), and the Conservation Law Foundation (Case 17-1195). New Hampshire communities are waiting to see what happens with the Massachusetts appeal.


Mill River in Taunton, Massachusetts

New Hampshire is also working toward assuming primacy for the MS4 permits, an effort supported by municipalities, the New Hampshire Department of Environmental Services (NHDES), and the New Hampshire Municipal Association. In the winter of 2017, a bill was introduced in the State Senate (Bill SB 121) to allow NHDES to pursue delegated authority. Owing to questions related to cost impacts, a commission was formed to study the financial impacts of primacy. The results had not been released as of this writing.

MASSACHUSETTS MS4

Small MS4 Permit

In 2003, EPA issued the first generation of the MS4 permits in Massachusetts. These permits were valid for five years; however, they were administratively continued after 2008, pending issuance of a new permit. In 2011, EPA released two draft permits for Massachusetts, effectively issuing different requirements for different regions of the state. Opposition to this approach was strong, and those draft permits were withdrawn. In 2014, EPA issued a single Draft MS4 permit for Massachusetts.

In Massachusetts, 260 communities are required to have MS4 permits. Since 2008, these communities have been complying with the previous permit, filing annual reports, and following the Massachusetts Stormwater Standards. In 2014, the Draft Small MS4 General Permit was released for comment, and the scope and depth of the proposed requirements surprised many communities. Municipalities are typically the front line for implementing stormwater management BMPs. The proposed permit conditions will require substantial increases to municipal funding, when most communities already struggle to control the costs of services to residents. Two significant stormwater collaboratives


Little River, Alewife Brook Reservation, Cambridge, Massachusetts

stepped forward to help communities manage the changes: the Massachusetts Coalition for Water Resources Stewardship (MCWRS) and the Central Massachusetts Stormwater Coalition. Both organizations worked with their members to review and submit comments on the proposed MS4.

EPA received 1,321 comments on the proposed permit conditions. Key concerns expressed by the municipalities included the short periods for deliverables, the financial impact to communities, the disconnect between the permit and integrated planning approaches, the lack of flexibility in approaches, the long-term goal of requiring phosphorous control plans (PCPs) for each community, and the use of numeric water quality limitation instead of the MEP standard for evaluation of compliance. In general, watershed groups were supportive of the permit, although some felt it could go further. The final Massachusetts MS4 permit, along with the response to comments, was released in April 2016.

Estimated Costs

Several studies have estimated the costs of both the Massachusetts permit and the proposed PCPs. Some estimates do not consider all the costs for compliance, such as additional staffing, purchase of specialty equipment (e.g., regenerative sweepers), purchase of sites to build BMPs, and appraisals and easements. Costs from different studies were evaluated based on different units of measurement, making them hard to compare. For example, estimates were based on cost per acre, cost per resident, and cost per pound of nutrient removed. Some of the sources and estimates are summarized below:

- Costs for an urban area to comply with the Minimum Control Measures (MCM) for the five-year permit term, assuming vehicles are purchased, are $788,000 to $1,940,000. This estimate is for labor hours and does not include structural improvements, which are not required in the first five years but will be in the next iteration of the permit. (Source: EPA memo dated January 18, 2016)
- The same memo reported the cost for nutrient-based watershed plans (planning only) to be $137 to $224 per ac ($338 to $553 per ha) for urban areas. The costs estimated for rural and suburban areas were lower, but included a wider range. This cost would be on top of the MCM permit compliance and does not include any structural controls. As a reference, the Charles River watershed is 198,400 ac (80,290 ha). Development of individual watershed plans alone will cost millions of dollars.
- The EPA Fact Sheet for the MS4 permit (Reference 7) presents costs for the implementation of the PCP, based on $18,600 per pound phosphorous removed ($41,000/kg phosphorous removed). It estimated the town of Franklin would spend $38 million to remove 2,026.2 pounds (921 kg) of phosphorous to achieve a 37 percent reduction. The current MS4 permit requires 35 percent reduction for Franklin, with that being a typical goal for most of the Upper Charles communities.
- A funding analysis prepared for EPA (Reference 15) focused on the Upper Charles communities of Franklin, Milford, and Bellingham. The report estimated the annual cost of compliance for Franklin to be between $1.65 million and $2.08 million. This same report estimated the cost of structural controls to reduce phosphorous by 37 percent as $74.6 million.

The range of the estimates is wide and difficult to compare, but the fact is that implementation of the 2016 Small MS4 permit in Massachusetts will cost cities and towns millions of dollars. Currently no state or federal loan or grant programs are available to fund MS4 permit compliance. Additionally, the requirements for the first five years of the permit are largely planning and reporting. Construction of BMPs and monitoring of compliance results will come in later versions of the MS4 permit and will have increased capital costs.

Legal Appeals and Permit Stay

EPA released the Final MS4 permit in April 2016, with an effective date of July 1, 2017. In August 2016, several appeals were filed, including:

- MCWRS and the town of Franklin made a request for review based on an assertion that the CWA "articulates the MEP standard" and "does not authorize EPA to include a requirement to meet water quality standards."
- The city of Lowell made a request for review based on the assertion that the permit will impose burdensome costs and that the IDDE requirements are "arbitrary and capricious." Lowell also asserts that the post-construction standards are effectively land use restrictions.
- The Massachusetts Home Builders Association made a request for review based on an assertion that EPA is over-reaching its authority, trying to regulate land use, and misinterpreting the CWA in reference to stormwater discharges.
- The Center for Regulatory Reasonableness (CRR) asserts that EPA's permit exceeds statutory authority because it (1) broadly imposes water quality-based limitations without a specific demonstration of need (e.g., convolutes the use of the MEP standard and violates specific CWA provisions), (2) regulates flow, (3) regulates land use, and/or (4) imposes more restrictive requirements on the regulated community based solely on geographic location.
- The Conservation Law Foundation (CLF) intervened in the claim filed by CRR, et. al., claiming that the MS4 permit is not stringent enough.

The MCWRS appeal was supported by all of the coalition's 47 member organizations, numerous non-member entities, and the Central Massachusetts Regional Stormwater Coalition. As of this writing, all the appeals have been combined and transferred to the D.C. Circuit Court.

As the deadline for the effective date of the permit approached, the parties in the appeals petitioned the court for a stay on the permit effective date (July 1, 2017) on the basis that communities should not start spending money on permit conditions that could change once the appeals are adjudicated. EPA agreed, and the effective date of the permit has been extended to July 1, 2018, by both EPA and the Massachusetts Department of Environmental Protection (MassDEP). As of this writing, no court date has been scheduled.

"The postponement is very important to our member communities and municipalities across Massachusetts," stated Philip Guerin, president of MCWRS. "It will give them a break from excessive spending on stormwater management until the court rules on some highly contentious permit language. During the postponement, most cities and towns will continue to implement reasonable and effective practices to improve stormwater quality and decrease stormwater quantity, just as they have been doing for many years."

On September 22, 2017, a Civil Action was filed against EPA Region 1 by the Massachusetts Rivers Alliance and several watershed groups. The suit requests that the court find "EPA's MS4 Stay Notice arbitrary and capricious, an abuse of discretion, not in accordance with law, in excess of EPA's statutory jurisdiction and authority, short of statutory right, without observance of procedure required by law, and otherwise in violation of 5 U.S.C. §§ 705, 706, and vacate the MS4 Stay Notice so that the MS4 General Permit will be reinstated effective immediately."

In Massachusetts, MS4 management and implementation have become an issue that pits environmental groups against municipalities. Environmental groups portray municipalities as polluters. Municipalities, on the other hand, feel unsustainable requirements are being imposed and that EPA has overstepped its authority and congressional intent of the CWA, and residents do not want to see their taxes raised to pay for management of "rain." For now, the contents of the permit, the implementation date, and the methods to fund the program are all undetermined. The longer the legal fights drag on, the less likely it seems that compromise will happen and the more likely that municipal funds that will be used towards stormwater management are diverted to paying legal bills.

Application for Primacy

The Massachusetts governor's office has supported the request from communities and stormwater coalitions to apply for primacy. The estimated cost to the state for delegated authority is $6 million annually, including additional staff. The governor initially asked for $1.4 million for 12 staff to get the program set up. Legislation has been drafted, and the Joint Committee on Environment, Natural Resources, and Agriculture is reviewing it in the fall of 2017. EPA has given Massachusetts primacy for other environmental programs, such as the drinking water program, and advocates for primacy argue that MassDEP is better positioned to work with cities and towns to achieve stormwater management goals based on conditions unique to Massachusetts communities. Additionally, allowing MassDEP to manage the program would facilitate integrated planning for all water resources.

CONCLUSIONS

Implementation of the MS4 permit varies from state to state and region to region. Giving states primacy to administer the MS4 permits enables the flexibility to address state-specific concerns and allows an opportunity to control costs. Municipalities have worked successfully with MassDEP for years on other programs, and there is no reason this collaboration could not be successful. The current Small MS4 permit for Massachusetts imposes limits not seen in other states and, some argue, are not the performance standard under the CWA. Municipalities want to protect water resources and the environment. That is what water, sewer, and stormwater professionals do every day. But there is a need to balance costs between competing needs and a need to maintain fiscal responsibility to residents. Solutions need to be implementable and sustainable, and provide a measurable benefit that outweighs costs or impacts to other systems. It is up to EPA to work with stakeholders to find cost-effective, technically achievable solutions. Stormwater management is not a simple issue and an MS4 permit, to be successful for all stakeholders, should allow for the flexibility for communities to craft a solution that meets their needs and limitations while protecting water quality.

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Corrosion basics for metals and concrete in wastewater applications

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ABSTRACT | Understanding the most prevalent corrosion mechanisms that degrade concrete and metals in wastewater applications is the first step in preventing and controlling corrosion damage. This article explains corrosion basics for concrete and metals in wastewater applications. It discusses the major corrosion mechanisms experienced in collection systems and wastewater treatment plants and guides the selection of suitable corrosion mitigation strategies to prevent corrosion-related deterioration.

KEYWORDS | Corrosion, galvanic, acidic, alkalinity, carbonation, sulfate reducing bacteria, MIC, passivation, chlorides, protective coatings, concrete protection, concrete, metals, pipes, water, wastewater

MAJOR CORROSION MECHANISMS OF METALS

The corrosion of metals can be best understood through two fundamental points. First, when metals are made from natural ores taken from the ground, their manufacture adds a great deal of energy to them. Generally, that energy involves the addition of heat. Thereafter, that energy is locked up in those metals and each metal can return to its original oxide or raw ore form. When this return is realized via corrosion, that pent-up energy is released as the electrical energy of corrosion. All metals have a certain energy level or potential (voltage) relative to one another. When a given metal returns to its original oxide or ore form through corrosion, that potential or voltage is released causing electrical current to flow from anodic sites to cathodic sites. This can occur between dissimilar metals or along the same metal surface due to compositional differences in the metal. Differences in that electrical potential or energy drive corrosion rates in both singular metal corrosion and in galvanic or dissimilar metals corrosion.

Second, under the right conditions, metals avoid corrosion because they form protective-barrier oxide films or passive films due to initial corrosion or atmospheric reaction with oxygen that isolate the metal from the corrosive environment or help it resist corrosion. This tendency for protective or passive film formation is critical to understanding metals corrosion. If the environments in which metals are exposed permit film formation and the stability of the film can be maintained, metals will not corrode or not corrode very much. When the environment includes conditions that break down or destabilize the passive or protective films, however, the metals will actively corrode. Understanding those conditions that maintain or break down passive or protective film formation is important in selecting proper materials and averting metals corrosion problems.

ELECTROLYTIC OXYGEN-DRIVEN CORROSION OF CARBON STEEL AND DUCTILE IRON

Corrosion of carbon steel and ductile iron occurs in immersion exposures or cyclical wetting conditions, and is rate-determined by how much oxygen reaches the metal surfaces. Various factors influence the corrosion of ferrous metals in water immersion, including pH, temperature, flow rate, and numerous other contributors. The relative acidity of the solution is generally the next most essential influence on corrosion rate. At low pH, the evolution of hydrogen tends to prevent the possibility of protective film formation so that carbon steel or ductile iron continues to corrode. In alkaline solutions, the formation of protective films is typically enhanced, and alkaline conditions often help maintain protective films such that the corrosion rates are greatly reduced for carbon steel and ductile iron. In near neutral solutions such as most municipal wastewater, other contributing factors become more corrosion-rate determining. The most important factor is aeration. How much oxygen reaches the surface of the ferrous metal has the primary influence on the corrosion rate. This corrosion mechanism is common for immersed carbon steel or ductile iron components in wastewater such as in primary and secondary clarifiers. Figure 1 shows a textbook case of electrolytic corrosion of carbon steel in a clarifier.

Figure 1. Badly corroded rake mechanisms in a primary clarifier

Galvanic corrosion occurs in many situations in wastewater treatment and causes deterioration of numerous metals, including most commonly carbon steel, zinc, and aluminum. Galvanic corrosion occurs when two dissimilar metals having a significant difference in electromotive energy or surface potential are electrically coupled and immersed or present in a common electrolyte. In these situations, the less noble or less corrosion-resistant metal corrodes or becomes anodic to the more corrosion resistant or cathodic (more noble) metal. The driving force for corrosion current becomes the potential difference between the metals. The most influential factors in galvanic corrosion rates are the potential difference between the two metals, the environmental conditions such as pH, conductivity, and chemistry of the electrolyte, the proximity of the two metals to one another, the relationship between anodic and cathodic surface area, and the polarization behavior of the metals or alloys. In wastewater treatment, common examples are the preferential corrosion of the zinc in galvanized steel relative to exposed and active carbon steel surfaces, the corrosion of immersed aluminum gates and gate frames when electrically coupled to the carbon steel reinforcing bars in concrete via anchor bolts, or the active pitting corrosion of coated carbon steel relative to close-by and electrically connected stainless steel surfaces. Figure 2 shows galvanic corrosion of aluminum in a clarifier where the aluminum is anodic to carbon steel rebar.

Figure 2. Close-up of aluminum clarifier baffle—electrically continuous with carbon steel rebar in concrete

Soil-related corrosion of ductile iron and carbon steel piping is also typically found in wastewater systems. In these instances, microstructural composition differences in the ferrous metal surfaces produce anodic and cathodic sites, and the resulting potential differences cause corrosion current to flow from the anodes to the cathodes. Several factors influence soil corrosion rates. The most important factors are the moisture content of the soil that serves as the electrolyte, the availability of oxygen, the resistivity of the soil (the inverse of conductivity), and the extent of chemical contamination of the soil. The presence of chlorides, sulfates, sulfides, and other chemical constituents can increase soil conductivity (or lower soil resistivity) and degrade the natural passive protective films formed on the ferrous metal surfaces.

Soil corrosion of metals can also be caused by stray current effects. This generally occurs when direct current leaves one structure and jumps through the soil onto another structure or pipeline. When that current again jumps or leaves the unintended electrical conduit, corrosion occurs. Stray current corrosion is common in cities where third rail electrical transit systems are used for public transportation. Stray current can also occur on metal pipelines when those conduits cross or are adjacent to other pipelines protected by impressed current cathodic protection systems.

Graphitic corrosion of cast and ductile iron is another corrosion mechanism often encountered in wastewater applications due to the prevalent use of ductile iron piping in the wastewater industry and the common presence of cast iron piping in older facilities and older collection systems. Figure 3

Figure 3. Corroded cast iron pipe

shows graphitic corrosion of a cast iron sewer collection pipe.

Graphitic corrosion involves the gradual leaching-out of iron from cast or ductile cast iron pipes generally exposed to slightly acidic soil or other corrosive water conditions whereby a network of graphite is left behind. Upon initial examination, the pipe will not appear to be badly corroded, but the remaining graphite network is weak and soft. Graphitic corrosion is more severe in old pit cast or spun cast irons, but it also occurs in ductile iron piping under acidic soil conditions.

UNDER-DEPOSIT CORROSION OF FERROUS METALS

In wastewater treatment plants the localized build-up of bioactive sludge and organic materials causes localized pitting corrosion of carbon steel and ductile iron. This is common in headworks, grit facility, and primary treatment structures. Localized deposits of these materials become established over breaches in protective coating systems, and tubercules form from the combination of the organic materials and the iron corrosion products. These tubercules or deposits create oxygen-starved areas at the metal surface (or in the pits), and oxygen concentration cells form. Generally, the reactions result in local acidification at the base of the pit promoting more aggressive corrosion. This under-deposit corrosion is exacerbated if the bacteria present metabolize various sulfur species and form dilute sulfur acids. The ever-present sulfate reducing bacteria (SRB) in wastewater that thrive in anaerobic conditions beneath biofilms and deposits contribute to this microbiologically influenced corrosion (MIC). Also important is that SRB-related MIC also occurs under nominally aerated environments where anaerobic micro-environments exist under bio-deposits of aerobic organisms, especially in crevices built into structures. Such crevices are commonplace in coated-steel primary clarifier rake mechanisms found in wastewater treatment plants. MIC is discussed below with specific reference to stainless and carbon steels. Under-deposit corrosion also occurs in secondary clarifiers and can involve SRB-associated MIC.

Erosion–corrosion of carbon steel and ductile iron is the conjoint action of corrosion and erosion in the presence of a moving corrosive fluid that leads to the rapid loss of steel material. Fluid flow by itself or in combination with suspended solids can cause this form of corrosion. Erosion–corrosion is common in grit piping and sludge-handling piping in wastewater treatment plants particularly in carbon steel elbows and reducer fittings where flow direction changes and velocity increases occur.

MIC OF FERROUS METALS, STAINLESS STEEL, AND CONCRETE

MIC occurs commonly in wastewater treatment plants both in anaerobic and aerobic conditions. The most prominent form of MIC in wastewater handling including collection systems is biogenic sulfide corrosion. Biogenic sulfide corrosion is a well-known phenomenon in wastewater treatment plants and collection systems but a review of the fundamental process of this biogenesis is important. This form of MIC is a vapor phase or headspace-related corrosion problem.

Domestic septic sewage contains an ample supply of sulfate ions ($SO_4^{=}$). Within the slime layers that form on sewer piping and other sewer transport surfaces, SRB exist. The bacteria require an anaerobic environment and do not become active until the slime layer is sufficiently thick to avert penetration by dissolved oxygen. Once this occurs, and it does not take long (one to three weeks depending upon various conditions), the SRB use the oxygen from the sulfate ions for metabolizing organic species in the wastewater. Through the metabolism, the oxygen is depleted and the byproduct is the sulfide ion or $S^{=}$. The sulfide ion byproducts are released back into the wastewater, and ultimately through chemical reactions the sulfide ion combines with hydrogen in the wastewater to form hydrosulfide.

Hydrosulfide is also called the bisulfide ion, (HS^-). Bisulfide ions further react to form dissolved hydrogen sulfide (drop gas) or aqueous H_2S. The dissolved H_2S subsequently comes out of solution at regions of turbulence in the wastewater system and becomes gaseous H_2S. Through the relationship of a dynamic chemical equilibrium, the aqueous H_2S lost to the headspace is constantly replaced with the conversion of HS^- to H_2S (aqueous). When H_2S comes out of solution at areas of turbulence in open-topped tanks, it enters the atmosphere and causes odors. When H_2S is released as a gas into the oxygen-rich headspaces of enclosed or covered structures, it is absorbed into wetted surfaces or is dissolved in moisture. This reduces the surface pH of the concrete. Carbon dioxide (CO_2) released from the wastewater also condenses and lowers the surface pH as weak carbonic acid. H_2S, when dissolved, also produces weak acids, mostly thiosulfuric acid.

Once the surface pH has been reduced to a level of approximately 9.5, naturally occurring sulfur oxidizing bacteria (SOB) colonize on the surfaces if sufficient oxygen and moisture are present. SOB are especially attracted to a nutrient-rich scum layer generally found just above the waterline. These bacteria use dissolved oxygen to metabolize the H_2S and other sulfides present. The H_2S is oxidized to form dilute sulfuric acid (H_2SO_4).

The SOB responsible for this reaction are mainly members of the genus Thiobacillus. Many species of Thiobacillus are involved in the production of sulfuric acid in sewer systems. As one species creates acid as a byproduct, the acid lowers the pH to a point at which that species of Thiobacillus cannot live and dies off. Another species of Thiobacillus capable of living at the lower pH then takes over and more acid is formed. This process continues to pH levels below 1.0. This mechanism requires a continued source of nutrition in the form of H_2S and an ample supply of dissolved oxygen and moisture.

The sulfuric acid produced dramatically affects the corrosion of iron-based metals such as carbon steel and ductile iron present in wastewater headspaces. As previously mentioned, pH is a major factor influencing the corrosion of especially iron-based metals. At a pH of 5.5 or lower, the corrosion rate of iron-based metals accelerates. Figure 4 shows a typical schematic of the biogenic sulfide corrosion process.

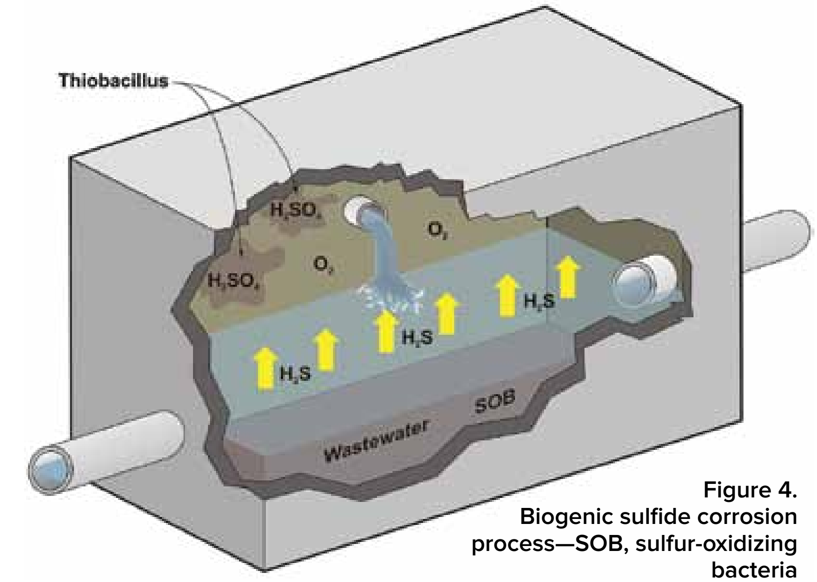

Figure 4. Biogenic sulfide corrosion process—SOB, sulfur-oxidizing bacteria

The biogenesis of sulfides to form sulfuric acid also causes significant deterioration of concrete in wastewater applications. The highly alkaline cement paste in concrete reacts with the acid and disintegrates. Protective coatings and linings are widely accepted and successful in preventing concrete acidic attack in municipal wastewater systems. Figure 5 shows typical acidic attack of concrete in the headspace.

Figure 5. Biogenic sulfide corrosion/ vapor phase, five years of exposure

This acidic attack is also a problem for prestressed concrete cylinder pipe (PCCP) and reinforced concrete pipe (RCP) wastewater transmission or conveyance pipelines when air bubbles or headspace conditions exist in the crowns of these pipes where SOB can colonize and metabolize H_2S.

Whenever sewage piping does not always run full (or where intermediate flow conditions permit the formation of air bubbles at the crown of the pipe), active biogenic sulfide corrosion will occur. The crowns of carbon steel, concrete, and ductile iron pipes in wastewater systems often completely fail due to biogenic sulfide corrosion (MIC).

As previously described, MIC also typically occurs in the anaerobic phase in wastewater systems where certain conditions coincide. Welds, heat-affected zones of welds, and crevice locations in stainless steel are often susceptible to MIC in stagnant and low-flowing wastewater conditions. Biofilm mounds generally form on the stainless steel creating acidic conditions at the base of the pits that are initiated. In wastewater treatment plants, the most common form of anaerobic MIC is associated with the ever-present SRB. This type of corrosion is frequently observed in ductile iron return activated sludge and waste activated sludge piping where stagnant or low-flow conditions exist for extended periods of time.

Past amendments to the Clean Water Act of 1972 required that industrial contributors to municipal wastewater treatment plants implement treatment processes for pH control and heavy metals removal for their discharged wastewater. These regulations required that their discharged wastewater be near neutral in pH and be mostly free of heavy metals such as lead, mercury, and copper. The pH control requirement made municipal treatment less prone to pH adjustment needs and improved treatment plant efficiency. The heavy metals removal requirements reduced the toxicity of treatment plant effluent and greatly helped the environment. However, the removal of these heavy metals, which are toxic to many types of bacteria, caused sulfide production in wastewater collection systems to rise. This, in turn, caused greater H_2S gas concentrations and thereby higher biogenic sulfide corrosion rates in municipal wastewater collection systems and treatment plants.

Important to note is that whenever a sulfuric acid attack of Portland cement concrete occurs, sulfate reactions also occur in the hydrated cement. Measuring both loss of alkalinity and sulfate

| CORROSION BASICS |

Figure 6. Typical crevice corrosion damage at a flanged connection due to chloride ion concentration

contents in concrete exposed to biogenic sulfide corrosion is important to determining the extent of the degradation.

LOCALIZED CORROSION OF STAINLESS STEEL

Stainless steel resists corrosion differently from carbon steel and other alloy steel in that it does not form films that are true oxide barriers separating the metal from the environment. Rather, stainless steel forms a passive film. The presence of oxygen is essential to the corrosion resistance of stainless steel. Stainless steel best resists corrosion when exposed to a flowing bulk environment with ample oxygen present and the surfaces free of deposits. If part of the metal surface is covered by coatings or biofilm buildup, or gasketed connections or other fabrication conditions create oxygen-depleted zones under such covered regions, the oxygen-depleted areas become anodic relative to the well-aerated (cathodic) surfaces exposed to flowing conditions. The anodic areas actively corrode under such exposures if these conditions continue over time.

Passive film formation under the right conditions for any type of stainless steel is immediate provided oxygen is present and no aggressive chemical species is present that could disrupt or break down the passive film. For these reasons, the most common form of stainless steel corrosion is localized in the form of pitting or crevice corrosion. General thinning or uniform corrosion of stainless steel is rarer and typically exposes the metal to a reducing environment where passive film formation is prevented.

Pitting corrosion and crevice corrosion are the most common forms of stainless steel corrosion expected in municipal wastewater environments. Pitting corrosion is associated with a local discontinuity in the passive film. It can be caused by a mechanical discontinuity such as a rough weld, a covered area, or damage to the metal surface. It can also be promoted by local chemical breakdown of the passive film. Chlorides are the most common chemical agent promoting the pitting corrosion of stainless steel. Once a pit is formed the corrosive species concentrates, and the local pit environment behaves more aggressively than the surrounding bulk environments. Hence, pitting corrosion rates can be high for stainless steel. Higher flow rates over the metal surface reduce pitting corrosion rates, because the higher flow prevents the concentration of the corrosive species within the pit.

Crevice corrosion should be considered a severe form of pitting corrosion. Figure 6 shows typical crevice corrosion damage at a flanged connection due to chloride ion concentration. Crevices are created by biofouling (under-deposit-type corrosion as discussed above), gasketed flanged surfaces, or other mechanical connections or flaws in structures that create conditions where corrosive species can concentrate and/or where oxygen-depleted regions develop. In wastewater treatment plants, pitting and crevice corrosion mainly occurs where relatively high chloride concentrations are present or where biofilm buildup can proceed under quiescent flow or stagnant bulk-solution conditions. Ferric chloride used as a flocculation agent or for sulfide removal creates conditions where chloride concentration levels can promote chemical breakdown of the passive film of both types 304 and 316 stainless steel (the most commonly used grades in wastewater treatment plants). Where ferric chloride concentrations are between approximately 200 and 300 ppm, both types 304 and 316 stainless steel suffer from pitting and crevice corrosion. Type 316 is slightly more resistant than type 304 but not at those levels of ferric chloride concentrations.

In normal wastewater exposure, types 304 and 316 stainless steel tend to pit at around 300 and 1,000 ppm chloride concentrations, respectively, at neutral pH and 95˚F (35˚C).

Stainless steel is scored for its relative resistance to chloride-associated pitting corrosion using a system called the pitting resistance equivalent number (PREN). Table 1 presents a typical comparison of commonly used types of stainless steel. The table presents the chromium and molybdenum contents (which drive chloride resistance), the PREN, and the approximate chloride ion concentration below which pitting does not occur for these metals.

CORROSION OF ALUMINUM ALLOYS

Aluminum alloys resist corrosion by forming a barrier oxide film that is well-adhered to its surface and, if damaged, reforms readily in most environments. But aluminum alloys are also thermodynamically reactive metals. Therefore, aluminum will corrode actively relative to more noble metals, and only beryllium and magnesium are more reactive than aluminum.

Table 1. Stainless steel—comparison of PREN

Stainless Steel Grade	UNS Number	Cr % (Typ.)	Mo % (Typ.)	PREN*	Approx. Cl- concentration below which pitting does not occur (ppm)**
304L	S30403	18	0	18	300
316L	S31603	17	2.1	23	1000
317LMN	S31726	18.5	4.1	32	5000
2205	S32205	22.5	3.3	34	5000
AL6XN	N08367	20.5	6.1	43	Seawater

* PREN = Pitting Resistance Equivalent Number; %Cr + 3.3 . %Mo + 16 . %N, based on minimum composition
** At 95ºF, neutral pH

Aluminum and its alloys effectively resist corrosion in wastewater with a pH between 4.5 and 8.5. This generally covers wastewater exposure except for headspace conditions where the biogenic formation of sulfuric acid, as previously discussed, creates condensing acidic conditions, which easily reduce the pH of the environment below 4.5. This typically results in localized pitting corrosion of aluminum alloys. Figure 7 shows low-pH-driven corrosion of an aluminum gate exposed to high H_2S gas-headspace conditions in a headworks facility. The extent of this type of pitting and the corrosion rate of the pitting formed depends on several factors in wastewater headspaces, including aluminum alloying additions, degree of condensation, temperature, airflow (related to odor control ventilation), and varying hydrogen sulfide levels in the incoming wastewater. Protective coatings are not well suited for aluminum corrosion protection especially if field applied. Replacing corroding aluminum with stainless steel or fiber-reinforced plastic (FRP) materials has been shown to be better.

CORROSION OF COPPER AND COPPER ALLOYS

Copper, a very noble metal, is almost totally impervious to corrosion from soils and natural waters. Protective copper oxide forms readily in aerated environments, and its noble nature means copper is not affected by reducing acids. Many underground copper pipes used to convey water thousands of years ago still exist, and copper exists as an element in its natural form. However, copper pipe or tubing in soils will corrode in a variety of special situations.

Corrosion of copper and copper alloys by thiosulfates and sulfides, especially hydrogen sulfide, manifests as dark tarnishing due to formation of copper sulfide. This problem often affects electrical equipment and wires. In wastewater treatment plants, copper corrosion is generally not a major problem except where copper components within electrical cabinets and equipment corrode actively due to the presence of high H_2S gas levels in the given atmosphere or where chlorine vapors cause copper to corrode in disinfection headspaces. Ferric chloride exposure is also extremely corrosive to copper.

FAILURE OF PCCP AND RCP

Causes of PCCP and RCP failure include breakdown of the natural passivation of the prestressed steel wires, conventional reinforcement, and/or the steel cylinders from exposure to chlorides in the soil and groundwater, breakdown of the external cement mortar coating from acidic (low pH) soil conditions,

Figure 7. Aluminum gate in open position in high H_2S headspace—pH = 3

sulfate attack of the cement mortar coating due to high sulfate containing soils, exposure to soft ground water high in carbon dioxide concentration resulting in carbonation of the cement mortar coating, or stray current interference. Some significant failures of PCCP have been related to both corrosion and to dynamic strain aging (DSA) of prestressing wires. This included the infamous Class IV prestressing wires used in PCCP manufactured in the 1970s (Ref. 1). The DSA problems caused by overheating of the wire during drawing promoted a propensity of the wire to suffer hydrogen embrittlement, causing subsequent explosive failures of the wire and therefore the pipe itself.

Use of protective coatings for PCCP and RCP pipe is limited. Under extremely aggressive soil conditions such as low pH soils (<5.0) or seawater exposure and tidally affected soils along coastal areas, PCCP and RCP have been externally coated with epoxy, coal tar epoxy, and/or polyurethane coating systems, but this has been rare. Also, the American Water Works Association (AWWA) has specific recommendations for enhancing the corrosion resistance of the external cement mortar coating for PCCP to improve its sulfate and chloride intrusion resistance. These include the use of type V Portland cement for better sulfate resistance, lower water-to-cementitious-materials ratios, and micro-silica admixtures to increase the density of the cement coating or concrete exterior of the pipe (PCCP or RCP dependent). Internal coatings are seldom used for these pipe types in wastewater service as PCCP is mainly used for force mains where no headspace conditions should exist under normal conditions.

OTHER CAST-IN-PLACE CONCRETE DETERIORATION MECHANISMS

Cast-in-place concrete is the main material of construction for secondary containment areas, pump station wet wells, screen chambers, and most tanks and basins in wastewater treatment plants. The predominant corrosion or deterioration mechanisms for these structures are described below.

Acid Attack (Non-Biogenic)

When concrete, with its newly hydrated pH of 12.5 or higher, interacts with an acid or acidic solution with a pH well below 7.0, the cement components are dissolved and form salts (chlorides, sulfates, and nitrates). As the cement paste is dissolved, the coarse aggregates are exposed, leading to greater porosity and a loss of strength. Fresh surfaces can then react further with the acidic solution.

Important to note is that acid concentrations do not always correlate with the aggressiveness of an acidic solution. Low concentrations of sulfuric acid will yield extreme pH values. For example, sulfuric acid at a 5 percent concentration will have a pH of less than 0.5. This means that Portland cement concrete is extremely vulnerable to acid attack, even at relatively dilute concentrations.

The aggressive action of most manufactured acids depends on the solubility of the calcium salts formed when the acid reacts with the calcium hydroxide and other less prominent alkali compounds found in the cement paste. Prolonged exposure to acidic solutions manifests as rust bleeding from corroding reinforcing steel, cracking, exposed coarse aggregate, spalling, and a highly weakened matrix. One way to protect concrete from acid attack is to use special cement overlays, such as those based on potassium silicates, or to apply properly selected coatings or linings.

Acidic attack of concrete occurs most often at wastewater treatment plants where alum and ferric chloride are used as coagulants and sulfuric acid is used for pH adjustment. Most of the acidic concrete degradation occurs in the ferric chloride and sulfuric acid storage and handling areas. All three solutions have a very low pH. The best coating solutions are properly selected Novolac epoxy, specialty amine cured epoxy, or vinyl ester coatings to protect concrete in these applications. In addition, anchored thermoplastic sheet linings such as polyvinyl chloride (PVC) and high-density polyethylene (HDPE) have been successfully used in these applications. These linings are cast into the concrete when the structures are built and are therefore not conducive to retrofit applications.

Alkaline Reactions

With a pH between 12 and 14, newly hydrated Portland cement concrete is typically unaffected by alkaline solutions unless solutions are very hot or there is sustained exposure under which expansive deterioration can occur from the reaction between caustic solutions and the calcium hydroxide in the cement paste. Under long-term exposure, a solution of sodium hydroxide at concentrations of 25 percent or more may degrade concrete progressively by solubilizing the calcium hydroxide and other alkalis in the cement paste, gradually washing them from the matrix when water flow is also typically present (Ref. 2).

Alkaline attack occurs in wastewater treatment plants in sodium hydroxide storage and handling areas where unattended leaks occur. This is mainly found in secondary containment areas. The best coating choices here are various amine cured epoxy coatings. However, both reinforced and unreinforced polyurea coatings have also been used with success in these applications.

Carbonation

Carbonation occurs naturally in all concrete exposed to the atmosphere, sometimes soon after curing, but often much later. It involves the reaction of atmospheric CO_2 with the hydrated constituents of Portland cement paste, especially calcium hydroxide {[Ca $(OH)_2$] (Ref. 2)}. The reaction is:

$Ca\ (OH_2) + CO_2 \rightarrow CaCO_3$ (Calcium Carbonate) + H_2O.

Carbonation in the aqueous phase most often occurs when the raw water supply is characterized by both low alkalinity and low hardness. Aqueous phase carbonation of concrete is common in secondary treatment in both ambient aeration tanks and secondary clarifiers. The biological treatment process produces dissolved CO_2, which lowers the pH of the wastewater in the form of some carbonic acid formation. Provided the raw water source has little buffering capacity as in southern New England, slow cement paste dissolution occurs leaving exposed coarse aggregate. This is generally a slow, gradual mechanism, which slows over time where quiescent conditions exist. The main reaction compound is calcium carbonate, and its solubility is fairly low in water. Once this calcium carbonate buildup occurs over the concrete surfaces, the diffusion of carbonic acid is greatly reduced. Aqueous phase carbonation damage can be much faster in pure oxygen reactors. These tanks have slightly pressurized headspaces, which keep dissolved CO_2 in solution. This drives higher carbonation rates in the cement paste of the concrete. Figure 8 shows the below-waterline cement paste losses typical of aqueous phase carbonation. Protection of concrete exposed to liquid phase carbonation is best accomplished using epoxy and flexible polyurethane coatings while polyurea has also been successfully used for this purpose.

Chloride-Induced Deterioration

When concrete is placed around reinforcing bars, the steel surface initially corrodes. Then, a tightly adherent oxide film forms over the surface to protect it from further corrosion, provided it remains intact. This passive protection film is maintained by the highly alkaline environment of the hydrated Portland cement in the concrete.

The protective film is compromised when moisture, chloride ions, and oxygen penetrate through pores or cracks to reach the steel surface, establishing local corrosion cells. Large amounts of iron oxide form as a result with concurrent volume expansion. If the expansive forces exceed the relatively low-tensile strength of the concrete covering the steel bars, the concrete cracks, allowing further ingress of chloride ions, water, and oxygen. Rust bleeding, cracking, and spalling are all manifestations of chloride-induced corrosion.

Chloride-induced corrosion has received more attention in recent years because it is the most prevalent form of concrete degradation in public infrastructure, especially in concrete bridges. In structures built prior to the mid or late 1970s and not exposed to external sources of chlorides, this sort of corrosion has occurred because calcium chloride was used as an accelerating admixture. This was common in wastewater treatment plants. Current limitations of calcium chloride accelerators are given in American Concrete Institute (ACI) 222. ACI recommends an upper limit of 0.2 percent chloride by weight of cement for cast-in-place concrete that is conventionally reinforced.

To reduce chloride ingress, the lowest possible water-cement ratio (less than 0.040) is recommended, minimizing capillary porosity and shrinkage. Structure design, mix properties, and placement and curing methods all influence cracking and permeability that facilitate chloride-induced corrosion. Pozzolanic admixtures, such as silica fume, fly ash, or blast furnace slag help reduce concrete permeability by water and chlorides. Compounds such as calcium nitrite are also helpful as corrosion inhibitors, but the use of sealers, coatings, overlays, and rebar coatings have proven more effective in controlling the effects of long-term chloride exposure.

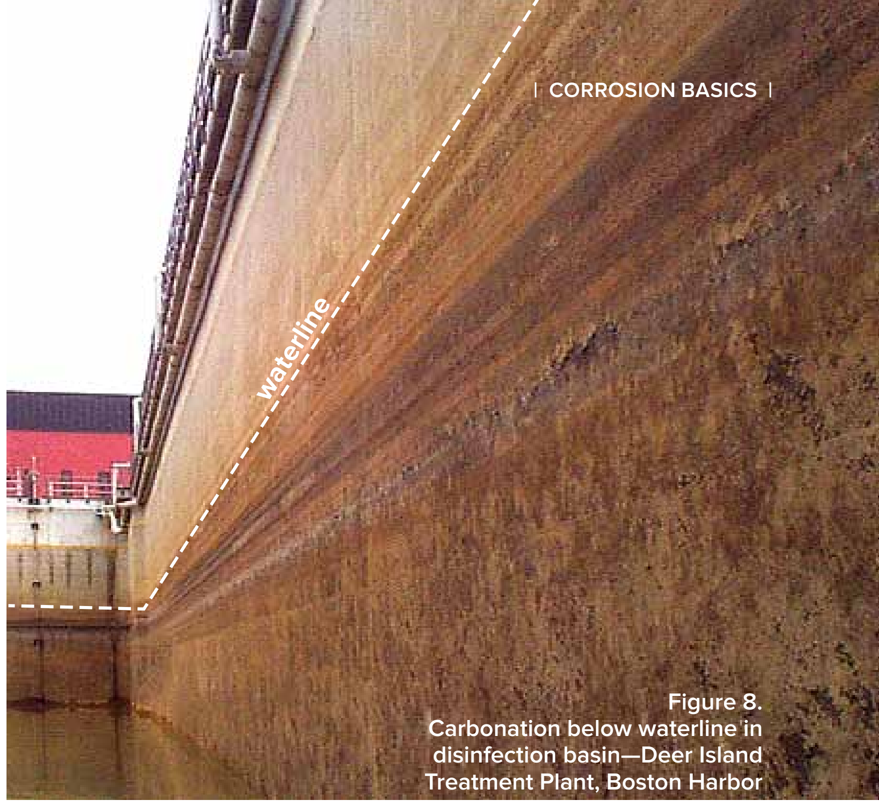

Figure 8.
Carbonation below waterline in disinfection basin—Deer Island Treatment Plant, Boston Harbor

Chloride exposure in wastewater treatment plants can be problematic for concrete in the areas in which ferric chloride and sodium hypochlorite are stored and handled. Some epoxy, polyurethane, and vinyl ester coatings have performed well in chlorine contact basins, ferric chloride containment, and other applications where needed.

SUCCESSFUL CORROSION MITIGATION STRATEGIES

Preventing or controlling corrosion in wastewater collection and treatment plant applications can be accomplished using four key mitigation strategies:

1. Alternative materials that resist the exposure conditions
2. Barrier protection via the application of coatings or linings
3. Cathodic protection—sacrificial or impressed current systems
4. Chemical treatment of the wastewater to reduce the severity of the corrosion

The following strategies have been demonstrated successfully:

- Preventing biogenic sulfide corrosion and related sulfate attack of concrete has been best accomplished through properly selected protective coatings and linings and FRP materials.
- Preventing aqueous carbonation can be successfully achieved with better concrete material design and the use of coatings and linings.
- For chloride-induced rebar corrosion, improved concrete design and coatings, linings, and corrosion inhibitors (and use of galvanized rebar) have been very effective.
- For stopping electrolytic corrosion of ferrous metals, protective coatings and/or cathodic protection has been successful in immersion

conditions. Also, replacement of ferrous metals with properly selected stainless steel or FRP has been very effective.

- For avoiding galvanic corrosion, avoid electrical couples of the dissimilar metals (or isolate them). This can be accomplished through isolation flange kits for piping or via the application of protective coatings over the cathodic metal surfaces in other applications.
- Avoiding non-biogenic MIC in metals can be accomplished through proper alloy selection or with coatings and linings or FRP materials.
- For averting aluminum corrosion, stay within the pH "sweet spot" of exposure (4.5 to 8.5) or use the right stainless steel alloy.
- For preventing zinc corrosion, keep it in atmospheric exposure and not in immersion service (unless you want it to be a sacrificial anode). This pertains to galvanized steel.
- Prevention of localized corrosion of stainless steel requires the knowledge to select the right alloy for the exposure conditions as well as proper welding practices and post-weld cleaning practice.
- To avoid copper corrosion, protect it from H_2S gas exposure.

SUMMARY

Understanding the corrosion damage mechanisms for each material of construction given the wastewater exposure conditions, designers can engineer structures, piping, and equipment to prevent corrosion, providing long-term valuable service in wastewater environments.

ABOUT THE AUTHOR

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Evaluating non-traditional nitrogen control measures for Cape Cod and the Islands

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ABSTRACT | Cape Cod and the Islands are largely served by septic systems. Traditional sewerage systems can address the nitrogen loading from septic systems, but the costs can be very high. Many non-traditional solutions hold promise for nitrogen control at lower cost and with quicker results. This paper presents a framework for the systematic evaluation of non-traditional solutions and identifies the principal hurdles to widespread use of specific options such as permeable reactive barriers, aquaculture, and fertigation.

KEYWORDS | Nitrogen control, non-traditional, TMDL compliance, adaptive management, estuary protection, risk analysis

INTRODUCTION

Many coastal areas in the United States have addressed wastewater-related water quality problems by constructing extensive sewer systems and centralized treatment facilities. Complete sewering of near-shore areas has been the norm. A clear exception is Cape Cod, the spit of glacial outwash extending into the Atlantic Ocean from southeastern Massachusetts, and the associated islands of Martha's Vineyard and Nantucket. There, very permeable soils have allowed intensive development that relies mostly on on-site septic systems. Septic-tank-and-leaching-field systems have addressed the sanitary needs of wastewater disposal, but their inability to remove significant amounts of nitrogen has led to widespread nutrient enrichment of coastal waters.

Many of the cities and towns in these areas are considering the elimination of these on-site septic systems to reduce the nitrogen loading to coastal embayments. The construction of traditional sewer systems and wastewater treatment plants can solve current problems, but the cost of such solutions can be very high and, in some cases, it could take many years for the investment to improve water quality. As a result, there is significant interest in many non-traditional solutions that hold promise for nitrogen control at lower cost and with quicker results. Discussed below is a framework for the systematic evaluation of non-traditional solutions considering such factors as the predictability of the nitrogen removal, permitting hurdles, potential need for traditional back-up systems to address reliability, and capital and operation and maintenance (O&M) costs.

EXAMPLES OF NON-TRADITIONAL TECHNIQUES

Many diverse approaches have been proposed for nitrogen removal, and many of them would be considered non-traditional. The Cape Cod Commission, in its 2015 *Cape Cod Area Wide Water Quality Management Plan Update (the 208 Plan Update)*, identified and described more than 30 such technologies. Examples include:

- Hydroponics
- Urine diversion
- Floating constructed wetlands
- Shellfish harvesting
- Fertilizer use restrictions
- Composting toilets
- Coastal ecosystem rehabilitation
- Permeable reactive barriers
- Land set-asides
- Transfer of development rights
- Pond destratification by mixing
- Fertigation

WHAT ARE THE MOST IMPORTANT FEATURES?

Given the wide range of systems proposed for controlling nitrogen, many features of such systems must be considered; however, the two most important questions are:

1. Where in the environment does the nitrogen removal occur?
2. Is enough known about the technology to allow its immediate application with little or no financial or compliance risk?

Source Control versus Remediation

Source control techniques reduce or eliminate the nitrogen load to the groundwater on the property where nitrogen is generated or where nitrogen-containing fertilizer is used. Examples include on-site denitrification, urine diversion, reductions in fertilizer use, land set-asides, and transfer of development rights.

Remedial measures reduce the nitrogen concentration in the groundwater leaving the site or within the estuary to be protected. These measures can be used instead of, or as supplements to, source control. Typical examples include permeable reactive barriers, wetland enhancements, and shellfish harvesting.

Readiness for Immediate Application

Traditional nitrogen removal techniques, by definition, have been commonly used, and typically are understood well enough to be readily permitted and confidently sized and costed. Conversely, a common element of non-traditional techniques is that they may not remove as much nitrogen as needed, or they may cost more than expected, and that uncertainty makes them less ready to be implemented.

Table 1 shows how applicable technologies might be categorized, including:

- Traditional source control—e.g., sewers
- Non-traditional source control—e.g., urine diversion
- Traditional remediation—e.g., pond destratification by mixing
- Non-traditional remediation—e.g., floating constructed wetlands

EVALUATIVE CRITERIA

Many factors must be considered in the use of a specific technology in a unique setting. Table 2 lists some of the most important criteria and compares typical traditional and non-traditional options. The checkmarks in Figure 2 indicate which type of system is generally more favorable for the given criterion.

- **Predictability**. Is it known with some certainty how much nitrogen will be removed and at what cost? Non-traditional systems are generally less proven and may require demonstration projects to better understand sizing criteria and cost.
- **Speed in cleanup.** How much time will elapse from the implementation of the technology to the restoration of water quality in the embayment to be protected? Remedial solutions can be very close to the impacted estuary and can show quick results. This can be significant in demonstrating to the public how expenditures are worthwhile concerning habitat protection and water quality.

Table 1. Framework for consideration of technologies

Where does N removal occur?	Is N Removal Technology Ready for Full-Scale Use?	
	Not Fully Proven (Non-Traditional)	*Ready to be Implemented (Traditional)*
Before N reaches groundwater (source control)	• Fertilizer control regulations • On-site denitrification • Composting toilets • Hydroponics • Urine diversion • Credit trading	• Sewers and treatment facilities • Stormwater BMPs • Land set-asides • Effluent irrigation • Golf course fertilization reduction • Transfer of development rights
After N reaches groundwater (remediation)	• Permeable reactive barriers • Floating constructed wetlands • Shellfish propagation • Wetland restoration • Inlet widening • Coastal habitat restoration	• Pond destratification • Sediment removal

Table 2. Favorability comparison

Important Criteria	Non-Traditional Technologies	Traditional Technologies
Predictability of cost and performance		✓✓
Speed in cleanup	✓	
Ability to document TMDL compliance		✓
Ability to manage multiple N sources	✓✓	
Ease in permitting		✓
Less climatic vulnerability		✓
Lower life-cycle cost	Uncertain	
Compatible with Accepted Cost Recovery Methods		✓
Lower Risk of Non-performance		✓✓

✓ More favorable ✓✓ Significantly more favorable

- **Ability to document Total Maximum Daily Load (TMDL) compliance**. How readily can nitrogen load reductions be measured? Source control measures are generally easier to document (e.g., by measuring nitrogen concentrations in a treatment plant effluent). The results of implementing a fertilizer control ordinance may be challenging to measure, for example.
- **Ability to manage multiple nitrogen sources**. Does the technology address just septic nitrogen, or are other nitrogen sources addressed as well? Remedial measures remove the nitrogen in the groundwater and/or embayment, regardless of the source. Septic systems generally are responsible for 70 to 80 percent of the watershed load, so removal of that source does not affect the other 20 to 30 percent of the locally controllable load.
- **Ease in permitting**. Is there a clear pathway toward the needed permits? Traditional approaches have been permitted before, and the types of permits and their conditions are well known. For some remedial measures, it is unclear which permits are needed, and the potential permit conditions are difficult to predict.
- **Vulnerability**. How will the technology perform in the face of climatic variability and sea level rise? Some remedial measures (such as floating constructed wetlands or shellfish beds) could be prone to coastal storms and climatic impacts. Similarly, traditional gravity sewers installed in near-shore areas could also be susceptible to sea level rise, where low-pressure sewers would be less susceptible.
- **Life-cycle costs**. What are the life-cycle costs of the technology including implementation, O&M, and monitoring? Many non-traditional approaches seem to offer capital cost savings over traditional public sewerage; this is a major driving force behind their attractiveness. However, long-term life-cycle costs of non-traditional technologies are not well understood.
- **Cost recovery**. Betterment assessments are a well-known method for recovering some or all the capital costs of public sewerage from property owners. For non-traditional remedial techniques, there is no clear "property served," and betterments may not be available as a cost recovery mechanism.
- **Investment risk**. How does a community plan for the possibility that a new technology does not perform as intended? If a large demonstration project, or actual full-scale use, shows that the non-traditional system needs to be larger, a simple cost-effective expansion may be accomplished without much wasted effort. However, if the demonstration shows poor removal or excessive costs, the costs of that demonstration may have been wasted. Historically, public funds have only been spent on "alternative approaches" if a risk assessment shows that the technology merits expenditures at risk. Worth noting, the Massachusetts Department of Environmental Protection (MassDEP) requires a traditional back-up plan be in place to support implemented non-traditional approaches. The cost of developing that back-up plan, and readying it for implementation, may offset potential savings with non-traditional systems.

COST ESTIMATING

Conventional life-cycle costing should be conducted to fairly evaluate traditional and non-traditional options. The *2010 Barnstable County Cost Report* presents a systematic approach to comparing life-cycle costs for various technologies. It uses confirmed capital and operating costs for municipal sewerage and for on-site denitrification systems. It recommends a "cost per pound of nitrogen removed" metric that incorporates the equivalent annual cost of the technology and the expected annual nitrogen removal.

The *2014 Barnstable County Cost Report Update* presents conceptual-level information for some non-traditional technologies. Some non-traditional options appear to have a strikingly low first cost and that feature has attracted much attention. O&M costs must also be considered and can be particularly difficult to estimate, especially when long-term monitoring costs are included for remediation options.

Grants are sometimes available to offset the local capital costs of a project but are rarely available for O&M costs. For options with similar life-cycle costs, high-capital, low-O&M alternatives may have an advantage over low-capital, high-O&M options when grants are considered.

READINESS FOR FULL-SCALE APPLICATION

One important consideration in implementing new technology is the time to establish sound data on cost and performance for site-specific circumstances. This information is necessary to adequately assess risks. If a community wants to implement a solution over the next 10 years, there will be time for demonstration projects. On the other hand, if the community faces an administrative order or third-party lawsuit, a stringent implementation schedule will be likely that could preclude demonstration testing.

Table 3 is a sample decision matrix for ranking nitrogen management options for their readiness for full-scale application. From left to right, the technologies become increasingly more applicable for immediate application, permitting is more straightforward, and the performance and cost are more predictable. The far-left column includes options not suitable for widespread use in coastal New England, whereas the far-right entries are ready for immediate application with a high likelihood of success. In the second-from-right column, the technologies are attractive enough to warrant delaying traditional approaches until a large-scale demonstration can be completed. In the second-from-left column, the attractiveness of the non-traditional technology is not great enough to defer traditional approaches, but the technology is worthy of a large-scale demonstration while a phased traditional approach is implemented. A successful demonstration could then allow cost savings by modifying the overall program's later phases.

Table 3. Sample decision matrix

Location of N Removal	Applicability to Near-Term TMDL Compliance			
	Not Applicable to Cape Cod and the Islands Situation	*Applicable as an Addition to an Ongoing Phased Plan After Further Study*	*Sufficiently Applicable to Allow Deferral of Traditional Approaches*	*Ready for Immediate Application as Primary Remedy*
Prevent future N loads		atmospheric deposition reduction	chemical fertilizer reduction	land set-aside down-zoning
Remove N before reaching groundwater	packaging toilets hydroponics	layered soil treatment area		conventional centralized sewer system stormwater management
Remove N from groundwater before reaching embayment		wetlands restoration	permeable reactive barriers	
Increase embayment's assimilative capacity for N	phragmites harvesting			inlet widening
Remove N from embayment water column	floating constructed wetlands	shellfish aquaculture		

ADAPTIVE MANAGEMENT

The thoughtful use of Table 3 allows an adaptive management plan to be formed. Adaptive management recognizes that the nitrogen overloading problem is severe enough to warrant some immediate action, even though not all the data are available to support a low-risk approach.

On Cape Cod and the Islands, towns should develop multi-phased plans including both traditional and non-traditional options. The number and extent of the phases and the specific technologies must reflect local circumstances, the town's risk tolerance, and the urgency to improve water quality. The plan should have a traditional framework (e.g., a core sewer area), with the ability to incorporate non-traditional elements as local demonstration projects bear fruit.

MassDEP is developing a watershed permitting program intended to establish a framework within which both traditional and non-traditional technologies can be implemented as part of an adaptive management approach.

Any adaptive management plan should reassess nitrogen loads associated with atmospheric deposition. Strong evidence exists that nitrogen concentrations in precipitation, and dry atmospheric deposition, have been declining since the imposition of air quality controls in other regions of the United States.

RECOMMENDATION

The performance and cost of new technology for nitrogen control must be systematically appraised as part of a risk analysis, using the approach and tools suggested in this paper. The environmental engineering and scientific community should advance those non-traditional technologies that can be developed and implemented at full scale in the 5- to 10-year period. Examples include permeable reactive barriers, shellfish harvesting, layered soil treatment areas, and nitrogen credit trading.

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Critical infrastructure cybersecurity—an overview

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ABSTRACT | Cybersecurity is often overlooked in protecting a critical facility and the ratepayers' investment. This threat of a cyberattack on critical infrastructure is relatively new. Malware, the umbrella title given to malicious software of all stripes, can do much damage. Until recently, it was a misbegotten belief that software could harm only software; this is not so. Early DOS-based software could destroy hard drives, and it will be shown how manipulation of SCADA and networked programmable logic controllers can cause real physical damage to controlled machinery. In recent years, high-level hackers, working with nation-states and government agencies, have rigorously investigated software for flaws unknown to anyone, exploiting these flaws for espionage or general mayhem.

So it is that our industry, which is increasingly relying on automation to manage rising costs and more stringent regulations, has turned to securing SCADA and other process control systems. Should such a system become compromised, the conditions for mayhem and social disruption are an opportunity for hackers. This paper provides a general overview of what could well become a major advanced persistent threat that will affect a broad class of facilities, and a few highlights illustrating the problem of protecting critical infrastructure against such a threat. Basic suggestions for site hardening are offered and recommended.

KEYWORDS | Cybercrime, critical infrastructure, social engineering, Stuxnet, firewalls, SCADA, wastewater

CYBER THREAT

The field of cybersecurity is broad. Ten years ago, few treatment facilities had the sophisticated control systems they do now, and if they had a SCADA or an automated process control system, it was not connected to the internet, or to any outside communication system. Until very recently, the preferred method of connecting to a SCADA system was to physically plug in a telephone modem and allow a vendor to "call in" to effect upgrades or troubleshooting—then the modem was unplugged. These were truly "air-gapped" systems in that there was no connection to any network outside the fence line. At that time, the implications of this rudimentary security precaution were not realized; connecting the system to outside resources was not necessary. "Hacking" or intrusion into a system to cause mayhem was not considered, or even imagined.

Things have changed. This paper will inform you of the threats facing your facilities' control systems, offering some suggestions on how to harden your system and prevent an intrusion and possible attack. Critical infrastructure—water and wastewater infrastructure, power generation and distribution networks, transportation systems—is a potential target for those wishing to disrupt or cripple a nation. Disruption of the water supply or power grid would have devastating consequences on society, particularly in urban areas. Millions of people would be adversely affected if water and wastewater treatment facilities were taken off line for an extended time.

There is no certainty of this happening. As the expression goes, there is no need to panic. Many threats have been identified, and mitigation has been designed and implemented. This is a continuous process happening at the highest levels of our federal government in concert with the major players in software development. New exploits are being discovered and then these zero-day exploits are patched by the vendor affected. It is a race, in a sense, because a new breed of "cyberarms" dealers are also searching for zero-days (a hole in software that is exploited by hackers) that they can sell for hundreds of thousands of dollars to hostile nation-states that wish to do the United States or others harm. Most of these exploits are financial; only recently have exploits been discovered and targeted at critical infrastructure. One incident involved a "worm," named Stuxnet, which successfully targeted the uranium enrichment centrifuge control systems in Natanz, Iran. Stuxnet and the Iranian response are discussed later in this paper.

Cybercrime is a growth industry. The risks are low and the rewards are high. Attacks can originate from anywhere there is access to the global internet. At this writing, 40 percent of the world's population (3.5 billion people) has internet access; there were about 1.3 billion connected in 1997 (source: internetlivestats.com). Attacks could also take place from airborne or orbiting platforms. For the malicious or opportunistic terrestrial hacker, the ground is fertile. Engaging in cybercrime requires much knowledge and experience. Many unsecured or poorly secured systems are among those 3.5 billion connections. Attacks can be made with practically no risk and low cost of execution. Payoffs can be huge. While there is no financial or technical gain by disrupting or damaging critical infrastructure, committing mayhem on a large scale is what cyberwarfare is all about; the disruption of critical service will have an immediate and dire impact on society and create a ripple effect with far-reaching consequences. In this weakened condition, the nation-state could become vulnerable to follow-up attacks, to which it could not easily respond. Cyberwarfare can also be ideological and political, as we have just witnessed during our last presidential election.

"Soft" targets will eventually be penetrated. In scanning the internet for vulnerable machines and open ports, attackers will naturally forgo a hardened target for a more accessible machine. A target can be soft in many ways, from being wide open with no access restrictions, to scant, poorly executed login or password policies, to purposely compromised access control. Any of these will allow an attacker to walk in, easily defeat, or work around the network gateway. Hardened targets will effect a defense-in-depth strategy that layers defenses, making it exponentially harder to penetrate the outer defenses.

Soft targets have many vulnerabilities. Critical infrastructure is now a soft target. Executive Order 13636, issued on February 12, 2013, by President Barack Obama, defines critical infrastructure as follows:

"Systems and assets, whether physical or virtual, so vital to the United States that the incapacity or destruction of such systems and assets would have a debilitating impact on cybersecurity, national economic security, national public health or safety, or any combination of those matters" (obamawhitehouse.archives.gov).

Water treatment facilities are being upgraded and new process monitoring systems are being installed to achieve a higher level of treatment and quality control. As more automation is added to the operation, vulnerability increases. This is a result of the "attack surface" becoming larger, increasing the threat. [Threat = Capability + Motivation]. However, by eliminating some of the human element, the attack or threat surface is also reduced. It should be recognized that the weakest element in any system is the human element. Social engineering, as will be explained, is one of the most powerful techniques in an attacker's arsenal. More than 80 percent of cyberattacks are estimated to begin with a social engineering attack.

Critical infrastructure is defined by Executive Order 13636 as:
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— OBAMAWHITEHOUSE.ARCHIVES.GOV

Air-gapping of a facility is no longer practical. Modern operating systems must be maintained, and regularly updated and patched to remain secure and operational; this operation requires access to a public network to allow communication with vendors and technicians. The convenience of remote monitoring and control of a facility also has far-reaching consequences. In a sense, all modern SCADA systems are a form of remote control. Routine operations or critical process control can be conducted from a central location. From that location, the process can be monitored at any remote location with network connectivity. Historical and process data can also be easily distributed to any authorized party, in real time, anywhere. Entire processes are, or can be, remotely operated; in fact, entire facilities are operated remotely, without on-site human involvement (pump stations, for example). The possibilities for automation are nearly endless. A high-speed networked communication infrastructure can and will provide for significant cost savings both within and beyond the fence line.

MODES OF ATTACK

The primary goal of any attacker is to gain access to a system. This is accomplished by defeating the systems in place to control access to a network infrastructure. For a treatment facility, this would

Iranian President Mahmoud Ahmadinejad (C) visits the Natanz uranium enrichment facilities in April 2008

be the log-in screen of the SCADA system, visible to the public-facing side of the network. Whenever you log in to a website by providing a user name and password, you enter the public-facing gateway of that website. Once inside, you are afforded all the rights and privileges assigned to your log-in credentials, including access to network resources such as process and file servers, printers, and other networked equipment, for instance, programmable logic controllers (PLCs).

The first step is finding and researching a target. Numerous techniques identify targets, such as scanning, which crawls on the internet "turning doorknobs." This is the reconnaissance phase, with the attacker identifying and researching the target, using several methods to learn as much as possible about the entity at that IP address. This often results in discovering vulnerabilities that can be exploited to gain access. An exploit is then designed for the vulnerability and executed, giving the attacker access or an escalation of rights. Once in, the attacker will move swiftly to consolidate control. A RAT (remote access Trojan) is installed to allow a "reverse shell" connection to the attacker's computer, typically allowing complete access and control without logging in each time, in effect bypassing the access control system. At this point, the attacker has complete control of the system. The attacker's computer is referred to as a command-and-control computer and maintains communication with the infected system and installed software, collecting data or initiating control actions without the owner's knowledge.

To recap, the attacker's modes of attack are:

1. Reconnaissance
2. Identification and assessment of vulnerabilities
3. Exploitation of the vulnerabilities and access to assets

Several methods are used to achieve these goals:

- **Social engineering.** The human element is the weakest part of the equation. In a famous experiment, British researchers gained access credentials from computer users in exchange for a piece of candy.* Phishing emails are a daily occurrence: "Click here to verify your credentials," is a common ploy. Social engineering—human hacking—is the manipulation of a person to gain the information required to acquire access credentials or to allow a RAT to be installed on a victim's computer. Social engineering is not new; playing on greed, curiosity, or incompetence is the starting point for many attacks. Eighty percent of all cybercrimes start with a social engineering campaign.
- **Bring your own device (BYOD)**. BYOD is when sensitive material, including access credentials, is loaded into a mobile device and carried into or out of an otherwise secure facility. A mobile device, including laptops and E-readers, can be infected with a worm or Trojan that will seek out vulnerable computers inside a private network as soon as the device connects to that network. The device can also be compromised while offsite, and its credentials or other valuable data can be stolen for later use in defeating access control systems.
- **Internal threats.** The disgruntled or compromised employee is a classic mode of attack. In the former case, an unhappy employee has the capability and motivation to create mayhem, and in the latter case is, for instance, being paid or blackmailed into providing credentials or information to a third party wishing access to a system.
- **External threats.** These threats are typically perpetrated by large organizations or hostile nation-state governments seeking state secrets, or wanting to commit industrial espionage or steal credit card data or other financial information, if not outright appropriate funds. This threat has also been used to influence national policy and elections. It has been shown that Russia used spambots to adversely affect public opinion through social media.

Examples of each of these threat exploits are provided below.

*news.bbc.co.uk/2/hi/technology/3639679.stm

Stuxnet, Game Changer

Stuxnet is a worm, a sophisticated piece of software engineering that selectively propagated inside the secure, air-gapped Natanz uranium enrichment facility in Iran. In a joint U.S.–Israeli operation, over a third of the facility's 3,000 enrichment centrifuges were destroyed by the worm. Stuxnet is a game-changer, because it was the first documented instance of a malware attack specifically directed at an industrial control system. The worm targeted the Siemens S7 PLCs that controlled and monitored centrifuge operation. What is more, the facility had no outside connections, so all previous understanding of cybersecurity had to be reconsidered.

As an initial step toward infecting the facility's computers, reconnaissance identified contractors known to provide goods and services to the facility. Once identified, laptops used by these contractors were infected with the Stuxnet worm. This was accomplished through USB flash drives, exploiting a vulnerability in Windows that allowed the unsecured execution of code on the drive without restrictions—a zero-day exploit. The flash drives were either left in common areas, or through agents, plugged into targeted laptops. The worm code executed and then hid itself within the kernel (the most basic, essential code) of the operating system, watching and waiting. When the laptop was connected to the Natanz process SCADA network, the worm infected every machine on the network, looking specifically for the S7 PLC. Once found, the worm replaced the PLC's operating system kernel with a modified version, giving the worm complete control. Throughout this process, the worm reported back to a command and control computer outside Iran when the laptop was subsequently connected to the internet outside the facility.

The centrifuge drive motors were controlled by frequency converters with a known operating range between 807 and 1,210 Hertz (Hz), nominal being 1,064 Hz. The Stuxnet worm recorded data for 13 days, then raised the frequency to 1,410 Hz for 15 minutes, and then reduced it to normal frequency for the following 26 days. The worm recorded normal operating during this time and then dropped the frequency to 2 Hz for about an hour before returning it to normal. This attack was repeated every 26 days; all the while the recorded normal operating data was fed back to the operators and the safety systems, indicating no problems with the systems. However, the attack unbalanced the centrifuges and caused the bearings to fail catastrophically.

Over one-third of the Natanz centrifuges were destroyed by software, greatly delaying the Iranian nuclear program. Stuxnet is the first instance of a specifically designed and targeted digital weapon; unfortunately, it is almost certainly not the last. It was later discovered that the attack had been in place as early as 2007, but independent researchers did not identify the problem until 2010 and pointed to the U.S.–Israeli intelligence services as the culprit. It has been described as "elegant" and "ingenious." The Iranian government, however, was not impressed and subsequently retaliated. Attacks were launched against financial institutions, military installations, and several infrastructure targets. One target was thought to be the Arthur Bowman Dam in Oregon.

This dam is 800 ft (244 m) long and 245 ft (75 m) high, impounding 10 billion cubic feet (283 million cubic meters) of water. The attack was designed and coordinated by the Iranian Revolutionary Guard Corps (IRGC). Attack scenarios included the manipulation of the dam's floodgates to cause overtopping and possible failure or to keep the gates open and adversely affect operation or damage the control systems. Owing to a lack of on-the-ground reconnaissance, the Iranians succeeded only in attacking another dam, the Bowman Avenue Dam in Rye Brook, New York.

This dam is 20 ft (6 m) high and 50 ft (15 m) long, impounding the waters of Blind Brook. The IRGC located and accessed an unsecured wireless modem

"The Russian and Chinese intelligence services that conduct these attacks have little to fear because we have no practical deterrents to those attacks."
–Admiral Michael Rogers, National Security Agency director

that would have been connected to the slide gate's control system—except that it was not connected. At the time, cybersecurity was not a consideration; most systems were wide open by default. In connection with this and the other attacks on American businesses, seven Iranian nationals were charged.

The IRGC performed their reconnaissance using commonly available search tools. Its primary tool was "Google dorking," or Google hacking. This technique takes advantage of Google's powerful search tools and the vast trove of public (and private) information accessible on the internet. The IRGC also used a search engine, Shodan, designed to locate internet-connected industrial control systems. Facebook and LinkedIn were used effectively to research who worked at the engineering firms involved and their roles. Worth noting, social media is an incredibly rich source for information about individuals and organizations; it is amazing what people put there for the world to see—and exploit. Finally, ordinary network auditing and trouble-shooting tools, such as Internet Control Message Protocol (ICMP) and Simple Network Management Protocol (SNMP), were used to complete the evaluation. A subsequent assessment of the information gathered led the hackers to exploit the unsecured modem and successfully access it. The attack followed the steps outlined above: reconnaissance, assessment, and exploitation.

ATTACKS ON CRITICAL INFRASTRUCTURE

Critical infrastructure can and will be attacked. When asked by Congress in 2014 about the threat to our critical infrastructure, Admiral Michael Rogers, National Security Agency (NSA) director and commander of the U.S. Cyber Command, replied:

"The Russian and Chinese intelligence services that conduct these attacks have little to fear because we have no practical deterrents to those attacks. This problem is not going away until that changes. It is only a matter of the 'when,' not the 'if,' that we are going to see something dramatic—I fully expect that during my time as the commander we are going to be tasked to help defend critical infrastructure."

Hostile nation-states have an interest in sowing discord, creating mayhem, and spreading misinformation to weaken an adversary. This was most apparent in the recent election, details of which are still unfolding. These entities are well-funded, and these efforts are having major adverse effects on global politics. By spreading "fake news" or by otherwise influencing normally rational people to doubt their own critical thought process, a hostile nation-state can capitalize on the confusion and compromise our vital interests. But nation-states are not the only players; several examples of individual cyberterrorism have occurred, causing mayhem.

One such attack occurred in 2000 at the Maroochy Shire Water District in Queensland, Australia, believed to be the first widely known instance of a person maliciously breaking into a control system. A disgruntled employee compromised the SCADA radio links controlling pump stations and caused 800,000 liters (210,000 gallons) of raw sewage to contaminate the pristine resort beaches in that area. Upset over not being promoted, the employee appropriated radio and control equipment and systematically manipulated the SCADA system. His intimate knowledge of the system allowed him to be particularly effective in fouling the rivers and canals, causing raw sewage to foul parks and high-end resort areas, while also disrupting commerce.

In 1982, the Trans-Siberian pipeline was allegedly attacked by the CIA using either a Trojan Horse or a Logic Bomb. According to author Thomas Reed in *At the Abyss: An Insider's history of the Cold War*, "The pipeline software that was to run the pumps, turbines and valves was programmed to go haywire, to reset pump speeds and valve settings to produce pressures far beyond those acceptable to the pipeline joints and welds. The result was the most monumental non-nuclear explosion and fire ever seen from space." A similar explosion on a Turkish pipeline in 2007 was attributed to the insertion of malware into the pipeline monitoring systems through vulnerable Internet Protocol camera systems. In the United States, the Olympic pipeline in Bellingham, Washington, ruptured, releasing about 240,000 gallons (900,000 liters) of gasoline into the Whatcom Creek, and subsequently exploded, killing three people. The cause was not determined to be cyberterrorism; rather, computer systems had not been maintained and updated, owing to poor training of personnel. As a result, the pressure monitoring and relief systems malfunctioned on the 16 in. (40 cm) pipeline and caused the rupture. This incident is well documented and provides a useful blueprint for would-be cyberterrorists.

Incidents in the transportation and power sectors also occur and are increasing. One incident, in 1997, set the stage for future attacks. On March 10, 1997, an unidentified juvenile computer hacker broke into a Bell Atlantic control system used for the air traffic communications at the Worcester, Massachusetts airport, causing a system crash that disabled the phone system at the airport for six hours. The system crash knocked out phone service at the control tower, airport security, airport fire department, weather service, and carriers that use the airport. Also, the tower's main radio transmitter and another transmitter that activates runway lights were shut down, as well as a printer that controllers use to monitor flight progress. The hacking also knocked out phone service to 600 homes in the nearby town of Rutland. In another incident, in July 2016, a group suspected of coming from China launched hacker attacks on the website of Vietnam Airlines with leaked client information, and on flight information screens at Vietnam's two biggest airports, posted derogatory messages against Vietnam and the Philippines. In November 2016, SF MUNI was hacked, and its computer systems were held for ransom.

Finally, power grids have been attacked and service interrupted to varying degrees. The Aurora Tests, conducted by DOE's Idaho National Labs in 2007, showed that a generator could be made to destroy itself using a mere 21 lines of computer code. The video can be seen at youtube.com/watch?v=fJyWngDco3g.

California Independent System Operators (CAL-ISO) systems were attacked in May 2001, highlighting the vulnerability of the electrical grid. During a two-day period, California was subjected to rolling blackouts affecting 400,000 customers. This attack came at the same time as hundreds of other reported attacks, allegedly of Chinese origin, defaced numerous websites and blogs with anti-American slogans. In 2015, part of the power grid in the Ukraine was taken down through hijacked virtual private networks (VPNs), allowing attackers complete access to control systems. The attackers shut down 30 substations and cut electricity to 230,000 consumers, also disabling the backup power systems at two of three distribution nodes. Ukrainian officials blamed Russian-sponsored hackers for the attack.

Despite these attacks, which are representative and not isolated, many industry professionals are reluctant to grasp or acknowledge the threat. Many operators consider the emphasis on cybersecurity a solution in search of a problem; this thinking will lead to system compromise, made worse by a continuing lack of adequate security measures. The worst argument is that these safeguards "cost money," and the cost outweighs the threat. Imagine explaining to your governing board or to the public why sewage is flooding their basements or flowing untreated into the receiving waters because an attacker virtually "walked in" and took over your system, and consider the consequences of untreated or improperly treated drinking water.

Most of these described attacks occurred, admittedly, when few countermeasures were in place, but were an ominous portent of things to come. To be fair, the threat was not even considered at the time. However, sophisticated intrusion detection and prevention systems have been developed, and it is likely that most attacks can be prevented or quickly mitigated—unless they are compromised by the human element of the system.

Critical infrastructure is most certainly now a viable, even desirable target. If an attacker can find you, you can be attacked. And anything can be hacked; the internet of things (IoT) is a new frontier that has already been actively exploited. Even a poorly secured internet light bulb can be a path into an otherwise secure network. The phenomenon of the "botnet" is beginning to be weaponized— armies of automated programs operating out of compromised "zombie" computers, each controlled by a "bot wrangler" from his "command and control" computer. The bot software is typically spread through malicious email attachments or infected software.

Social media is regularly infected with bots spreading propaganda and "fake news." The internet in the northeastern United States was taken down by the Mirai botnet that searched and found vulnerabilities in unsecured IoT devices, particularly security cameras (change the default passwords!). One point bears repeating: social engineering is a powerful and destructive tool. More than 80 percent of all attacks start with a social engineering campaign. Regardless of how much training, expense, and enforcement are applied, security comes down to the individual.

SWPCA TAKES SECURITY SERIOUSLY

In 2016, the Stamford Water Pollution Control Authority (SWPCA), as part of an overall plant upgrade, updated and improved its SCADA system. The older system had no need or requirement to connect to the outside world except in rare occasions requiring additions or modifications. The new system, by dint of its sophisticated control architecture and security apparatus, required that parts of the system be connected to the public network to allow upgrades, monitoring, alarm processing, and remote access by select personnel. A dedicated internet connection was installed and connected to the perimeter firewall. A firewall controls access from one secure network segment to another, or between an unsecured network, such as the internet and a secured network. The firewall is "locked down" based on rules that allow only specific traffic and users to access and use the internal networks.

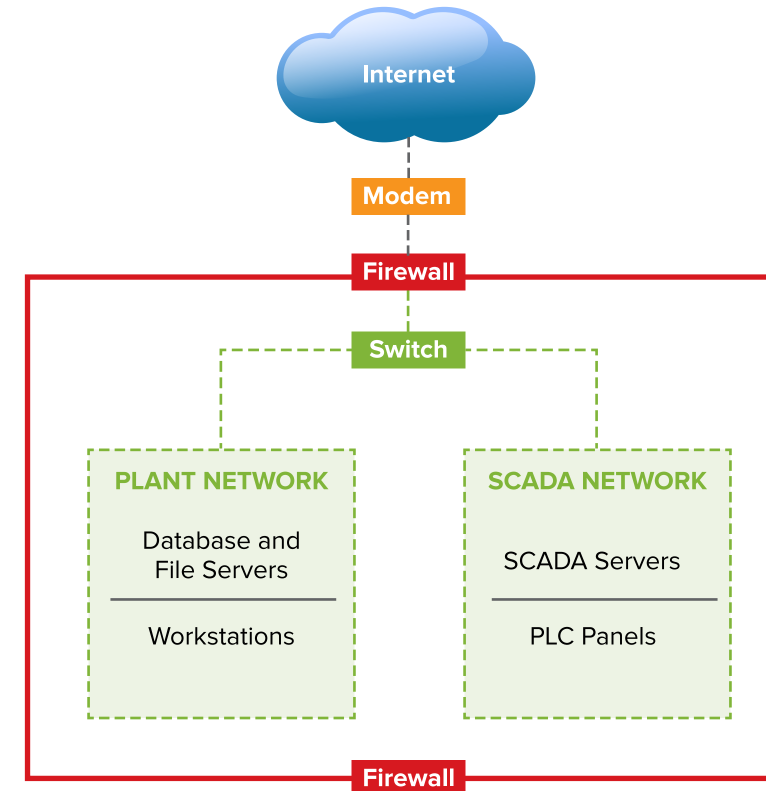

Figure 1 . Network protected by firewall

Firewalls can be extremely granular in their ability to filter traffic. Of note, while control of network ingress—traffic entering the network—is of primary importance, traffic egress is of almost equal importance. Many successful attacks piggyback on legitimate traffic and can defeat the firewall's configuration and function. As was shown, VPNs can also be compromised, allowing malicious traffic to sidestep the firewall. However, to enable complete command and control of the malicious software, two-way traffic must be established. This is sometimes referred to as a "reverse shell" and constitutes an unfettered communication channel between the attacker and the secure network assets. Properly configuring the firewall to restrict outgoing traffic to legitimate purposes and addresses helps to defeat attacks designed to get around perimeter security.

Again, no matter how much money is spent, how secure and robust the system, how segmented and layered the defenses, it all comes down to the human element.

The two networks shown in Figure 1 are segmented at the switch to allow for greater control of access to the SCADA network. Segmentation is a common technique to prevent unauthorized users from accessing areas beyond their privilege. This allows greater realization of assigning "least privilege" or the least amount of rights and access required to perform one's duties. It is also called role-based access control and is usually combined with a

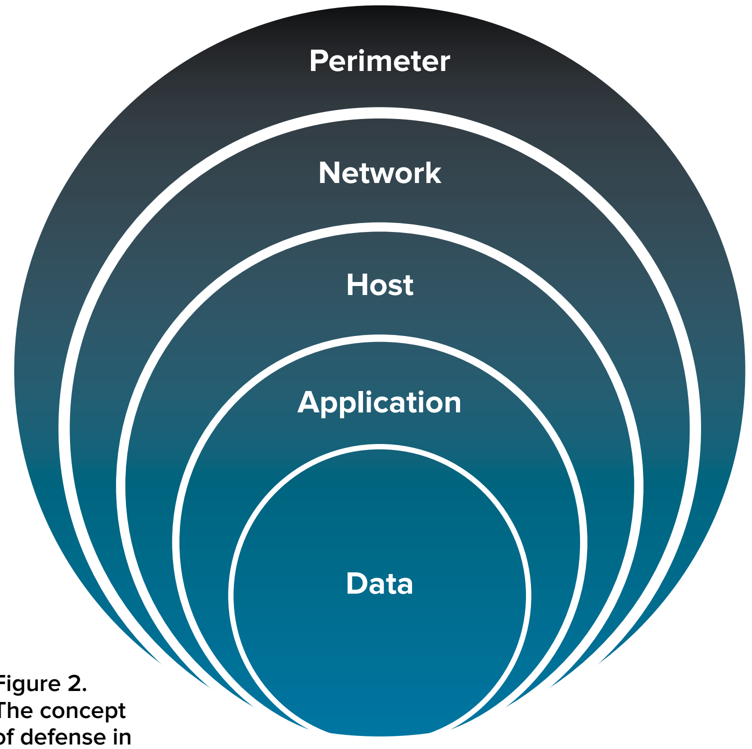

Figure 2. The concept of defense in depth

hierarchical system of privileges, i.e., Administrator, Operator, Technician, or View only. Segmentation creates separate virtual networks within the same physical network; this eliminates the need for additional physical wiring. The firewall regulates traffic to the networks based on a rule base and uses access control lists (ACLs) to control who gets access to where on a per-user basis. A VPN (not shown) is used for remote access, and logging of all transactions is done continuously to facilitate intrusion and threat detection, bandwidth, and process utilization and optimization, as well as for security advisories.

Another technique, virtualization, is used to manage and secure the networks. While a switch creates virtual LANs (VLANs) that can be individually configured and controlled, creating separate "collision domains" that are more efficient at moving data, virtualization is used within a server to segment traffic without the benefit of hard circuitry or wiring. All data paths are virtual, that is, logical, and being such the actual path exists only during the transaction between nodes. This is a very secure model in that data paths are very difficult to determine and compromise. This technique also improves performance using load sharing and balancing, creating and tearing down virtual paths as needed. This makes the best use of available bandwidth and greatly decreases latency. Finally, there is a single point of entry for management instead of multiple interfaces, making the entire virtual network much easier to secure.

The VPN, mentioned earlier, is a logical connection created when needed, rather than a dedicated link. VPNs are very secure connections. Think of a VPN as a tunnel between two users or machines. The inner tunnel contains the encrypted data, including the sender and receiver addresses; the outer identity is the public face of the private connection, a wrapper that can be just about anything and encapsulates the protected data. VPNs are temporary connections, though specialized software and equipment must be used at each end of the connection to set it up. Modern firewalls typically include a VPN server to effect secure remote access to the network. In the SWPCA network, the VPN connection will be used by remote administrators and equipment vendors to access the network and servers for maintenance, monitoring, and upgrades. Eventually, it is anticipated that operators will be able to remotely access and operate plant systems from virtually anywhere in the world.

HARDENING YOUR FACILITY

Knowing the basics of cybersecurity and the risks facing critical infrastructure, the discussion can now turn to hardening your facility against some of the threats described. The water treatment industry does not produce anything with intrinsic value; we do not operate banks or develop advanced technology. That someone would purposely break into the SCADA system of a treatment plant sounds outlandish, and it does not seem worth the risk. But cybercrime is a growth industry; the risks are low, and the payoffs can be huge. As we have seen, critical systems can be held for ransom, and systems can be manipulated to cause great harm to people, the environment, or equipment. Those of us who operate and maintain these facilities have a fiduciary duty to the public we serve to protect these assets from harm.

Protecting your facility mostly comes down to common sense and some technical acumen. The first principle is defense in depth. This ancient military principle is well applied to network security: It layers defenses from the outside that either prevent or slow intrusion by an attacker. Following is an example of a highly secured facility, describing the defenses from the outside layer into the protected area. The most obvious outer defense is a secure, guarded, gated perimeter with a high fence or wall, with or without razor wire. Sometimes a facility will have two or more layers of fence, with intrusion sensors monitoring the interstitices for vibration or movement. Within those perimeters is the building containing the assets to be protected, sturdily built and entered through a strong, locked door with robust access control. These control mechanisms include keypads, palm readers, or even retinal scans (as well as deadbolts and controlled key distribution). Within the building, a strong locked cabinet or secured inner room containing the network equipment or other assets would be a minimum, with access controlled as described above. The network equipment is secured by passwords, tokens, or USB keys and can be enhanced by disabling USB and or keyboard/mouse ports. Any number of access control methods can be used at the protected machine or asset, including individual hard drive or file encryption and passwords. Breaching each of these defenses in turn requires motivation and a strong desire—and time. The time and effort required to breach each layer also implies some sort of a return, and making your defenses harder to breach will diminish returns. They will also slow an attacker's progress, allowing automatic defensive countermeasures to take effect and possibly mitigate the attack. These delays can also give the administrator or the intrusion prevention system time to identify the attacker and activate additional countermeasures. The end game is to make any attempt at breaching defenses difficult and costly enough to make the attacker move on to a softer target or other low-hanging fruit. Figure 2 gives a rough approximation of the concept of defense in depth.

Wireless networks present some challenges, but wireless security is robust and superior to the security of a wired network in many cases. Proper design of a wireless network and adherence to strict password and access policies will ensure a virtually impenetrable wireless network. Access to a network is all too often as simple as walking into a wiring closet and plugging into a switch port. Many wiring closets or network cabinets, if they have a door at all, are not locked (if they even have a lock). This vulnerability can easily be exploited and put a SCADA system, and possibly the plant, out of operation. Although it may seem that the expense of achieving robust security is not worth the risk, this omission would be hard to explain after the breach and the damage that could result.

Finally, remember to change the default passwords of any new device being installed. Most devices have simple initial logins, such as "admin" for the user name and password. These devices are increasingly being targeted by attackers as an easy back door into an otherwise secure network. Remember, many attackers have nothing but time and are well financed. This simple step will reduce your attack surface by several orders of magnitude.

Security controls are how robust, layered security is achieved. There are three main categories:

- Physical: fences, guards, locked doors, cabinets, secured IT infrastructure, and closed-circuit television (CCTV)
- Logical: firewalls, segmentation, virtualization, obfuscation, misdirection, proxy devices, DMZs, and reduction of internet facing services
- Administrative: security policies, training, enforcement, "least privilege," separation, and classification of responsibilities

Each of these security controls fits neatly into a defense in depth strategy. If you make it harder to breach your defenses, the attacker will move on to a softer target.

ABOUT PASSWORDS

Passwords such as "1234" or "p@ssword" are not secure. Yet these passwords are used regularly by those who should know better. Default, out-of-the-box passwords must be changed as soon as a device is powered up: Make this the first thing that you do when configuring a new device. The phrase to remember when deciding on a password is "longer is stronger." A password of eight characters or more will make it much harder to crack, and 12 characters are even better. Use a mix of upper- and lower-case letters, numbers, and symbols (special characters such as @#$%&), and the resulting password approaches are computationally infeasible. For example, a four-character password (e.g., 1234) can be cracked in .29 microseconds. By comparison, a 12-character password, with numbers and mixed letters, would take about 108,000 years to crack. Do not be fooled by this, however; special word lists containing millions of words and word combinations are available and regularly used to crack passwords, using what is called a "brute force dictionary attack," which is just that.

Unfortunately, many people use common words or numbers as passwords that are easy to remember but that are in almost every word list and easily guessed. Use of an easily remembered phrase that only you would know is a better approach. Adding a few numbers or symbols can only improve the likelihood of foiling an attacker. Remember that reconnaissance will be performed before an attack campaign, and the attacker will learn your personal details through social media—your mother's maiden name, your street address, your dog's name, your favorite book—so be very careful what you post.

For organizations and operating authorities, establishing a strong password policy and enforcing it is a sure way to get ahead of the threat. Specifying the length and content of a password is one step. Changing the password regularly is another good safeguard. For those with the budget, a very strong and practically uncrackable method of authentication is called "multi-factor" authentication, which requires a combination of something you know (password), something you have (smartcard or RSA tag—a radio-frequency identification tag to protect privacy), or something you are (biometrics). Very strong access control is achieved by using these methods in combination. Of course, this is all for naught if an individual gives away his or her credentials, or writes his or her password on the wall or on a slip of paper taped to the monitor. It must become instilled in staff that security is everyone's responsibility. Penalties for non-compliance must be enforced.

In closing, let us return to the threat of social engineering. Social engineering is the starting point for almost all cyberattacks. In the Stuxnet example, flash drives were reported to have been left lying around at cafes or parking lots that the targeted engineers and technicians were known to frequent. It is human nature to simply plug in, and people are very predictable in their behavior. Greed is a powerful motivator and very predictable; once hooked, the victim almost follows a script to reap vast rewards but often winds up with an empty bank account. Playing the heartstrings is also a proven method for compromising someone's good nature; most people want to help someone out of a jam, and this behavior is also predictable. Social engineers are adept at sizing up their prey. Individuals who are in debt or have substance abuse issues are the ultimate prize. An NSA technician with financial problems sold Russian agents the technical manual for the United States' KH-11 reconnaissance satellites for a mere $3,000, compromising a multi-billion-dollar (taxpayer) espionage program. For this, he received 40 years in prison.

The best defense is to grant least privilege required to do the task, and develop, implement, and enforce password and acceptable use policies. Perform regular audits and log all transactions for future investigation. Reduce your attack surface by reducing your online presence. Remember, egress control is just as important as access control, so be aware of traffic going out, and from whom and to whom. Automate wherever possible to reduce or curtail human interaction, particularly in critical processes.

Regardless of the level of diligence, however, there are simply too many human factors to consider and guard against, and breaches will occur. In those cases, consider a rapid incident response program to minimize damage. Isolate and control terminated employees, and have a plan. Maintain logs of all traffic and invest in intelligent intrusion detection systems.

Machines and their behavior, for the most part, can be controlled under normal circumstances and with reasonable care. The same cannot be said for people.

ABOUT THE AUTHOR

Daniel Capano is a senior instrumentation project manager with Gannett Fleming Engineers and Architects, Inc. A certified wireless security professional (CWSP), he has been in the water and wastewater field for most of his career. Mr. Capano participates in NEWEA's Asset Management Committee and IT&A subcommittee. He is vice-chair of the Stamford Water Pollution Control Authority in Stamford, Connecticut.

The author thanks Justin Finnigan of Arcadis for co-presenting at NEWEA 2017 and for providing several illustrations.

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NEBRA Highlights

The Magic Hat "Artifactory" and its co-digestion, solids separation, and energy system was the second tour at the Northeast Residuals & Biosolids Conference

NEBRA Continues Work on PFAS Related to Biosolids and Residuals Management

NEBRA has become a leading organization nationally on understanding and addressing questions about perfluorinated and polyfluorinated alkyl substances (PFAS) in biosolids and residuals applied to soils. This was not a goal for NEBRA this year; NEBRA developed an understanding of the issue when biosolids, as a "source" of PFAS, came under scrutiny by drinking water and groundwater bureaus in regulatory agencies in a few of our region's states. NEBRA believes that biosolids are not a source, but rather that societal use of the ubiquitous chemicals is the source.

Wastewater and biosolids partially mirror the chemistry of our lives; they *convey* PFAS. Recent data indicates that all biosolids and residuals contain PFAS, including perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS)—the two most prominent PFAS—in single to a few tens of parts per billion. PFAS issues are complicated, and data and understanding are limited. States are feeling pressure, however, to adopt standards, at least for drinking water, because of health concerns (see atsdr.cdc.gov for health information). Regulatory and public health focus is appropriate where there are highly elevated levels in drinking water near industrial, military, aviation, and other sites [e.g., see the New Hampshire Department of Environmental Services (NHDES) website]. But NEBRA believes knowledge is too limited at present for accurate risk assessment or modeling of PFAS fate and transport in soils. And it is important to recognize that PFOA and PFOS have been phased out of most uses in the U. S., with a resulting significant reduction in human blood serum levels already. (However, other PFAS are increasing in use, as replacements, and less is known about these chemicals, except that they are less bioaccumulative and/or less persistent.)

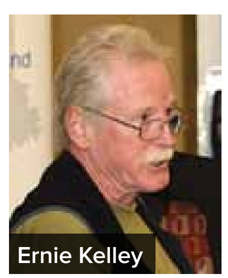
NEBRA continues to encourage members and all in the wastewater and solids management profession to be aware of this issue. Members can access information on NEBRA's "members only" webpages. Michael Rainey, on behalf of NEBRA, provided an update on the topic at the annual Residuals Conference in October (presentations available from the NEBRA and NEWEA websites), and NEBRA is collaborating on a PFAS session at the NEWEA Annual Conference in Boston, in January 2018.

NEBRA Hails Retiring Biosolids Coordinators

2017 saw the retirement of three expert biosolids coordinators from our region and one from EPA.

Mike Rainey

Last winter, **Mike Rainey** left NHDES after about 30 years, most spent in an active role in the residuals management section. Mr. Rainey was there in the late 1990s, during public controversy over biosolids programs, and he helped usher in several iterations of state regulations, including the latest, 2016 version. His biosolids knowledge and laboratory experience made him an excellent candidate when NEBRA needed help understanding PFAS concerns, and he has been contracted by NEBRA for the past six months.



Ernie Kelley

This summer, **Ernie Kelley** formally retired from the Vermont Department of Environmental Conservation (DEC), where he had served two decades as biosolids coordinator and, in the past year, on emerging contaminants. Mr. Kelley was a national leader among state biosolids coordinators, especially in the 1990s and 2000s, when there were annual coordinator meetings and a more active nationwide listserv. He is continuing part-time work with DEC to help complete

> **CAPTIONS** (photos right) **1.** Ned Beecher and Heidi Lemay **2.** A packed session **3.** NEBRA President Mike Lannon and speaker Frank Sapienza **4.** Patrick Ellis and Mary Waring **5.** Exhibitors Tim Bezler, Mike Sullivan, Yasmine Boudhaouia, and Matt Williams **6.** A tour of Essex Junction WRRF, led by Jim Jutras **7.** Michael Potash and Andrew Carpenter **8.** NEWEA Committee Chair Natalie Sierra **9.** Claude Alla Joseph from Quebec's Université Laval **10.** Sessions generated lively questioning and discussion **11.** A tour of the So. Burlington WRRF, led by Bob Fischer

Managing Residuals in a Complex World—The Northeast Residuals & Biosolids Conference

October 25–27, 2017 • Burlington, Vermont

NEWEA's Residuals Committee and NEBRA once again presented the annual Northeast Residuals & Biosolids Conference. More than 100 attendees enjoyed technical sessions, local activities (the chocolate factory tour got the most raves), facility tours, and networking. Participants included a dozen Canadians, and a special session Friday morning summarized biosolids management and policy in nearby Quebec. The Green Mountain Water Environment Association co-sponsored the conference, held tours, and helped put together a Vermont session. Hot topics included a less-expensive mercury-removal system for incinerators and PFAS in biosolids and residuals. Research topics included Cairn Ely expounding on amazing plant root-soil microflora interactions and Chris Peot (DC Water) on developing a fine, Class A product ("Bloom"). Conference presentations are available from the NEWEA and NEBRA websites. (See page 75 for conference proceedings)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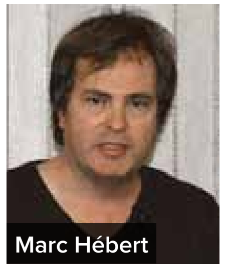
the stakeholder review of biosolids management and regulation in Vermont, and to assist current biosolids coordinator Eamon Twohig with biosolids regulation revisions expected in 2018.

And, in November, **Marc Hébert** retired from the Quebec environment ministry, after more than two decades as the leading expert and advocate for biosolids recycling in *la belle province.* As noted at the recent residuals conference, regarding Mr. Hébert's long service, he has been prolific in instigating and completing research into some of the most critical questions in biosolids management. For example, do polybrominated diphenyl ethers (PDBEs) and metals get into milk via the biosolids–forage–cow pathway? This research has resulted in numerous government guidance documents and published papers in peer-reviewed journals (e.g., "Long-term response of forest plantation productivity and soils to a single application of municipal biosolids"). He spearheaded the development of Quebec's unique and highly effective odor classification system for biosolids and other land-applied residuals, and, as a member of the biosolids task group for the Canadian Council of Ministers of the Environment, he helped advance biosolids policy and standards for the nation. Mr. Hébert plans to continue as a consultant in the field.


Marc Hébert

At the federal level, **Rick Stevens**, a key figure in EPA's biosolids efforts, retired from the EPA Office of Water/Science and Technology in August. Mr. Stevens led the biennial reviews of potential contaminants of concern required by 40 CFR Part 503 and developed the biosolids core risk assessment model (BCRAM) and other risk assessment tools. Thank you, each of you, for your excellent work. You will be missed.

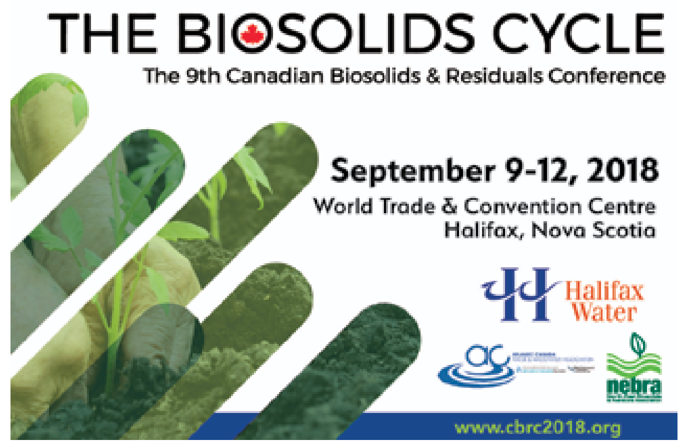

Rick Stevens

NEBRA's 20th Annual Meeting

October 27, 2017—Burlington, VT

Thirty NEBRA members and guests attended this year's meeting, at which two important new developments were presented by the board and staff: a new, simplified fee structure—watch for details coming to you soon and plan accordingly—and a final draft Vision 2021 strategic plan for NEBRA. This strategic plan, on NEBRA's "members only" webpage (contact the office for the passcode), includes aggressive goals to increase membership and the budget to ensure another 20 years strong for NEBRA, including transition to a new executive director several years from now. Members are encouraged to provide feedback to the NEBRA office or board members.

Four members of the board of directors were re-elected to new, three-year terms, so that the board remains the same for the next year. Chris Hubbard was thanked especially for his work on sponsorships and the silent auction,



Save these dates for next year's NEBRA conference, in collaboration with the 9th Canadian Biosolids and Residuals Conference, "The Biosolids Cycle" (cbrc2018.org/)

and Charlie Alix and Mike Lannan were recognized for creating the Fields of Dreams annual summer fundraiser. Next year's event will be a Fisher Cats' baseball game in Manchester, New Hampshire. Committees reported on their activities, and a new slate of officers was approved: Mr. Lannan, president; Tom Schwartz, vice president; Andrew Carpenter, treasurer; and Isaiah Lary, secretary.


Chris Hubbard


Lise LeBlanc

Board member Lise LeBlanc, who made the long trek from Nova Scotia, announced next year's NEBRA conference—to be in Halifax, September 9–12. Our 2018 Annual Meeting will also be there. (In 2019, NEBRA will team up with NEWEA, once again, for our annual conference.)

Biosolids Recycling Affirmed

An increasing number of court actions and formal state reviews are confirming the safety and effectiveness of biosolids recycling to soils. Last year, a decade-long legal battle in Kern County, California, ended with an endorsement of biosolids when a superior court struck down a county ban, stating "the overwhelming weight of the evidence is that there is no basis in fact for any determination that land application of biosolids poses any risk to Kern County residents, let alone a real and substantial risk that would be alleviated by banning such land application." This case included testimony and hearings on the technical basis for land application of biosolids. During the years of litigation, biosolids land application in Kern County was never interrupted, and Los Angeles and other Southern California water resource recovery facilities continue to rely on Kern County and other land application sites for biosolids management.

Likewise, in 2015, the Pennsylvania Supreme Court declared that biosolids land application on farms is "a normal agricultural activity." In June 2017, the Pennsylvania state legislature mandated a statewide review of biosolids management. The review confirmed many of the benefits of land application (e.g., less costly than landfill disposal or incineration, beneficial to farmers) and made only one major recommendation: that "DEP should modify its General Operating Permit requirements to require biosolids generators to develop odor management plans covering both the operating facility and the receiving sites." (Odors have been, and are, the Achilles' heel of biosolids recycling programs; their proper management is critical for success.) The report is available at lbfc.legis.state.pa.us/Reports.cfm?ReportID=301.

In 2016, a Virginia court threw out a challenge to that state's biosolids regulations. In October of this year, a review of Virginia's biosolids regulations and practices, mandated by the Virginia legislature, found: "Land application of biosolids and industrial residuals poses some risk to human health and water quality, but the risk is low under current state regulations." The authors reviewed more than 150 recent scientific papers and interviewed numerous scientists with varying perspectives on biosolids. The report found Virginia's regulatory oversight, with numerous inspections, to be robust, and it detailed the benefits that biosolids recycling provides. It noted, however, that there has been little epidemiological research and recommends that such a study be funded. Additional evaluation of the risk of aerosol transmission of pathogens from Class B biosolids was also recommended. The report is available at jlarc.virginia.gov/landing-biosolids-2017.asp.

New Rhode Island Digester Operating

NEBRA helped facilitate a tour on October 6 of the new Blue Sphere anaerobic digester complex near the Central Landfill in Johnston, Rhode Island. This facility takes in source-separated food scraps and other organic residuals (but not biosolids) and processes it in a biopulper before digestion. The biogas produced runs a 3.2 MW combined heat and power system that provides electricity to the grid through an interconnection agreement with National Grid. Blue Sphere is developing a similar facility in Charlotte, North Carolina, and has several digesters operating in Italy that process energy crops and vegetable oils. Thank you to Barry Wenskowicz (Narragansett Bay Commission) for organizing this tour.

Meanwhile, NEBRA is planning to tour another new anaerobic digester complex—Connecticut's first such facility—in Southington. Owned and operated by Quantum Biopower, it will divert an expected 40,000 tons (36,300 tonnes) of food waste per year from local food waste generators including Shop Rite, the Aqua Turf Club, and the Farmington Club. The facility will produce 1.2 megawatts of electricity and 10,000 tons (9070 tonnes) per year of organic compost. Watch for the tour announcement in NEBRA's email newsletter or the NEBRA website.

NEBRA's Resources—*Just a click away*

That's NEBRA's message to members when they have questions about biosolids and residuals management. NEBRA has extensive files and contacts around the continent that can help address questions quickly. Much of the most useful information is on our website (nebiosolids.org) under the four menu tabs *biosolids, residuals, resources*, and *news*.

The Blue Sphere anaerobic digester complex near the Central Landfill in Johnston, Rhode Island, takes in source-separated food scraps and other organic residuals (but not biosolids) and processes it in a biopulper before digestion

Ned Beecher, Executive Director
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For additional news or to subscribe to NEBRAMail, NEBRA's email newsletter, visit nebiosolids.org

nebra
North East Biosolids & Residuals Association

Spotlight: **Lynn Water & Sewer Commission Regional Water Pollution Control Plant**

The regional Lynn Water & Sewer Commission (LW&SC) Water Pollution Control Plant (WPCP) services around 133,000 people and 50,000 households in Lynn, Nahant, Swampscott, and Saugus, Massachusetts. The collection and outfall facilities were built in 1884 and expanded in 1928. The treatment process has evolved over the years along with its management. In 1982, the LW&SC was created to manage the regional facility. The current treatment process was constructed through a design-build-operate contract in 1985, with further secondary treatment facilities built in 1990.

2 Circle Ave., Lynn, Massachusetts
LW&SC Director of Wastewater Operations: **Robert Tina**
Contract Operator: **Veolia North America**
Veolia Project Manager: **Alfred F. Waitt, III**

Today it has an average design capacity of 25.8 mgd (98 ML/d) and can provide more limited treatment upwards of 111 mgd (420 ML/d) during extreme wet weather events using a manually activated secondary process bypass. The plant's primary discharge is to Lynn Harbor via a 60 in. (152 cm) cast iron buried outfall pipe, extending 2.9 miles (4.7 km) into the harbor. Up to 73.3 mgd (277 ML/d) can pass through the harbor outfall A second, manually activated wet weather outfall discharges just beyond the seawall for flows above that level. The facility has evolved to meet the demand of its service area and its abutting waterfront business community. Over the past 30 years, the facility has been recognized with several awards for outstanding performance.

The WPCP includes the following unit treatment processes: influent screening and grit removal, primary clarification, activated sludge treatment using pure oxygen, secondary clarification, disinfection and dechlorination. The plant also accepts septage and leachate, conducts on-site sludge/residual processing and fluidized bed incineration with on-site landfilling of ash/solids. The facility also has odor control facilities. It has expanding tank covers for containment and uses carbon for odor reduction. Numerous SCADA system upgrades have also been conducted allowing all 13 remote pump stations to be interlinked for monitoring using a city-wide wireless SCADA system.

Saugus, Swampscott, and Nahant deliver flow to the facility via three separate force mains, two 30 in. (76 cm) and one 18 in. (46 cm), respectively. The Lynn flow enters the plant through a 72 in. (182 cm) gravity sewer and then passes through preliminary treatment consisting of bar screens, after which it combines with flow from the other communities and then passes through four aerated grit chambers. Grit is collected and disposed at an on-site landfill. Activated carbon odor control units scrub (remove) odors out of the building air before it is discharged to the atmosphere. Large rectangular primary clarifiers then remove settleable solids and floatables/scum. Primary sludge is pumped to sludge treatment processes. Non-settleable pollutants pass to secondary treatment where microorganisms help to remove them. The secondary aeration tanks are also rectangular and use oxygen (85 to 98 percent pure oxygen) for aerobic treatment of the wastewater. Three covered oxygenation tanks, a mechanical mixing system, and a pressure-controlled oxygen feed and oxygen purity-controlled venting system make up the oxygenation system. Pure oxygen helps to accelerate the activated treatment process and improve transfer efficiency. Pure oxygen's generation system incorporates a pressure swing adsorption (PSA) oxygen generating system. The PSA system can provide 27 tons per day (24.5 metric tons/day) of pure oxygen to the oxygenation system. As a backup to the oxygen generating system, two liquid oxygen storage tanks can hold 18,000 gal (68,000 L) of liquid oxygen. After the activated sludge aeration process, the flow passes to four circular secondary clarifiers. Sludge collected from the primary and secondary clarifiers is pumped to gravity thickeners for thickening prior to being pumped to sludge holding tanks for solids processing.

The clear water from the secondary clarifiers goes to the chlorine contact chamber. Chlorine is injected into the water at the beginning of this long tank in order to disinfect the treated water. At the end of the contact tank, excess chlorine is removed with the addition of sodium metabisulfite before the dechlorinated water is discharged to the inner or outer harbor.

The solids or sludge produced by the removal of pollutants through primary and secondary treatment go through dewatering via centrifuges and are either incinerated on site or removed to a remote location for either composting, land application, incineration, or landfill placement. The thickening and dewatering process includes two gravity thickeners (one primary and one secondary), polymer addition (secondary sludge only), and two high-speed centrifuges that thicken the sludge up to 30 percent solids. The thickened sludge is either incinerated or landfilled.

The Lynn incineration system comprises a Von Roll fluidized bed incinerator, which burns the sludge at approximately 1,400°F (760°C). The resulting ash is hauled to the on-site landfill for disposal. Almost all (99.9 percent) of the remaining ash is then removed in the venturi gas scrubber. The gas stream flows through a wet electrostatic precipitator (ESP), which also helps to remove sulfur dioxide. The ESP uses high-voltage electrical coils that charge any particles of ash still in the gas stream and then removes those particles with an oppositely charged plate much like a magnet. The gas exiting the stack into the air has some water vapor with almost no particulate.

The incinerators are permitted by the Massachusetts Department of Environmental Protection (MassDEP). A continuous emissions monitoring system is on the incinerator measuring oxygen, sulfur dioxide, oxides of nitrogen, and carbon monoxide. The information from these delicate and sensitive instruments is collected by a data logger and sent to a computer in the Administration building. These results are compiled for quarterly, semi-annual, and annual reports for both MassDEP and EPA. This information is used to operate the incinerators within the guidelines of the Federal Maximum Achievable Control Technology (MACT) regulations and MassDEP permit as well as to optimize efficiency and performance without excess emissions.

WEF Delegate Report

L–R: Howard Carter, Mary Barry, Matt Formica, Jennifer Lachmayr, Susan Sullivan, Fred McNeill

NEWEA's Water Environment Federation (WEF) delegation continued to work at a national level promoting New England's needs and issues while helping to develop and implement national goals and objectives. To guide the federation, WEF has developed a formal strategic plan that is closely aligned to NEWEA's, with five critical objectives that are presented below:

1. Develop an engaged membership representative of the multiple practice areas of the water environment industry
2. Provide a broad range of professional content and programming relevant and widely valued by the water sector worldwide
3. Generate an increased public awareness of the value of water leading to increased funding to protect water quality through appropriate levels of infrastructure, management approaches, and services
4. Establish the conditions that promote accelerated development and implementation of innovative technologies and approaches in the water sector
5. Operate a sustainable business that supports our mission and enables WEF to seize new opportunities in the emerging water sector

Our delegates will work with NEWEA to help implement WEF's long-term strategic plan.

At this year's WEFTEC, NEWEA's Howard Carter completed his service as the 2016–2017 Speaker of the House of Delegates (HOD), a position of national leadership in our industry. Mr. Carter, the director of the Water Resource Recovery Department for Saco, Maine, is a long-time NEWEA leader who served as NEWEA president in 2010. He spent four years in the HOD as a representative of NEWEA, with one year as speaker-elect. During his time in the HOD, he has chaired the House Nominating Committee, served on the House Steering, WEF Member Association Exchange (WEFMAX), Outreach, and Budget committees, and has been a member of numerous work groups. Mr. Carter represented NEWEA on the national level with great leadership, respect, and good old Maine common sense. Many thanks are due for his significant contributions to NEWEA and WEF over the past 20 years. A thank you is also in order to outgoing WEF Delegate-at-Large Jenn Lachmayr, who contributed to several subcommittees during her tenure, and to former (2012) NEWEA President Dan Bisson, who has served energetically for the past three years as a delegate.

NEWEA's current WEF delegates were each assigned to a workgroup for 2017–2018. Noted below are the workgroups and their respective NEWEA representatives.

Susan Sullivan, executive director of the New England Interstate Water Pollution Control Commission, was assigned to the Membership Relations workgroup. This workgroup will assist in the effective implementation and communication of the WEF Membership Dues Strategy by:

- Educating the delegates on the strategy
- Providing organized feedback to the WEF board of trustees (BOT) and WEF Staff
- Developing educational materials (e.g. toolkit, fact sheet, etc.) on strategy and process that can be used by member associations (MAs)

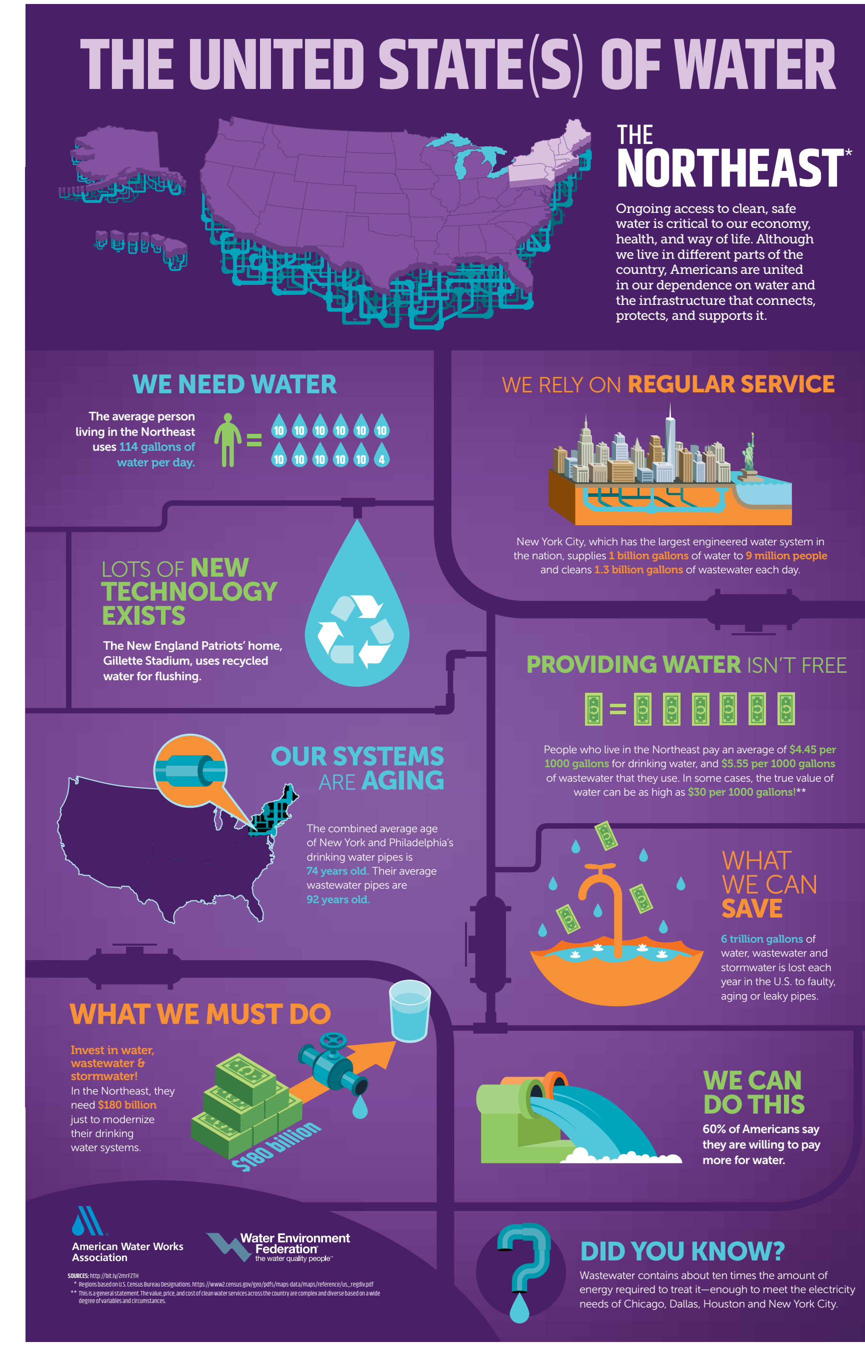
The workgroup will also continue the work of the 2015–2017 HOD Membership workgroups in soliciting feedback from the MAs and WEF staff on how to effectively develop promotional material to accompany the list of new members generated from the WEFTEC Membership Initiative. It will also explore the possibility of extending conference reciprocity to the MAs that participate in the program. Additionally, this workgroup will assist the BOT and staff in the development of Member Engagement metrics as requested. Ms. Sullivan also serves on the HOD Steering Committee and chairs the legislative subcommittee for WEF's Government Affairs Committee.

Matt Formica, past NEWEA president and a senior project manager with AECOM, was assigned to the Student Chapters workgroup, a partnering effort of the HOD and WEF's Students & Young Professionals Committee (SYPC) to further WEF's strategic goal of increasing the number of student members. Together, the HOD workgroup and the SYPC will:

- Identify gaps in current WEF and MA communications with student chapters, as well as any MA challenges and successes with student chapter communications and engagement—knowledge that can be obtained through polling, calling, or emailing MA leadership.
- Using the HOD's expansive network and SYPC data, update MA student chapter contacts and university contacts (the true champions of the work) as well as identify the level of engagement MA SYPC's have with student chapters
- Provide up to three tangible improvement concepts to streamline communications of WEF opportunities with student chapter MA leaders that may include improvements to tool kits, recorded MA student chapter training webinars, or other value-adding concepts

Mr. Formica has also joined the HOD nominating committee and will participate in the WEF Nominating subcommittee, which reviews the applications for WEF vice president, trustees, and treasurer (when applicable), and makes recommendations for BOT and HOD candidates.

Fred McNeill, chief engineer of the city of Manchester, New Hampshire's Environmental Protection Division, was assigned to the Operator Initiative workgroup. This workgroup will assist the WEF Operator Advisory Panel in promoting and supporting the professional operator through promotional materials to support and encourage participation in WEF operator-oriented programs and services, including the Operator Ingenuity Contest. The workgroup will also assist in the panel's survey of MAs on operator workforce development and review of operator training materials (both WEF and MA developed) to provide a gap analysis for content. The workgroup will further assist in other WEF operator initiatives as needed.



WEF partnered with the American Water Works Association to develop a suite of public outreach materials (to help communicate the value of water and wastewater services), which are available free-of-charge (news.wef.org/communicating-the-value-of-water)

At WEFTEC, NEWEA's delegation participated in a full day of Saturday meetings that included table-talk discussions, formal HOD meetings, a WEF business meeting, workgroup meetings, and finally a field trip to the Young Professionals' service project. The delegates and several other NEWEA members also participated in a Leadership Day, a half-day session that focused on communication and public awareness. Plans for 2018 WEFMAXs, to be held in Arkansas, Indiana, Alaska, and North Carolina, were also unveiled at this session.

Finally, NEWEA's WEF delegates thank Meg Tabacsko and Kate Biedron, who graciously and professionally presented NEWEA's "Water for Life Champions" at WEFTEC. It was great to see NEWEA's successful regional water awareness campaign shared and so positively received on the national stage.

WE'RE WORKING FOR WATER QUALITY. WH$_2$O'S WITH US?

Annual Conference & Exhibit Preview

January 21–24, 2018 • Boston Marriott Copley Place, Boston, MA

President James Barsanti will preside over this year's NEWEA Annual Conference—themed: *We're Working for Water Quality. WH$_2$O's With Us*? The conference features technical and management sessions, student presentations, two days of poster sessions (professional and student), over 200 exhibitors, an Innovation Pavilion and our prestigious Awards Ceremony.

Thirty-one sessions spanning a variety of areas focused on water reclamation will be offered Monday through Wednesday.

Back by popular demand, we will have not only one but two Public Agency Days. Public agency representatives may attend either Monday or Tuesday for an exhibit hall entrance and afternoon networking reception for $25. Monday's registration will include attendance at the Opening Session.

Sunday we will be holding a Young Professionals Summit, which will include training and networking opportunities.

Monday & Tuesday include the NEWEA/NEWIN Water Innovation Pavilion, where many of the New England Water Innovators will present their ideas.

Conference Events

SUNDAY, JANUARY 21

Registration—4th Floor .... Noon – 4:00 PM

MONDAY, JANUARY 22

Registration—4th Floor .... 7:00 AM – 6:00 PM
Technical Sessions 1 – 5 .... 8:30 – 10:30 AM
Technical Sessions 6 – 11 .... 2:00 – 4:30 PM
Exhibits .... 10:30 AM – 6:30 PM
Opening Session .... 11:00 AM
Exhibit Hall Reception .... 4:30 – 6:30 PM

TUESDAY, JANUARY 23

Registration—4th Floor .... 7:00 AM – 6:00 PM
Exhibits .... 8:00 AM – 6:30 PM
Technical Sessions 12 – 16 .... 9:00 – 11:30 AM
Technical Sessions 17 – 22 .... 1:30 – 4:00 PM
Exhibit Hall Reception .... 4:00 – 6:00 PM

WEDNESDAY, JANUARY 24

Registration—4th Floor .... 7:30 AM – 2:00 PM
Exhibits .... 8:00 AM – 1:00 PM
Awards Presentation & Gavel Passing ... 11:00 AM
Technical Sessions 23 – 27 .... 8:30 – 11:00 AM
Technical Sessions 28 – 31 .... 1:00 – 3:00 PM

Event Hotel

Boston Marriott Copley Place Hotel
110 Huntington Avenue
Boston, MA 02116
617-236-5800

SINGLE—$204
DOUBLE—$224

Conference Registration

Register online/download a complete conference program at newea.org
Phone: 781-939-0908

Early registration before January 5

Keynote Speaker Juliette Kayyem

Juliette Kayyem is founder of Kayyem Solutions, LLC, a female-owned security business providing strategic advice to a range of companies, and has served as a national leader in America's homeland security efforts.

She was President Obama's Assistant Secretary for Intergovernmental Affairs at the Department of Homeland Security. There she played a pivotal role in major operations including handling of the H1N1 pandemic and the BP Oil Spill response.

Conference Exhibitors

ABBA Pump Parts & Service
ADS Environmental Services-Idex
Advanced Drainage Systems, Inc.
Airvac- A brand of Aqseptence Group
AllMax Software, Inc.
Aqua Solutions, Inc.
Aries Industries, Inc.
Asahi/America, Inc.
Associated Electro-Mechanics, Inc.
Atlantic Fluid Technologies, Inc.
BAU Hopkins Inc
BDP Industries
Blake Equipment Co.
BMC Corp
Boyson and Associates, Inc.
Cabot Norit Activated Carbon
Carl Lueders & Company
Carlsen Systems, LLC
Casella Organics
ChemFree DeFoam LLC
CN Wood
Coyne Chemical Environmental Services
Cretex Specialty Products
CSI Controls
CST Covers
CUES
David F Sullivan & Assoc., Inc
Denali Water Solutions
DN Tanks
Doetsch Environmental Services
Duke's Root Control
Duperon Corp.
Eastern Pipe Service
Environmental Dynamics, Inc.
Environmental Operating Solutions, inc. (EOSi)
eRPortal Software, Inc.
EST Associates
Evoqua
F. R. Mahony & Associates, Inc.
F.W. WEBB Co. - Process Controls Div.
FCB Insurance LLC
Flottweg Separation Technology
Flow Assessment Services LLC
Flow Tech, Inc.
FlowWorks, Inc.
Flygt Products - A Xylem Brand
Ford Hall Company
Gabriel Novac & Assoc.
Green Mountain Pipeline Services
Groth Corporation
Grundfos
Hach Company
Hayes Pump, Inc.
Hazen and Sawyer
Hobas Pipe USA
Holland Company, Inc.
Hydro Logic
Infiltrator Water Technologies
Innovyze
ITpipes
J&R Sales and Service, Inc.
JPS Industries, Inc.
Kemira
LandTech Consultants, Inc.
Lystek International Inc
Maltz Sales Company
Mechanical Solutions Inc
Methuen Construction Co., Inc.
Michie Corporation
National Filter Media
National Water Main Cleaning Co.
New England Environmental Equipment
NEWEA
Oakson, Inc.
Oldcastle Precast - Stormwater
P&H Senesac, Inc.
Performance Chemicals, LLC
Perma-Liner Industries, LLC.
PipeLogix
POND Technical Sales
Precision Trenchless, LLC
PRIMEX Controls
Pump Systems, Inc.
Pure Technologies U.S. Inc.
R. H. White Construction Co., Inc.
Rain for Rent
Resource Management, Inc.
RI Analytical Laboratories Inc
Rockwell Automation
Russell Resources, Inc.
Seepex Pumps
SNF Polydyne
Sprayroq, Inc.
Stacey DePasquale Engineering, Inc.
SUEZ
SULLIVAN ASSOCIATES/RITEC ENVIRONMENTAL
Synagro Northeast, LLC
Technology Sales Associates, Inc.
Ted Berry Company, Inc.
The MAHER Corporation
The Vortex Companies
Thompson Pipe Group
Trumbull Industries, Inc.
United Concrete Products, Inc.
USABLUEBOOK
Utility Cloud (AESC)
Vogelsang
Walker Wellington LLC
Wescor Associates, Inc.
WESTECH
Williamson Pump & Motor
Worcester Polytechnic Institute
Xylem Dewatering Solutions Inc - Godwin Pumps

as of 11/16/16

2018 Award Recipients

NEWEA Awards

Alfred E. Peloquin, CT	Jay Sheehan
Alfred E. Peloquin, ME	Phyllis Arnold Rand
Alfred E. Peloquin, MA	James Legg
Alfred E. Peloquin, NH	Kenneth Kessler
Alfred E. Peloquin, RI	Edward Davies
Alfred E. Peloquin, VT	John Lazelle
Asset Management	City of Portland, ME
Biosolids Management	Shelagh Connelly
Clair N. Sawyer	Annalisa Onnis-Hayden
Committee Service	Donald St. Marie
E. Sherman Chase	Jeff Kalmes
Elizabeth A. Cutone Executive Leadership	Julia Forgue
Energy Management Achievement	Village of Essex Junction WWTF
Founders	NH Water Pollution Control Association
James J. Courchaine Collection Systems	George Kathios
Operator, CT	TBD
Operator, ME	Annaleis Hafford
Operator, MA	Scott Skelley
Operator, NH	Michael Carle
Operator, RI	Christopher Petrone
Operator, VT	John Alexander
Operator Safety	Richard Gould
Past President's Plaque and Pin	Raymond Willis
Paul Keough	John Howell
Public Educator	Zeb Arruda
Wastewater Utility	Waterbury WPC
Young Professional	Michael Guethle

NEWEA Recognition (Stockholm Junior Water Prize)

CT	Luca Barcelo
ME	Mei Tian
MA	Sangwon Cha
NH	Meghana Avvaru
RI	Nicolas Berg
VT	Aida Arms

WEF (presented at WEFTEC)

WEF Fellows	Paul Dombrowski
WEF Fellows	April Gu
WEF Service Award	John Trofatter
WEF Service Award	George Vercelli
WEF Student Design Competition	Northeastern Univ.

WEF—MA Awards

Arthur Sidney Bedell Award	Susan Guswa
George W. Burke, Jr. Award	Veolia/Sturbridge WPCF
Laboratory Analyst Excellence Award	Danielle Morrison
Quarter Century Operators' Club	Raymond Drew
Quarter Century Operators' Club	Brendan O'Regan
Quarter Century Operators' Club	Timothy Levasseur
WEF Life Membership	Frank Arnold
WEF Life Membership	Robert Dangel
WEF Life Membership	Paul Gormsen
WEF Life Membership	Robert Hill
WEF Life Membership	Francis Hopcroft
WEF Life Membership	John Jackman
WEF Life Membership	Bruce Pierstorff
WEF Life Membership	Leo Potter
WEF Life Membership	Anthony Tawa, Jr.
WEF Life Membership	Kevin Wholley
WEF Service Award	Daniel Bisson
WEF Service Award	Jennifer Lachmayr
William D. Hatfield Award	Raymond Vermette

Specialty conferences, workshops, and networking events

Poo & Brew #7 featured a tour of Hartford, Connecticut Water Pollution Control Facility

YOUNG PROFESSIONALS NETWORKING EVENTS

NEWEA's Young Professionals Committee hosted several popular multi-discipline networking events aptly named Poo & Brew. These events each included a tour of a local wastewater treatment facility followed by networking at a brewery. These events are open to organization members and non-members who are professionals in the early stages of their water industry careers.

POO & BREW #7—Attendees toured the Hartford, Connecticut Water Pollution Control Facility followed by a networking reception at the Hog River Brewery in Hartford, Connecticut. Forty-five attendees participated in the event held on Saturday, June 3. Cohosted with New York Water Environment Association, Connecticut Water Pollution Abatement Association, and Connecticut Association of Water Pollution Control Authorities.

POO & BREW #8—A tour of South Portland, Maine's Water Pollution Control Facility was featured, followed by networking at Foulmouthed Brewing Company in South Portland, Maine. Twenty-five attendees participated in the event held on Thursday, July 13. Cohosted with Maine Water Environment Association (MeWEA)'s Young Professionals Committee.

POO & BREW #9—This event highlighted the Greater Lawrence Sanitary District Wastewater Treatment Facility in North Andover, Massachusetts. A networking event was held afterward at Oak & Iron Brewing Company in Andover, Massachusetts. Over 55 attendees participated in the event held on Thursday, August 17.

POO & BREW #10—This event highlighted MWRA's Deer Island Treatment Plant in Winthrop, Massachusetts. A networking event was held afterward at Mystic Brewery in Chelsea, Massachusetts. More than 50 attendees participated in the event held on Thursday, October 5.
Cohosted with Boston Society of Civil Engineers Section, Young Members Group

SMALL COMMUNITY CONFERENCE

Resiliency Planning: Operator and Engineer Collaboration and Design

The Small Community Committee of NEWEA held a specialty conference at the Courtyard Marriott in Keene, New Hampshire on September 26, 2017. The event had 40 attendees participate.

The technical presentations commenced on Tuesday, September 26th with NEWEA President-Elect Janine Burke-Wells and NEWEA Small Community Committee Vice-chair Kurt Mailman providing the Welcome and Opening Remarks to meeting attendees.

TECHNICAL PRESENTATION

Climate Predictions and Implications on Infrastructure and Operations
- Phil Forzley, Fuss & O'Neill

Warwick Sewer Authority: Flood Response, Recovery & Mitigation
- David Caouette & Janine Burke-Wells, Warwick, RI Sewer Authority

Climate Adaptation Strategies for Four Maine Coastal Communities' WWTFs
- Kyle Coolidge, Wright-Pierce

Hazard Mitigation: Upgrade of a Vulnerable Pump Station from A to Z
- Ian Catlow, Tighe & Bond

Evaluation of Critical Infrastructure in Mattapoisett, MA
- Kevin Flood, Fuss & O'Neill

Addressing the Drought in Massachusetts through Beneficial Wastewater Reuse
- Meghan Trahan, Environmental Partners

ANNUAL NORTHEAST RESIDUALS & BIOSOLIDS CONFERENCE

NEWEA's Residuals Management Committee held a three-day specialty conference and exhibit on October 25–27, 2017, at the Hilton Hotel in Burlington, Vermont. Meeting registrants included: 109 attendees and 11 exhibitors for a total of 120 registrants. The conference was held jointly with the North East Biosolids & Residuals Association (NEBRA) and Green Mountain Water Environment Association (GMWEA).

The technical presentations commenced on Thursday with NEWEA President James Barsanti and GMWEA Director Bob Fischer providing the Welcome and Opening Remarks.

In addition to the conference, facility tours to Essex Junction, Vermont, Water Resource Recovery Facility and Magic Hat Brewery digester tour were offered. A networking reception was held in the exhibit area on Wednesday. A special 20th Anniversary NEBRA celebration dinner was held Thursday.

TECHNICAL PRESENTATIONS—THURSDAY

SESSION 1: WELCOME TO VERMONT!

Moderator
- Michael Lannan, Tech Environmental

Net Zero Strategy: Montpelier VT's Approach for Total Water Resource Recovery
- Larry Doyle, Energy Systems

15 Years of 2PAD at the Airport Parkway WWTF, South Burlington, VT
- John Reilly, Hoyle, Tanner & Assoc.

It's All in the Mix—Design of New Mixers for Anaerobic Sludge Digestion Facilities at St. Johnsbury WWTF
- Meredith Zona, Stantec

Significant New VT Laws & Regulations
- Eamon Twohig, VT DEC

SESSION 2: RESEARCH

Moderator
- Tracy Chouinard, Brown and Caldwell

Characterizing Root-Associated Bacteria for Improvement of Soil Health
- Cairn Ely, Central CT State University

Phosphate Fertilizer Value of Sludge Incineration Ashes
- Claude Alla Joseph, Laval University

Analysis of Startup and Long-Term Performance of a High-Throughput Deammonification System
- Mudit Gangal, Ovivo

Minimizing Sludge Generation Using an Anaerobic Side-Stream Reactor Process
- Chul Park, UMASS Amherst

Developing Product Blends for Urban Uses
- Chris Peot, DC Water

SESSION 3: HOT TOPICS

Moderator
- Charlie Alix, Stantec

Innovative Mercury Control at a Biosolids Incineration Plant
- Frank Sapienza, CDM Smith

All the Remarkable Benefits of Recycling Biosolids to Soils
- Ned Beecher, NEBRA

Regional Update on PFAS in Biosolids & Residuals
- Michael Rainey, Formerly NH DES

SESSION 4: THINK C

Moderator
- Ben Smith, NEIWPCC

Impact of Greenhouse Gas Emissions on Biosolids Management Decision-Making
- Tracy Chouinard, Brown and Caldwell

Approaching Energy Neutrality with Carbon Diversion
- Sergio Pino-Jelcic, Evoqua Water Technologies

Carbon Considerations in Biosolids Management
- Chris Peot, DC Water

TECHNICAL PRESENTATIONS—FRIDAY

WELCOME & OPENING REMARKS:
- Mark Young, NEBRA President

BIENVENUE AU QUÉBEC
Moderator
- Ned Beecher, NEBRA

Updates on Recycling of Fertilizing Residual Materials in Quebec
- Patricia Goulet, RECYC and Serge Loubier, Englobe

SESSION 5: ANAEROBIC DIGESTION

Moderator
- Eric Spargimino, CDM Smith

To Codigest or Not to Codigest?
- Natalie Sierra, Brown & Caldwell

Cortland WWTF: Digester Upgrades and CHP Integration in an Antiquated System
- Matt Williams, WesTech Eng.

Are Your Digesters Burping, Frothing, or Otherwise Not Behaving?
- Chris Muller, Brown and Caldwell

Comparative Life Cycle Assessment & Cost Analysis of Bath, NY WRRF Upgrades
- Xing (Cissy) Ma, US EPA

SESSION 6: PHOSPHORUS

Moderator
- Ray Gordon, NH Dept. of Environmental Services

Reducing Plant-Available Phosphorus in Agricultural Soils Using Water Treatment Residuals: Current Field Trials
- Michael Potash, Resource Management Inc.

Phosphorus in Biosolids Composts and Risks to Water Quality
- Geoff Kuter, Agresource

Phosphorus Regulation & Research in Massachusetts & Beyond
- Ned Beecher, NEBRA

EXHIBITORS

Aqua Solutions
Casella Organics
David F. Sullivan & Associates
Lystek International
Quantum Biopower
Resource Management Inc
Statewide Aquastore, Inc.
Technology Sales Associates Inc
Walker Wellington LLC
WeCare Denali
Weston& Sampson

SPONSORS:

AECOM
Aqua Solutions
ARCADIS
Brown and Caldwell
Hazen and Sawyer
Hoyle, Tanner & Associates
Kleinfelder
Lystek International Inc
NEFCO
Resource Management Inc.
Suez
Synagro Northeast
The MAHER Corporation
Tighe & Bond
Woodard & Curran
Wright-Pierce

WATERSHED MANAGEMENT CONFERENCE

NEWEA's Watershed Management Committee in conjunction with New England Water Works Association (NEWWA), New England Chapter of American Public Works Association (NE APWA), and New England Interstate Water Pollution Control Commission (NEIWPCC) held a joint specialty conference on July 12, 2017, at the UMASS Conference Center in Lowell, Massachusetts. More than 80 attendees participated.

The specialty conference focused on climate change impacts and strategies for improving infrastructure resilience in flood-prone inland and coastal watersheds. The technical presentations commenced with NEWEA President Jim Barsanti, NEWWA President Matthew Pearson, and NE APWA Past President Rick Merson providing the Welcome and Opening Remarks to meeting attendees.

In addition to the program, a keynote presentation was given by Juliette Rooney-Varga, director of UMASS Lowell Climate Change Initiative and associate professor of Environmental Biology and Alicia Hunt, city of Medford, Massachusetts.

MORNING PANEL DISCUSSION

- Adam Horst, Project Director, Boston Water and Sewer Commission
- Roy Schiff, Water Resources Scientist and Engineer, Milone & MacBroom for VTrans
- Nancy Durfee, Coastal Resources Officer, Scituate, Massachusetts
- Patricia Bowie, Coastal Resiliency Specialist, Massachusetts Office of Coastal Zone Management
- Kate Theoharides, Director of Climate and Global Warming Solutions, Massachusetts Executive Office of Energy and Environmental Affairs

AFTERNOON CONCURRENT SESSIONS: COASTAL COMMUNITY RESILIENCY

Moderators:
- Brian Creamer & Madeline DeClerk

Coastal Resiliency Challenges and Planning in Fairfield, Connecticut
- Dana Huff, Tighe & Bond, Inc. and Joseph Michelangelo, Town of Fairfield, CT

Step 0—How Portland, Maine Is Working to Protect a Low-lying Neighborhood
- David Senus, Woodard & Curran and Troy Moon, City of Portland, ME

Rhode Island South Shore Habitat and Community Resiliency Project—Ninigret Salt Marsh Restoration
- Nils Wilberg, Fuss & O'Neill, Inc.
- Caitlin Chaffee, RI, Coastal Resource Management Council

PLANNING FOR INLAND FLOODING AND CLIMATE CHANGE IMPACTS

Moderators:
- Sara Greenberg & Zach Henderson

When Rolling Easements are Ineffective—Possessory Adaptation Alternatives to Sea Level Rise in Armored Urban Communities
- Deirdre Hall, Quincy, MA DPW

Enhancing Flood Resiliency in the Wood-Pawcatuck Watershed through Multi-Benefit, Ecosystem-based Approaches
- Erik Mas, Fuss & O'Neill

Keeping the Lights On—Energy Facility Flood Mitigation and Resilience Takeaways for Protecting Critical Assets and Infrastructure
- Jennifer Burke and Gary McAllister, GZA GeoEnvironmental

INFRASTRUCTURE CHALLENGES AND OPPORTUNITIES

Moderators:
- Renee Bourdeau & Phil Forzley

Infrastructure for a Livable Future—Integrating Human and Natural Water Systems
- Bruce Douglas, Natural Systems Utilities and Julie Wood, Charles River Water Association

Possible vs. Practical: Designing a Seawall for Sea Level Rise in Hampton, NH
- Tristan Donovan, Tighe & Bond, Inc.

Climate Change Impacts on Stormwater Best Management Practices and Recommended Design Considerations
- Cristina Kennedy, MA Coastal Zone Management

UTILITY SYSTEM UPGRADES & OPERATION IN A CHANGING CLIMATE

Moderators
- Courtney Eaton & Rick Merson

Preparing for Extreme Weather
- Ben Smith, NEIWPCC

Increasing the Coastal Resilience of Vulnerable Wastewater Infrastructure on Massachusetts Coast and Islands
- Anastasia Rudenko, GHD

Resilience: State of Science and Practice
- Igor Linkov and Catherine Fox-Lent, U.S. Army Engineer Research and Development Center

EXHIBITORS

Landtech Consultants
Lockheed Martin Energy
SmartVent Products

SPONSORS

AECOM
ARCADIS
Brown and Caldwell
Dewberry
Environmental Partners Group
EST Associates
Fuss & O'Neill
Milone & MacBroom Inc
Nitsch Engineering
SUEZ
Tata & Howard
The MAHER Corporation
Weston & Sampson
Woodard & Curran

JOINT EFFECTIVE UTILITY MANAGEMENT WORKSHOP

NEWEA in conjunction with New England Water Works Association (NEWWA) and New England Chapter of American Public Works Association (NE AWPA) held a joint workshop with U.S. EPA on Tuesday, June 27, 2017 at NEWWA's Training Center in Holliston, Massachusetts. Twenty-five attendees participated.

Attendees learned about EPA's Effective Utility Management (EUM) framework and how to self-assess utilities and implement to protect current infrastructure investments.

Upcoming Events

Save the Date

NEWEA SPRING MEETING

June 3 – 6, 2018

Gurney's Resort and Marina
Goat Island, Newport, RI

NEWEA ANNUAL CONFERENCE & EXHIBIT
January 21 – 24, 2018
Boston Marriott Copley Place Hotel, Boston, MA

ASSET MANAGEMENT AND ENERGY CONFERENCE
April 11 – 12, 2018
Merrimack, NH

NATIONAL WATER WEEK – DC FLY-IN
April 16 – 19, 2018
Washington DC

STORMWATER CONFERENCE & EXHIBIT
May 7 – 8, 2018
Sheraton, Portsmouth, NH

NEWEA SPRING MEETING
June 3 – 6, 2018
Hyatt Regency Goat Island, Newport, RI

AFFILIATED STATE ASSOCIATIONS AND OTHER EVENTS

MEWEA FAMILY ICE SKATE DAY
January 19
Thompson's Point Arena, Portland

MAINE WATER UTILITIES ASSOCIATION ANNUAL MEETING AND TRADE SHOW (WITH MEWEA TRACK)
February 6 and 7
Holiday Inn by The Bay, Portland

NWPCA (RI) CLEAN WATER LEGISLATIVE LUNCHEON
March (TBD
RI State House, Providence

NHWPCA & MEWEA SKI DAY
March 2, 2018
Black Mountain Ski Area, Rumford, ME

NHWPCA LEGISLATIVE BREAKFAST
March 7, 2018
Holiday Inn, Concord, NH

MAINE SUSTAINABILITY AND WATER CONFERENCE
March 29, 2018
Augusta Civic Center, ME

NHWPCA TRADE FAIR
April 13, 2018
Radisson Hotel, Nashua, NH

MEWEA SPRING CONFERENCE
April 13, 2018
Bangor Four Points Sheraton, ME

URBAN RUNOFF 5K
April 21, 2018
Portland, ME

GMWEA SPRING & ANNUAL MEETING
May 24, 2018
Killington Grand Hotel, Killington VT

NWPCA (RI) ANNUAL AWARDS BANQUET
May 24
Potowomut Country Club

MWPCA ANNUAL GOLF TOURNAMENT
June 19, 2018
Shaker Hills Country Club, Harvard, MA

NHWPCA SUMMER MEETING
June 22, 2018
Ellacoya State Park, Gilford, NH

NHWPCA OCEAN NETWORKING TRIP
July 13, 2018
leaving from Seabrook, NH

NWPCA (RI) PAWTUCKET RED SOX EVENT
June 23,2018
McCoy Stadium, Pawtucket, RI

NWPCA (RI) ANNUAL GOLF CLASSIC
June 25
Potowomut Country Club

This is a partial list.
Please visit the state association websites and NEWEA.org for complete and current listings.

STORMWATER CONFERENCE: Enhancing Stormwater Resilience in the Built Environment

May 7–8, 2018 • Portsmouth, New Hampshire

2018 SPECIALTY CONFERENCE & WORKSHOP SERIES

The Enhancing Stormwater Resilience in the Built Environment Specialty Conference is aimed at showcasing projects, strategies, and case studies by public and private entities preparing to effectively manage stormwater and build resilient networks in an uncertain climate with significant physical and financial constraints. This two-day conference will focus on flood and disaster preparedness and mitigation projects using green and gray versatile designs that can increase resilience and provide water quality and other community benefits. The conference will also focus on financial tools, strategies, and opportunities to help fund these multi-purpose, resilient projects and initiatives in the years to come.

The audience for this conference includes municipal, state, and federal employees as well as private consultants, contractors, and researchers involved in flood mitigation, stormwater resilience, and stormwater management initiatives. Those interested in learning more about financial strategies, tools, and funding opportunities to help finance the new demands of building a more resilient future should also attend this conference.

JOINT ENERGY & ASSET MANAGEMENT CONFERENCE: KNOWLEDGE IS POWER! Know Your Assets and Understand Your Energy Use

2018 SPECIALTY CONFERENCE & WORKSHOP SERIES

This two-day conference, offered by NEWEA Energy and Asset Management Committees, will explore asset management, energy efficiency, cost analysis, decision making, data collection and sustainability. Included are tours of Merrimack WWTF and the Anheuser Busch anaerobic digester process. This conference is a "must" for all wastewater practitioners and industry professionals, especially those involved in asset management, reducing overall energy usage, and increasing the sustainability of their wastewater treatment facilities.

Training Contact Hours will be awarded for operator recertification.

April 11–12, 2018 • Merrimack, New Hampshire

NEWEA
WORKING FOR WATER QUALITY

2018 NEWEA Executive Committee*

*Proposed 2018 NEWEA Executive Committee—pending the election vote at the annual business meeting of the membership on January 22, 2018, at the annual technical conference and exhibition

PRESIDENT
Janine Burke-Wells
Warwick, RI

PRESIDENT-ELECT
Raymond A. Vermette, Jr.
Dover, NH

VICE PRESIDENT
Jennifer K. Lachmayr
Wakefield, MA

TREASURER
Priscilla J. Bloomfield
Orleans, MA

PAST PRESIDENT
James R. Barsanti
Framingham, MA

EXECUTIVE DIRECTOR
Mary Barry

DIRECTORS—COUNCIL
Collection Systems and Water Resources
John M. Digiacomo
Natick, MA

Communications
Meg Tabacsko
Chelsea, MA

Meeting Management
Elena Proakis Ellis
Melrose, MA

Public Outreach
Justin Skelly
Worcester, MA

Treatment, Systems Operation and Management
Marylee Santoro
Stamford, CT

DIRECTORS—STATE
Virgil J. Lloyd
Manchester, CT

Clayton "Mac" Richardson
Lewiston, ME

Justin deMello
Andover, MA

Sean Greig
Newmarket, NH

Scott Goodinson
Warwick, RI

Chris Robinson
Shelburne, VT

WEF DELEGATES
Susan J. Sullivan
Lowell, MA

Frederick McNeill
Manchester, NH

Matthew Formica
Chelmsford, MA

Susan Guswa
Enfield, CT

National Water Week–DC Fly-In

April 17–18, 2018
Capitol Visitor Center
Washington, D.C.

The NEWEA Congressional Briefing is the annual hallmark for the Association and its government affairs program. Mark your calendar to join us on April 17–18, 2018.

This is a great opportunity for our membership and elected officials to join together to discuss water, wastewater and stormwater infrastructure issues facing communities of the Northeast. We look forward to meeting with you and providing you with the latest information affecting our industry. Your involvement is critical—come to D.C. and be heard.

Attending the Briefing will allow:

- Opportunities to meet with senators, representatives and legislative staff
- Substantive discussion of federal clean water legislative initiatives and opportunity to provide feedback related to the impact that these initiatives have on our communities and the water quality industry
- A forum for presentation and discussion of the NEWEA Position statements
- Opportunities to learn about key federal regulatory initiatives
- A forum to provide comments directly to regulatory leaders from EPA's Washington, D.C. Headquarters

In addition to the Briefing Lunch, an important part of this day is holding individual meetings with senators and representatives on the Hill. If you plan to attend the briefing, the government affairs committee will work with you to schedule these individual appointments.

NEWEA
WORKING FOR WATER QUALITY

New Members
October – November 2017

Benjamin Agrawal
Hazen & Sawyer
East Boston, MA (YP)

Neil H Amwake
Wallingford Sewer Divison
Wallingford, CT (PRO)

Chris Ciardelli
Merrimack Wastewater Treatment Facility
Merrimack, NH (PWO)

Brooke Cotta
Boston Water & Sewer Commission
Roxbury, MA (YP)

David DeSousa
Sensata Technologies Inc.
Assonet, MA (PWO)

Edward Gardiner
Tetra Tech
Marlborough, MA (PRO)

Maria George
Environmental Partners Group Inc
Quincy, MA (YP)

Patrick Gordon
StormTrap
North Hampton, NH (PRO)

Insley Haciski
Onset Computer
Bourne, MA (PRO)

Annaleis Hafford
Olver Associates Inc.
Winterport, ME (PRO)

Sean P Harrington
Town of Needham
Needham, MA (PRO)

Justin Hayes
Wakefield, RI (STU)

Alexandria Hidrovo
Durham, NH (STU)

Ryan Johnston
Waterleau Inc
Dalton, MA (PRO)

Andrew Keyser
Montague Waste Water Treatment
Montague, MA (PWO)

Deanna Lambert
Milton, VT (STU)

Catherine Mallon Traynor
Yorktown Heights, NY (PRO)

Dayton Marchese
Opti
Boston, MA (YP)

Joseph Marcolini
Laura Marcolini & Associates Inc
Cumberland, RI (PWO)

Philip Marrone
Framingham, MA (PRO)

Erika Martin Weinstein
Hartford, CT (STU)

Andrea Martucci
Inception Technologies, Inc.
Manchester, NH (EXEC)

Sharon A McMillin
NHDES-WRBP
Franklin, NH (PRO)

Jeffrey R Mercer
Wright-Pierce
Portland, ME (PRO)

David Moering
Woodard & Curran
Andover, MA (PRO)

Paul Wilson Moulton
AECOM
Manchester, NH (PRO)

Tim Peura
Montague Waste Water Treatment
Montague, MA (PWO)

Robyn Saunders
Cumberland County Soil and Water
Windham, ME (PRO)

Scott Skelley
Greater Lawrence Sanitary Dist.
North Andover, MA (PWO)

Lloyd Snyder
Portland, ME (PRO)

Timothy Sommer
New England WEA
Durham, NH (STU)

Newton Tedder
USEPA
Boston, MA (PRO)

James Wilson
Weston & Sampson Engineers Inc.
Plymouth, MA (PWO)

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Affiliate (AFF)
Complimentary (COMP)
Corporate (COR)
Dual (DUAL)
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Build relationships with water industry leaders *and* make a positive impact on the water environment

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- Increased corporate visibility and marketing opportunities before a wide audience of water industry professionals
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- Recognition as an environmental leader among peers and customers

For more information contact Mary Barry
Email: mbarry@newea.org
Call: 781-939-0908

NEWEA
WORKING FOR WATER QUALITY

Advertiser Index

Upcoming *Journal* Themes

Spring 2018—**Operators**

Summer 2018—**Engineers**

Fall 2018—**Public Works/Municipal**

Winter 2018—**Young Professionals**

NEWEA/WEF* Membership Application 2017

Water Environment Federation — the water quality people
NEWEA — WORKING FOR WATER QUALITY

Personal Information

Last name | M.I. | First Name | (jr. sr. etc)

Business Name (if applicable)

Street or P.O. Box (☐ Business Address ☐ Home Address)

City, State, Zip, Country

Home Phone Number | Mobile Phone Number | Business Phone number

Email Address | Date of birth (month/day/year)

☐ Please send me information on special offers, discounts, training, and educational events, and new product information to enhance my career ☐ by e-mail ☐ by fax

☐ Check here if renewing, please provide current member I.D.

***NEWEA is a member association of WEF (Water Environment Federation). By joining NEWEA, you also become a member of WEF.**

Employment Information (see back page for codes)

1. ORG Code: | Other (please specify): | 2. JOB Code: | Other (please specify):

3. Focus Area Codes: | Other (please specify:

Signature (required for all new memberships) | *Date*

Sponsorship Information

WEF Sponsor name (optional) | Sponsor I.D. Number | ACQ. Code for WEF use only | WEF 15

Membership Categories (select one only)

		Member Benefit Subscription	Dues
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☐ **Young Professional Package**	New members or formerly student members with 5 or less years of experience in the industry and less than 35 years of age. This package is available for 3 years.	■ *WE&T* (including *Operations Forum*) ■ *WEF Highlights Online*	$69
☐ **Professional Wastewater Operations (PWO) Package**	Individuals in the day-to-day operation of wastewater collection, treatment or laboratory facility, or for facilities with a daily flow of < 1 mgd or 40 L/sec.	■ WE&T (including *Operations Forum*) ■ *WEF Highlights Online*	$109
☐ **Academic Package**	Instructors/Professors interested in subjects related to water quality.	■ *WE&T* (including *Operations Forum*) ■ *WEF Highlights Online* ■ *Water Environment Research* (Online)	$181
☐ **Student Package**	Students enrolled for a minimum of six credit hours in an accredited college or university. Must provide written documentation on school letterhead verifying status, signed by an advisor or faculty member.	■ *WE&T* (including *Operations Forum*) ■ *WEF Highlights Online* ■ *Water Environment Research* (Online)	$10
☐ **Executive Package**	Upper level managers interested in an expanded suite of WEF products/services.	■ *WE&T* (including *Operations Forum*) ■ *WEF Highlights Online* ■ *World Water* ■ *Water Environment Research* (Online) ■ *Water Environment Regulation Watch*	$353
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☐ **Corporate Membership** (member benefits for one person)	Companies engaged in the design, construction, operation or management of water quality systems. Designate one membership contact.	■ *WE&T* (including *Operations Forum*) ■ *Water Environment Research* (Print) ■ *Water Environment Regulation Watch* ■ *WEF Highlights Online*	$411
☐ **New England Regulatory Membership**	This membership category is a NEWEA only membership reserved for New England Environmental Regulatory Agencies, including: USEPA Region 1, CT Department of Energy and Environmental Protection, ME Department of Environmental Protection, MA Department of Environmental Protection, NH Department of Environmental Services, VT Department of Environmental Conservation, and RI Department of Environmental Management		$50

WEF Utility Partnership Program (UPP): NEWEA participates in the WEF Utility Partnership Program (UPP) that supports utilities to join WEF and NEWEA while creating a comprehensive membership package for designated employees. As a UPP Utilities can consolidate all members within their organization onto one account and have the flexibility to tailor the appropriate value packages based on the designated employees' needs. Contact WEF for questions & enrollment (703-684-2400 x7213).

Payment

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Depending upon your membership level, $10 of your dues is allocated towards a subscription to the NEWEA Journal.

NEWEA/WEF* Membership Application 2017

To help us serve you better, please complete the following:

(choose the one that most closely describes your organization and job function)

***NEWEA is a member association of WEF (Water Environment Federation). By joining NEWEA, you also become a member of WEF.**

What is the nature of your ORGANIZATION?

(circle one only) (ORG)

1 Municipal/district Water and Wastewater Plants and/or Systems

2 Municipal/district Wastewater Only Systems and/or Plants

3 Municipal/district Water Only Systems and/or Plants

4 Industrial Systems/Plants (Manufacturing, Processing, Extraction)

5 Consulting or Contracting Firm (e.g., Engineering, Contracting Environmental, Landscape Architecture)

6 Government Agency (e.g., U.S. EPA, State Agency, etc.)

7 Research or Analytical Laboratories

8 Educational Institution (Colleges and Universities, libraries, and other related organizations)

9 Manufacturer of Water/Wastewater Equipment or Products

10 Water/Wastewater Product Distributor or Manufacturer's Rep.

11 Stormwater (MS4) Program Only

12 Public Financing, Investment Banking

13 Non-profits (e.g., Trade, Association, NGO, Advocacy, etc.)

99 Other ______________ (please specify)

What is your Primary JOB FUNCTION?

(circle one only) (JOB)

1 1. Upper or Senior Management (e.g., President, Vice President, Owner, Director, Executive Director, General Manager, etc.)

2 Engineering, Laboratory and Operations Management (e.g., Superintendent, Manager, Section Head, Department Head, Chief Engineer, Division Head, Landscape Architect etc.,)

3 Engineering and Design Staff (e.g., Consulting Engineer, Civil Engineer, Mechanical Engineer, Chemical Engineer, Planning Engineer, Landscape Architect, Environmental/ Wetland Scientist etc.)

4 Scientific and Research Staff (e.g., Chemist, Biologist, Analyst, Lab Technician, Environmental/Wetland Scientist etc.)

5 Operations/Inspection & Maintenance (e.g., Shift Supervisor, Foreman, Plant Operator, Service Representative, Collection Systems Operator, BMP Inspector, Maintenance, etc.)

6 Purchasing/Marketing/Sales (e.g., Purchasing, Sales Person, Market Representative, Market Analyst, etc.)

7 Educator (e.g., Professor, Teacher, etc.)

8 Student

9 Elected or Appointed Public Official (Mayor, Commissioner, Board or Council Member)

10 Other ______________

What are your KEY FOCUS AREAS?

(circle all that apply) (FOC)

1 Collection Systems

2 Drinking Water

3 Industrial Water/Wastewater/ Process Water

4 Groundwater

5 Odor/Air Emissions

6 Land and Soil Systems

7 Legislation (Policy, Legislation, Regulation)

8 Public Education/Information

9 Residuals/Sludge/Biosolids/Solid Waste

10 Stormwater Management/ Floodplain Management/Wet Weather

11 Toxic and Hazardous Material

12 Utility Management and Environmental

13 Wastewater

14 Water Reuse and/or Recycle

15 Watershed/Surface Water Systems

16 Water/Wastewater Analysis and Health/ Safety Water Systems

17 Other ______________

Optional Items (OPT)

Years of industry employment? _______

1 (1 to 5) **2** (6 to 10) **3** (11 to 20) **4** (21 to 30) **5** (>30 years)

Gender? _______

1 Female **2** Male

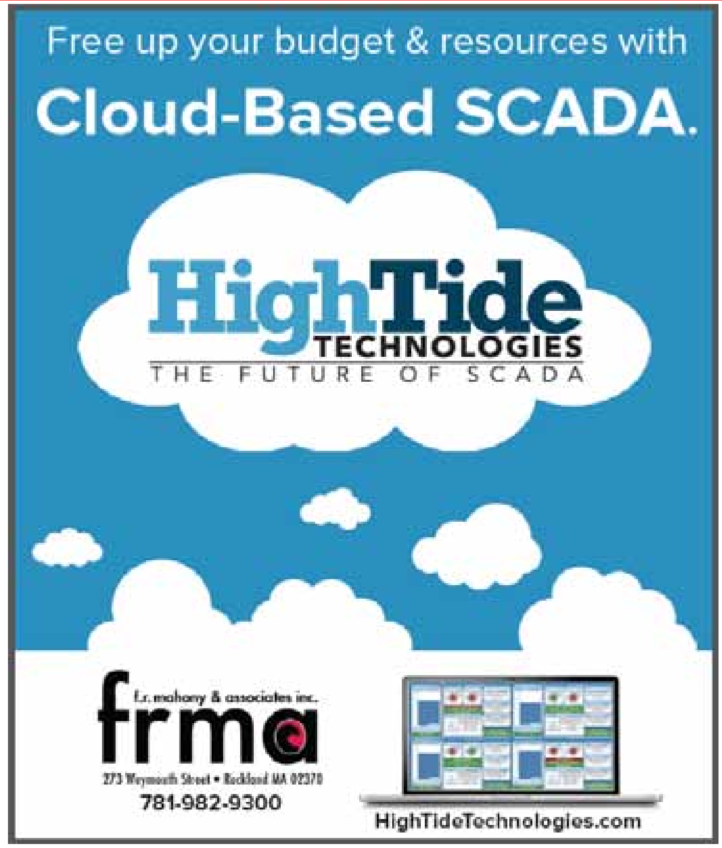
Education level? (ED) _______

1 High School **2** Technical School **3** Some College **4** Associates Degree **5** Bachelors Degree **6** Masters Degree **7** JD **8** PhD

Education/Concentration Area(s) (CON) _____

1 Physical Sciences (Chemistry, Physics, etc.) **2** Biological Sciences **3** Engineering Sciences **4** Liberal Arts **5** Law **6** Business

Water quality professionals, with fewer than 5 years working experience and under the age of 35, are eligible to join WEF as an Active Member, while participating in the NEWEA/WEF Young Professionals Program. This program allows up to 50% off of the Active Member dues, valid for the first three years of membership. This program is available for new member applicants and Student Members.



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