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SUNSPOTS WERE OBSERVED by telescope as early as the 1600s. Astronomer Galileo Galilei was the first to document the location of these solar specks by making ink marks directly onto paper. While maintaining the precise image plane, he translated complex data points into an accessible and easily read format.

Galileo’s sunspot charts were contested during the early 1600s because they conflicted with the general belief that celestial bodies were perfect, without blemish. The astronomer, therefore, proceeded to convert empirical observation into focused evidence by pinpointing the precise location of these sites on a rotating sun from a rotating earth.

As observations by other scientists were collected and diagrammed, with the data indexed on time, the insightful layers heightened the dimensionality of the information. Eventually, these early ink-marks made the existence of sunspots abundantly clear.

“...the paper is static, flat. How are we to represent the rich visual world of experience and measurement on mere flatland?” asks Edward Tufte in his landmark book Envisioning Information. From Galileo’s sunspot charts to elaborate GIS maps, technological diagrams, and displays of a smart city’s operational analytics, throughout the millennia, mankind has sought to convert data points into actionable information.

Translating data into useful strategy is an increasingly important topic throughout the water industry. And data is increasingly accessible. It’s in front of us on mobile devices and displayed in app dashboards, where it integrates information streams from across our utilities, creating rich data layers and consequentially, heightened operational awareness.

In this issue of Water Efficiency magazine, we honor the diverse ways that water organizations are finding to interpret data and make it usable. In the following pages, we invite you to join us in exploring methods of employing data to optimize water conveyance systems, plant operations, water conservation efforts, and energy efficiency.

The ability to curate and analyze data is changing the paradigm and leading to enhanced operations for water agencies across the country. In “Accessibility and Analysis” (pg. 32), we discuss the fact that utilities have access to more data than ever before. Today’s data management platforms not only make information accessible to personnel across the utility on user-friendly mobile interfaces, but they are also increasingly customizable, allowing utilities to target specific areas and use granular insights to inform decision making.

In “Efficiencies at the Water-Energy Nexus” (pg. 10), we see the benefit of combining data sets from across organizations and of using that data to find opportunities for energy conservation. From LED lighting at pump stations and variable frequency drives, to diverse generation portfolios supported by solar power, wind power, biomass, pumped hydro, and energy storage, water agencies across the country are capitalizing on these energy efficiency opportunities and reaping the benefits.

In “Looking for Leaks” (pg. 24), we identify key strategies, technologies, and techniques for detecting and locating water loss. We observe ways in which today’s mobile technology, supported by sensors, meters, ground microphones, and loggers, facilitates listening in the field and data mapping. We look at improvements in asset management made possible by the availability of on-demand historical analyses displayed on mobile apps and tablets in the field.

Today, as in Galileo’s time, data’s usability is considered its highest virtue. Mobile access, easy user interfaces, and aggregated data layers are making information increasingly accessible and enhancing the operational efficiency of our water systems. With numbers, maps, and graphics, these digital tools are offering deeper, multidimensional insights. How does your organization use data to optimize its operations?
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Efficiencies at the Water-Energy Nexus

Water utilities pursue energy efficiencies.

By Lyn Corum

“The interdependence of water and energy forms a nexus or convergence that means efficiency measures in one area have the potential to produce additional efficiencies in the other, thus benefiting both water and electric utility customers as well as the environment.”

American Water – Water-Energy Convergence: Efficiency Challenges and Opportunities

Energy efficiency and how to pursue it at water utilities has been studied by various agencies and nonprofits for the past 15 years, particularly in the western states. A few have published papers on the water-energy nexus, which focus on how utilities can reduce energy use. Most recently, they are linking the need to reduce greenhouse gases to energy efficiency. Two papers, in particular, stand out.

The US Department of Energy and the University of California, Irvine, held a two-day Water-Energy Workshop in 2015 and brought together experts from academia, utilities, and state agency representatives from California and the southwestern states to discuss issues regarding the interactions between water and energy sustainability. A report titled Capturing the Benefits of Integrated Resource Management for Water & Electricity Utilities and their Partners was published in May 2016 by the DOE and the University of California. It can be found on the DOE website.

California utilities took the report seriously. For example, the California Public Utilities Commission’s requirement that utilities examine embedded energy savings associated with water prompted the San Diego County Water Authority Board to coordinate efforts to implement water efficiency programs with San Diego Gas & Electric. They developed three programs: comprehensive water/energy audits, a landscape irrigation management program, and a recycled water program.

Pacific Gas and Electric and a number of Bay Area water utilities collaborated on developing a high-efficiency clothes washer rebate program which brought together a number of uncoordinated efforts already active from individual utilities.

The Pacific Institute, in its 2013 publication Water-Energy Synergies: Coordinating Efficiency Programs in California, wrote that all forms of energy from hydropower to solar panels use water to extract and process the fuels, construct the processing...
facilities, or generate the electricity. And water supply, treatment, use, and disposal use considerable amounts of energy.

The California Energy Commission found in a 2005 study that water efficiency improvements could save as much energy as some of the state's existing energy-efficiency programs at about half the cost.

The profiles below illustrate emerging energy trends among water utilities. Generating renewable energy is growing in popularity. Improving pump performance is also high on their list. And a few are pursuing or volunteering to participate in research projects.

LADWP LIKES DEMAND RESPONSE
The Water Operations Division of the Los Angeles Department of Water and Power (LADWP) has been executing numerous projects for several years throughout its many facilities to reduce energy use and make its equipment more efficient, according to Steven Cole, assistant director of the division.

Starting with the basics, Cole says his crew has swapped out incandescent and fluorescent lights for LEDs at 80 pump stations, 120 water storage tanks, and a filtration plant. They will move on to switch out lights at 400 underground vaults containing pressure regulation valves, he says.

The division is installing premium-efficiency motors on their pumps, says Cole. Variable frequency drives are installed on the bigger pumps. A 2,000-horsepower (hp) pump requires a tremendous amount of power to start up, so staff uses soft starts and installed variable frequency drives (VFD) on them. However, since VFDs require air conditioning to keep them cool, smaller pumps do not have them—they get the premium efficiency motors, he says. He explains that air conditioning small pumps to install VFDs would negate any energy savings. Cole says they are also eliminating any unnecessary use of uninterruptible power supply equipment because they require air conditioning.

The insides of new and refurbished pumps are recoated with Belzona, a metal super glide coating to improve water flow efficiency by repelling water away from the pump’s metal surface. Cole says this improves a pump’s efficiency by 6%.

Monitoring pumps in real time makes them more efficient, says Cole. They are monitored according to their temperatures, vibration, flow rates, and pressure. “We’ll turn on the most efficient pump first, and the least efficient last,” he says. Real-time monitoring also improves maintenance, by identifying pump/motor problems early.

The water operations division participates in LADWP’s demand response program between June 15 and October 15 each year. When the division gets a call, between 1:00 and 5:00 p.m. on weekdays, they work to adjust pump performance to reduce power and operating hours. They also adjust air conditioning and lighting during those hours when called upon.

In 2016, the division reduced power by 7.9 MW during peak periods, and in 2017, they reduced power by 7.6 MW. Cole said the average commercial customer will reduce demand between 500 kilowatts (kW) and 1 MW, on average, when called upon. “LADWP gave us our own peak reduction award,” he says.

Cole says they have begun a pilot for the water distribution system in the last six months by putting pressure and flow sensors in the lines. “Some lines may not need to have high pressure, and by monitoring, they may be able to dial back pressures,” he says. Lower pressure will avoid leaking in a pipe, he says.

This pilot is in preparation for a state regulation requiring all water utilities to reduce water loss starting in 2019, Cole says.

Cole says they haven’t calculated dollar savings but do work closely with the power teams. “We want to save our rate payers money. We need to reduce power consumption in terms of that,” he concluded.

SDCWA PURSUES SOLAR, HYDRO POWER
The San Diego County Water Authority has been aggressive in developing local renewable energy systems and continues to do so with its growing list of energy initiatives. Its intent is not to become energy self-sufficient, but to produce the revenues that will keep rates low. Andrea Altmann, a senior management analyst in the Water Authority’s Energy Program, says, “We use renewables during the day and what we don’t use we send back to San Diego Gas & Electric to reduce our utility bill costs.”

SDCWA delivers wholesale water supplies to 24 retail water providers, including cities, special districts, and a military base. It uses 86,000 MWh annually in its operations. Its solar systems, pumped hydro, and inline hydro projects produce 66,000 MWh annually.
The Water Authority has also been very successful in reducing water usage in response to the decades of off- and on-again droughts. It has seen a 47% decline in per capita water use since 1990, from 235 gallons per capita per day (GPCD) in 1990 to 124 GPCD in 2017. The state-mandated 2020 target is 167 GPCD. This reduction offsets the need for over 300,000 acre-feet per year within the region.

SDCWA signed a 20-year agreement with San Diego-based Borrego Solar Systems, which built three solar arrays. They have been operating since 2011 on the roofs and car ports of its headquarters in Kearney Mesa, its Escondido Operations Center, and the Twin Oaks Valley Water Treatment Plant. Together, the three systems generate about 2.7 million kilowatt-hours (kWh) annually, representing 45% of energy used in the facilities. Combined, they will cut the agency’s energy expenses by nearly $5.6 million over 20 years.

Borrego owns and operates the systems and sells the power to the Water Authority at a reduced and fixed rate with an annual price escalation factor.

SDCWA is exploring the potential of building a floating solar system on its Hodges Reservoir in the northern portion of San Diego County. It is discussing a public-private partnership with Cratus Energy which is working on the design of a solar/utility connection and environmental review. Altmann says the Water Authority would expend no capital. The current issue is working through a business model.

Jeff Shoaf, also in the Energy Program, says the issue confronting both the Water Authority and Cratus is that they do not know of an installed floating system on which to model a design. They need to coordinate with regulatory agencies and deal with environmental issues such as impacts on water quality. He said there is a very large learning curve involved here beginning with how to anchor the solar framework to the floor of the reservoir or on the shoreline and dealing with fluctuating water levels. “The developer has been struggling,” he says.

The current plan is to have the floating solar system cover about 20 acres of the 2,300-acre Hodges reservoir. The idea began with a request for proposals in 2014, which produced no responses. Another RFP was released in 2016 and Cratus was the lone contractor to respond. The SDCWA Board approved general terms and conditions in 2017. Staff will ask the Board to approve a power purchase agreement once the project receives California Environmental Quality Authority (CEQA) approval, says Altmann.

**CLEAN ENERGY STORAGE**

In March 2018, SDCWA announced that ENGIE Storage had completed installation of commercial-scale energy storage batteries at the water authority’s Twin Oaks Valley Water Treatment Plant near San Marcos. The system was commissioned five months later, in August, following testing. The Water Authority says the 1-MW/2-MWh system will save approximately $100,000 annually.

The energy storage system is designed to reduce operational costs at the facility by storing low-cost energy for use during high-demand periods when energy prices are at their highest. ENGIE Storage will use its GridSynergy software to charge and discharge stored energy, either from the grid or the onsite solar energy system which generates 1.75 million kWh annually.

Santa Clara, CA-based ENGIE Storage, a division of ENGIE
North America, signed a power efficiency agreement with the Water Authority to install the $2 million system at no cost to SDCWA. It owns, operates, and maintains the system under the 10-year contract. The California Energy Commission provided $1 million to help fund the project, under the California Public Utilities Commission's Self Generation Incentive Program.

**PUMPED STORAGE**
SDCW A has several pumped storage facilities in operation or in the planning stages. The 40-MW Lake Hodges Pumped Storage Facilities began operating in 2012 following seven years under construction. It has eight hours of storage capability, says Altmann. It provides emergency water storage for up to 40,000 homes. She says the water authority works cooperatively with the City of San Diego which owns the Hodges Reservoir while SDCWA owns the pumped storage facility.

Water is stored in Olivenhain Reservoir 770 feet in elevation from the Hodges Reservoir through a 1.25-mile-long pipeline connecting the two reservoirs at the Lake Hodges Pump Station. The pump station extends 10 stories underground and houses two 28,000-hp pump turbines capable of generating 20 MW each. An inlet-outlet structure is located below the surface of Hodges Reservoir and links the pump station through a 200-foot-long tunnel, allowing water to be moved back and forth.

When electricity rates are low, water is pumped uphill to the Olivenhain Reservoir and during high energy demand periods, that water is released downhill, passing through the pump station, activating the pump turbines, and generating 40 MW of power, helping to manage temporary peak demands or unplanned outages.

SDCW A is also planning a 500-MW pumped hydro system with eight hours of storage at the city-owned San Vicente reservoir and is currently undergoing negotiations with Brookfield Renewable. Altmann says construction has not been scheduled.

Lastly, while not considered pumped hydro, SDCWA buys 1.7 MW from Hoover Dam under a federal preference power contract.

**INLINE HYDROPOWER**
SDCW A is expanding its inline hydropower production as well. Like a water wheel, explains Altmann, energy is captured by small pump turbines as the water flows through large-diameter pipes. It already owns and operates the Rancho Peñasquitos inline hydro generation facility which has been operating since 2006. Power is generated year-round using a single 4.5-MW horizontal turbine, providing 25,000 to 30,000 MWh annually.

The power is sold on the California ISO wholesale energy market and generates approximately $500,000 in annual revenue for SDCWA.

The Water Authority is planning to rehabilitate the Alvarado Hydroelectric Facility, which was built in 1984 and damaged by flooding in 2007. The two original 1-MW pump turbines will be replaced by a 1.7-MW turbine since flows have changed quite a bit, says Altmann. She says the staff was planning to go to its board for approval of a design and construction plan this summer and release an RFP later in the year. Construction is estimated to cost between $7 million and $8 million. Once operational, the facility is expected to bring in $600,000 in annual revenues.

**DE Salination**
SDCW A buys up to 56,000 acre-feet per year of water from the Carlsbad Desalination Plant owned by Poseidon Water. It started operating in December 2015 and is the Water Authority's largest energy user. Altmann says its energy costs are much larger than what SDCWAs solar, clean energy, and hydropower resources produce. The Water Authority holds a 30-year power purchase agreement with Poseidon that includes a minimum 48,000 acre-feet per year take-or-pay guarantee. Poseidon also built a 10-mile pipeline to SDCWAs aqueduct.

**GREAT LAKES UTILITIES REDUCE POLLUTANTS**
The Great Lakes Protection Fund and the American Water Works Association created the Water Utility Energy Challenge (WUEC) in 2017 and focused on the Great Lakes Basin. The challenge aimed to connect the utilities with new and innovative software that reduces mercury and other emissions while reducing the utility’s operations and management costs. Two of the winners are profiled below.

The Locational Emissions Estimation Methodology (LEEM) is designed to allow energy managers to track, control, and reduce emissions that result from consumption of electricity. The Pollutant Emission Pump Station Optimization...
The Los Angeles Department of Water and Power is refurbishing pumps, as seen in these before and after photos, and coating them with Belzona, a metal super glide coating to improve flow efficiency.

For related articles: www.WaterEfficiency.net

software package (PEPSO) is designed to perform optimization of large water distribution systems including cost and environmental emissions. PEPSO is integrated with the LEEM data stream coupled for ease of utility operator use.

Developed and maintained at Wayne State University, LEEM provides predictive and real-time emission intensity data for mercury, CO₂, SO₂, NOₓ, and lead in 18 midwestern and eastern states. With PEPSO, water utilities can reduce pump energy consumption and reduce related pollution emissions while maintaining the required flow and pressure of the water distribution system.

Consulting firm E2i, formed by Wayne State and Commonwealth Associates to commercialize LEEM and PEPSO, provided the emissions data free of charge to the water utilities participating in the challenge. Its founders are developing a price schedule to offer it to all interested water utilities with special pricing available to AWWA member utilities, according to Stephen Miller, with Commonwealth.

ANN ARBOR OPTIMIZES WATER OPERATIONS

The City of Ann Arbor, MI, was awarded $20,000 by the Great Lakes Protection Fund and the American Water Works Association for their program to track and eventually reduce emissions, including mercury, lead, carbon, and nitric oxide produced by local power plants on Lake Erie.

The Ann Arbor Water Treatment Plant won the title of Water Utility Emission Champion by using LEEM to shift the schedules of their filter washing, based on tracking emissions. Energy efficiency and sustainability were top priorities of the water treatment plant.

Michigan is located within the MISO bulk electricity transmission market for the mid-US states. Its generation sources include coal, nuclear, natural gas, hydro, and wind. The water treatment plant receives both surface water and groundwater sources and supplies an average daily demand of 14 million gallons per day to approximately 125,000 people.

Brian Steglitz, manager of water treatment services for Ann Arbor, says, “We are getting hourly reports of emissions from [E2i] and using the data to optimize the operations of our water treatment plants.” LEEM data adjusts the timing of the 26 filter washing system operations which do 220 to 280 filter washes a month.

Every evening E2i sends the WTP an email providing a table and graphs of estimated marginal carbon, mercury, SO₂, NOₓ, and lead emission intensities for electricity consumed at the WTP’s location over the next 24 hours. The supervisor reviews the email, looks at the LEEM day-ahead graph for hourly mercury emission intensities, and then schedules, when possible, the filter washes to take advantage of periods of both low energy costs and low marginal mercury emissions.

Before the competition, the treatment plant normally scheduled filter washes between the hours of 11:00 p.m. and 7:00 a.m. to take advantage of low electricity rates, says Steglitz. This changed when LEEM day-ahead forecasts regularly showed midnight and very early morning hours to be high-emission periods when the likely marginal generator fuel was coal.

So the treatment plant supervisors started scheduling filter washes during later morning hours—around 6:00 a.m. to 10:00 a.m.—when power costs were still low. Natural gas was often the marginal generator during that period and thus, marginal emissions for mercury were lower. Each filter wash shift from a high emission hour to a low emission hour reduced the emission impacts.

From May 2017 through March 2018 the water treatment plant reduced carbon emissions of filter washing relative to the historical baseline by 25.7%. Mercury emissions were reduced by 32%. The treatment plant used LEEM consistently to keep emissions levels below the prior-year baseline.

Other energy efficiency improvements at the treatment plant included installing variable frequency drive pumps. Treatment plant staff also tried to use the PEPSO pump scheduling optimization software tool to further reduce energy and emissions, but it proved to be more complicated than they hoped.

Steglitz says they are still analyzing the savings already achieved and have yet to decide if they want to pursue using PEPSO to optimize power pumping. The decision may rest on whether they decide to sign up for the subscription service with E2i.

Steglitz says the department has sustainability goals and is seeking to be as efficient as it can be and to reduce costs. The city has two hydropower plants and generates 1.5 MW which goes into the grid.

LAKE HURON WATER SWITCHES WASH TIMES

The Great Lakes Water Authority (GLWA) won Best Pilot Project in the Water Utility Energy Challenge. It has five water treatment plants which supply water to 3.9 million people living...
in eight Michigan counties. It is also located in the MISO bulk electricity transmission market. GLWA entered its Lake Huron Water Treatment Plant in the energy challenge as a pilot project with the potential to extend it to its other four plants.

The Lake Huron Water Treatment Plant has 30 very large filter wash systems and typically does 120–200 filter washes a month, depending on water demand and water quality conditions. The plant supervisor receives the day-ahead LEEM emission forecasts every night from E2i and posts the carbon emissions graph in the control room. Using the graph, the supervisors are able to schedule filter washes during hours when both carbon emissions and electricity prices are low. They take care to not schedule too many filter washes at the same time to avoid potential demand charges.

From June 2017 through March 2018, the Lake Huron WTP reduced carbon emissions through filter washing relative to the historical baseline by 4.1% and mercury by 8.8% by shifting operations to low emission/low-cost periods.

In March 2018 a large variable drive primary intake water pump failed, affecting the emissions levels. Colder than normal water temperatures contributed to poorer intake water quality and the need to significantly increase the number of filter washings over the prior year’s baseline. This combination increased the overall emissions from filter washings.

However, the plant staff followed an active schedule of switching to lower emission time periods and this resulted in emissions per kWh for filter washing not increasing as much as might have occurred. For example, in March 2018 the number of filter washings increased 13% over the prior year’s baseline. However, mercury emissions rose only 8% during that time and the normalized pounds per kWh of mercury emissions fell by nearly 5%.

Shaker Manns, GLWA’s energy manager, said pumps did not use less energy during the period studied; instead, megawatt hours were reduced using the LEEM data to drive strategic operating decisions.

GLWA is actively reducing energy usage in other ways at its plants as well. It is upgrading its heating, ventilating, and air conditioning system at the Lake Huron plant with a high-efficiency system. GLWA’s pump system is also getting an energy efficiency upgrade. In one program, GLWA staff is using real-time booster station data to optimize booster station operations. Furthermore, LEEM or PEPSO could potentially be used to manage water tower reservoirs in some communities.

**AMERICAN WATER PROMOTES SOLAR**

American Water maintains a portfolio of solar, wind, and biomass facilities. The company has installed over 3.1 MW of solar generating capacity at 11 facilities across three states (New Jersey, Illinois, and Missouri) with plans to install more solar at additional facilities. Furthermore, its affiliates have initiated projects to generate alternative energy or reduce energy for clients or in their own operations.

Indiana American Water broke ground on a new $1.4 million solar project at its Newburgh Operations and Treatment Center. It will cut the company’s cost for electricity by approximately $65,000 annually and abate nearly 500 tons of CO₂ emissions a year.

In 2005, New Jersey American Water installed the state’s largest ground-mounted solar electric system at its Canal Road Water Treatment Plant in Somerset, NJ. It produces up to 730,000 kWh annually and supplements 20% of the peak power usage needed to run the plant. The savings in carbon dioxide is equivalent to planting 94 acres of tree seedlings or preserving 2.6 acres of land from deforestation, according to the American Water white paper *Water-Energy Convergence: Efficiency Challenges and Opportunities*, which can be found at [www.pr.amwater.com/static-files/f7c300b6-0cad-4c81-b2eb-15a0d85fa577](http://www.pr.amwater.com/static-files/f7c300b6-0cad-4c81-b2eb-15a0d85fa577).

Furthermore, in 2011, New Jersey American Water installed solar modules on a reservoir at the Canoe Brook Water Treatment Plant in Millburn, NJ. It was the first solar array on the East Coast on a body of water designed to withstand a freeze/thaw environment. The 538 solar modules rest on a docking station designed to float on the water’s surface as it rises and falls. The array produces 135,000 kWh annually—about 2% of the plant’s power for an estimated cost savings of $16,000. The $1.35-million project was designed and built by ENERActive Solutions of Asbury Park, NJ.

At Pennsylvania American Water’s Shire Oaks Pumping Station, a successful pilot program using the Enbala Power Networks smart grid technology offset 2% to 3% of the site’s total energy cost. Essentially, this technology manages the electricity use of the treatment plant and pumps. Instantaneous water pumping is aligned with the instantaneous electrical demand of the grid thereby allowing the water utility to benefit from short-term peak shaving.

American Water has been awarded three patents for a technology called NPXpress which reduces aeration energy consumption during wastewater treatment by up to 50% and supplemental carbon source by 100%. It has been implemented at seven full-scale wastewater treatment plants in New Jersey and New York and is currently being implemented at a system in California as part of the company’s overall initiative to achieve sustainable energy-neutral wastewater treatment.

Lyn Corum is a technical writer specializing in water and energy topics.
Upon Closer Examination
Pipe inspection methods and technology
By Daniel P. Duffy

Never has it been more important to inspect and maintain hydraulic infrastructure. Never has it been harder in both remote rural areas and crowded urban environments to do so. Direct inspection of pipes and sewers is essentially impossible given the small diameter sizes of the pipes in question. Yet aging infrastructure is more prone than ever to damage and in need of repair. Fortunately, the technology for remote pipe inspection with closed-circuit television (CCTV) camera crawlers or submersible remotely operated vehicles (ROV) provides a cost-effective solution. Inserting these camera-mounted vehicles at a pipe opening and running them along its length while digitally recording what they see through the camera lens eliminates the need for costly excavation to expose the pipe while detecting.

Furthermore, this operation quickly identifies and locates problems, allowing for preventive repair operations, and flags those minor defects that could become major problems in the future. This nondestructive inspection method is fast, precise, environmentally friendly, and easy to operate. It includes software for comprehensive data recording to explain the video images, allowing for accurate reporting on the condition of the pipes being inspected.

**NASSCO AND PACP, MACP, AND LACP CERTIFICATION**
A technology needs well-established and universally recognized methodology and usage rules. These have been established for pipe inspections by the National Association of Sewer Service Companies (NASSCO). They have committed themselves to “setting industry for the assessment, maintenance, and rehabilitation of underground infrastructure, and to assure the continued acceptance and growth of trenchless technologies.” In doing so they created, in partnership with the United Kingdom’s Water Research Center (WRC), the Pipeline Assessment and Certification Program (PACP) which has become the industry standard in North America for identifying pipeline defects, assessing the condition of pipelines, standardizing inspection methods, and establishing consistent scoring procedures.

The goal of the PACP program is to establish a comprehensive and standardized database to evaluate pipeline conditions and manage pipeline repair efforts. It does not just create a unified system of coding, it also establishes a Code of Ethics as outlined by NASSCO for Certified Operator’s to follow. Similar programs were established by NASSCO for a Manhole...
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Assessment and Certification Program (MACP) and a Lateral Assessment and Certification Program (LACP).

THE PACP SCORING AND RATING SYSTEM

Before we examine the various types of structural failures or operational and maintenance defects, we need to understand the scoring system that is used to rate the condition of the pipes. These scores are referred to as “condition grades” and are rated in two categories: structural or operations and maintenance. Scoring is on a numerical scale with the highest (5) denoting the worst conditions and the lowest (1) designating minor defects—and zero indicating no defects at all:

- 5 – Most significant defect
- 4 – Significant defect
- 3 – Moderate defect
- 2 – Minor to moderate defect
- 1 – Minor defect
- 0 – No defect

Naturally, this rating system is somewhat subjective. A lot depends on the training, experience, competence, and skill of the technician doing the inspection. Furthermore, the depth and quality of the water within the pipe may obscure the pipe wall, preventing the camera from providing a clear image. Inspectors need to double-check each other’s evaluations and often have to work together to come up with a consensus on the pipe scoring. This is why PACP training and certification of the technicians performing the pipe inspections (or its equivalent) is absolutely necessary for accurate pipe appraisals.

But not every defect is a point defect. Some can extend for considerable distances along the length of the pipe or around its circumference. These can include cracks and fissures in the pipe wall or entire sections of crushed pipe. The PACP system has a simple and elegant way of converting these elongated defects into an equivalent number of point defects. This number of converted point defects is calculated by dividing the length of the defect by 5 feet (or 1.5 meters for the metric system) with the result rounded to the nearest whole number. For example, a 32-foot-long longitudinal crack would be the equivalent of 6 each point defects (32/5 = 6.4).

Tallying up the scores of the individual pipe defects results in a pipe rating. Rather, there are three different kinds of ratings: Quick Rating, Overall Pipe Rating, and Pipe Rating Index. The basic **Segment Grade** score is calculated by summing up the multiple of the number of each defect grades (1 through 5) by the number of each category of defect. For example, a pipe with 8 each grade-5 structural defects and 4 each grade-3 operational and maintenance defects would have 40 for the pipe’s structure and 12 for its O&M.

The pipe’s **Quick Rating** is a kind of shorthand describing the worst defects present in the pipe. It is a four-digit number that lists the highest and next highest severity grades followed by the number of times each of these graded defects occurs. For example, a pipe segment with a Quick Rating of 5236 would

<table>
<thead>
<tr>
<th>Condition Grades</th>
<th>Number of Defects</th>
<th>Segment Grade</th>
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<tr>
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</tbody>
</table>

### Table 1. Pipe Evaluation Computations (Example)

- Structural Quick Rating = 4516
- O&M Quick Rating = 3427
- Overall Quick Rating = 4534
- Structural Pipe Rating Index = 2.4
- O&M Pipe Rating Index = 2.4
- Overall Pipe Rating Index = 2.4

A video recording of a pipe’s interior can be considered a form of non-destructive testing in that nothing is disturbed or dislocated in the process of evaluating the condition of the pipe.
have the equivalent of 2 each defects with a severity grade of 5 (worst) and 6 each defects with a severity grade of 3 (moderate). A pipe with zero defects would have a Quick Rating of 0000. For those types of defects that number more than 9 each, letters are used to designate their quantity in increments of 5 (A = 10 to 14, B = 14 to 19, C = 20 to 34, etc.). So, a pipe with a Quick Rating of 4F2K would have 35 to 39 category 4 defects and 60 to 64 category 2 defects. The Quick Rating does not include any reference to defects in categories lower than the worst two. So, the above examples could represent pipes with the equivalent of 100 each category 1 defects, but these would not be reflected in the Quick Rating.

The Overall Pipe Rating is a grand total of all the pipe segment scores, both point defects and equivalent linear defects, for structural and operations and maintenance. There are separate Overall Pipe ratings for structural defects and operational and maintenance defects. Caution should be exercised when using the Overall Pipe rating to evaluate a pipe since it can include a large number of low-grade defects, while only a few high-grade defects are required to endanger the pipe.

The Pipe Rating Index solves this problem by indicating the overall severity of the pipe’s defects. The Pipe Rating Index is calculated by dividing the Overall Pipe rating by the number of actual defects (both point defects and the equivalent number of lengthy defects). The result is an average of the Segment Grades and gives an indication of the overall severity of the pipe defects but without indicating the actual number of defects or whether the severity is high or low.

The table on the previous page provides a summary example of these pipe evaluation calculations.

The tabulated calculations result in an overall quick rating for the pipe of 4534 with a Structural Quick Rating of 4516 and an O&M Quick rating of 3427. With a structural pipe rating of 26 and an O&M pipe rating of 26, the total Overall Pipe Rating is 52. Similarly, these result in Pipe Rating Indexes of 2.4 for both the overall score as well as the structural and O&M ratings.

### A pipe in poor condition can cause potentially catastrophic failure via pipes and seepage through the soil or the earthwork.

These ratings are assigned to pipe segments rather than the entire pipeline. Pipe segments are defined as sections of pipe between manholes, outlets, or other structures. So, a storm sewer with a length of one mile, consisting of 10 segments, each starting and ending at a manhole inlet structure, and ending with an outlet discharge at a local creek, would receive 10 ratings, one for each pipe segment. This eliminates the need to arbitrarily designate a length of pipeline for the purpose of inspection ratings and it distinguishes those segments that may have significant defects from those that have minor defects or none at all—instead of lumping unlike segments all together.

### PACP STRUCTURAL STANDARDS AND SCORING

Pipe inspections are performed to discover any defects that could impair a pipe’s structural soundness or ability to transport water. What sort of structural defects are we looking for? What could go wrong? Structural defect codes established by the PACP include the following:

- Crack
- Fracture
- Broken
- Hole
- Deformed
- Collapsed
- Joint Displaced
- Surface Damage
- Lining Feature Damage
- Weld Failure
- Point Repair
- Brick Work

Each type of defect comes in several varieties. Cracks and fractures can be longitudinal, circumferential, multiple, or spiral. Broken pipe or pipe with a hole can reveal soil or empty space outside of its walls. Deformed conditions can exist in both rigid and flexible pipe and include creasing of the wall or the pipe taking on an elliptical shape. Collapse is complete failure of the pipe wall, whereas joint displace is localized and small, medium, or large. Damage can occur to both the original pipe wall and subsequently installed lining in place. These can include spalling and delamination. Failed welds and previously patched and repaired pipes count as structural defects. For old-fashioned sewers constructed from brick, missing or displaced bricks constitute a structural defect.

In general, the scoring assigned to each type and sub-type of defect depends on its inherent severity and potential danger to the pipe’s structural integrity. That is why a damaged or missing pipe wall would rate as a 5, while an increase in pipe wall roughness rates only as a 4. Rating also changes with location depending on whether the pipe is installed as part of a standard storm or sanitary sewer system running under streets or in a more critical location passing through an earthen dam or levee. A pipe in poor condition can cause potentially catastrophic failure via pipes and seepage through the soil or the earthwork. So, a medium joint separation in a sewer would rate only a score of a moderate 3, whereas the same defect in a levee would rate as a worst case 5.

### PACP OPERATIONS AND MANAGEMENT STANDARDS AND SCORING

Operational and maintenance defects do not directly threaten the pipe’s structural integrity, but they can negatively impact its operation and performance. As with structural standards, operations and maintenance standards include multiple defect codes:

- Deposits and Encrustations – these are accumulations of various types of waste materials (grease, ragging, fines, gravel, etc.). Deposits accumulate on the pipe bottom while encrustations cling to the pipe wall up to the surface water elevation within the pipe.
- Roots from adjacent trees can enter a pipeline from various locations
Pipe inspections are performed to discover any defects that could impair a pipe’s structural soundness or ability to transport water.

**PIPE SCORING AND RISK MANAGEMENT**

At the end of the day, inspecting and rating pipes is all about risk management, specifically minimizing risk. And this risk is evaluated by estimating two factors: the likelihood of failure and the consequences of failure.

The likelihood of failure is based on the pipe’s Quick Rating. So, the likelihood of failure is calculated by dividing the first two numbers in the quick rating by 10. Again, the first number is the pipe’s highest defect category. In the example above the first two numbers are 45 (for 5 each defects rated as category 4). Dividing this number by 10 gives us a Likelihood of Failure of 4.5. If the last number is a letter, it is replaced by 0 and 1.0 is added to the result of the division. So, a 5C would have a Likelihood of Failure of 6.0.

The Consequences of Failure is a more broad-based analysis. It factors in potential social costs (impact on society and properties such as hospitals, schools, parks, etc.), economic costs (direct and indirect costs to the owner and third parties for resultant damages and subsequent repair work), and environmental costs (negative impacts on environmental assets, and post damage resource extraction). These, in turn, are rated according to the pipelines location and local demographics. Factors assigned to the calculation of the Consequences of Failure are based on pipe diameter, pipe depth below surface grade, location of the pipe segment within the pipe network, location near various types of roadways, nearby environmentally sensitive features, number of customers serviced by the pipeline, and ease of accessibility for maintenance and inspection.

The Likelihood of Failure is cross-indexed to the Consequences of Failure to form a two-axis space with the x-axis measuring likelihood and the y-axis measuring consequences. The higher the likelihood of failure, the more aggressive the rehabilitation effort needs to be. The higher the consequences of failure, the more aggressive the inspection regime has to be.

**CCTV CRAWLER AND SUBMERSIBLE ROV TECHNOLOGY**

A CCTV crawler is a form of telepresence, no different than the sophisticated submersible that found the HMS Titanic on the ocean floor. It allows for the human operator to establish a remote presence in an inhospitable environment along the entire length of...
the pipeline while providing a perfect digital memory in the form of video recordings and data entry. And it is not just limited to use in pipelines that are too small for humans to enter. The inspection of even a pipeline large enough for a man to stand up in can benefit from technology because of this superior safety, ease of use, and quality provided by CCTV crawlers. The video recording of the pipe’s interior can be considered a form of non-destructive testing in that nothing is disturbed or dislocated in the process of evaluating the condition of the pipe.

The CCTV crawler is delivered to the pipeline site by a service truck, which also contains all of the system’s electronic controls and recording technology. Equipped with a small generator, it also provides an electrical power source for the crawler and its support equipment. The crawler is connected and anchored to the service truck with a wire cable deployed from a winch. The winch plays out the cable as the crawler moves forward under its own power (either on wheels or tractor treads) until it reaches the end of the pipe or the limit of the inspection. When the inspection has been completed, the cable is then reeled in, bringing the crawler back to its point of entry. The camera is mounted to the body of the crawler on a swivel head that allows it to look in a 360-degree arc to the sides and 180-degree arc towards the front of the camera. It is equipped with LED lights and is connected via a signal cable back to the truck’s recording equipment. Some cameras come with sonar for measuring pipe wall thickness or lasers to perform accurate measurements. The location of the camera as it moves along the pipe is measured by the amount of cable deployed by the winch.

The unfortunate thing about pipelines is that they are often partially, or completely, filled with water. If only a certain percentage of the pipe has water, a CCTV crawler can still be used, though it may have trouble seeing what lies under the water’s surface. For pipes completely filled with water, a floating submersible ROV is typically used. Though similar in function and basic components as a CCTV crawler (front-mounted camera, LED lights for illumination, towing cable, signal wire, etc.), it’s basically a small submarine, with adjustable ballast tanks for changing depth and propellers for movement and maneuvering. Since the submersible can easily adjust its orientation and depth, its camera is typically not mounted on a swivel head since the whole ROV can effectively swivel while moving.

The critical elements of any pipeline inspection (dry or submerged) include proper control of online data collection systems, accurate location and measurement to ensure that defects are correctly accounted for, a means of reporting defects, and the correct maintenance and storage of the inspection data.

MAJOR SUPPLIERS
To meet the need for innovative new pipe technology, Pearpoint went back to the basics. They asked themselves, what innovative new pipe inspection technologies are available? The pipe inspection industry has a simple requirement, with a very complex response. New technology is not always the answer for a clear, complete picture of the pipe with enough clarity to identify defects. This being said, the company has created a system that will go the length of the inspection in a timely fashion, while giving the operator the tools to record defects properly with accurate footage information. New technology on the market that helped advance inspection thoroughness follows. In the last 10 years to 15 years Pearpoint has added several tools to the arsenal of the CCTV inspection operator. Laser Profiling allows the camera a reference to record the ovality of the pipe being inspected. Sonar offers the ability to see inside pipes that hold water and cannot easily be drained. The biggest advances have been on the inspection standard side of the industry with guidelines being put in place to standardize what operators see and code in the pipe.

That being said, there is the Pearpoint P350 pipe inspection system. Pearpoint uses an optical counter, making it one of the most accurate on the market. This allows the operator the comfort of knowing the footage he records is going to be solid information for reporting the location for repairs. The system uses LED lights, giving the surrounding environment ample illumination for a quality inspection of the condition of the pipes, scores are referred to as “condition grades” and are rated in two categories: structural or operations and maintenance.

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Under the scoring system used to rate the condition of the pipes, scores
defects and lateral connections into the main pipe. Pearpoint also uses low LUX cameras tuned to the light output used in the pipe. This allows for a crisp, clear, color-correct image of the interior. The Pearpoint system also has an active interface with some of the largest asset management software packages on the market. This allows the images, footage, inclination or grade, and the ovality recorded in the pipe to be stored and transferred in a standard easily used by most engineers, contractors, and system owners.

Pearpoint supports water conservation and asset management. As Pearpoint spokesperson Whitney Williams states, “The PACP standard by NASSCO has helped with this, as well as guidelines installed by the government, making it mandatory to record issues like SSO’s and offering resources to system owners helping them deal with antiquated and combined sewer systems. The more accurate the equipment that records the errors, the more proficient the planned repair should be. The industry is making a move to apply the baseline standards used for sanitary sewer upkeep and diagnostics to its aging storm sewer infrastructure in the future. I feel this is driven by the knowledge that clean water is an asset that has been overlooked for a long time, especially around the great lake regions where it is so plentiful.” What is defined as a “passing grade” for a pipe inspection? “I think if we answered this by saying, a system with proper grade, no infiltration, no offset joints, no structural defects, everyone would agree. The problem comes in with the system owner’s resources. A large community may make a 1.2-million-dollar repair to a piping system without a problem, where a Township might be forced to perform a band-aid-style repair as a triage reaction because of limited resources.”

Any differences between pipelines passing through dikes and dams versus standard sewer or supply pipe installations? According to Williams, “The placement of the pipe system always gives unique challenges to an operator. A pipe in a casing through a damn wall would have different concerns than an aerial sewer or a direct bury sewer. A cased pipe would be harder to access for a certain type of repair than a pipe buried 7 feet in the ground. A buried pipe might have other utilities in the way; electric, water, gas.” And which are more critical, structural defects or O&M issues? “This question will go down in history as, as easy to answer as which came first, the chicken or the egg. This depends on an almost endless supply of criteria. To each system owner, the answer would be different. One owner might find infiltration during a rain event to be the downfall of the system. The next one might have the treatment of the water for free release to be his biggest concern.”

Aquam Corporation, a global water and gas infrastructure firm, has launched Amplus, the most advanced remote operated vehicle (ROV) on the market. It is their most innovative pipe inspection technology launched to date. Designed for use in pressurized water, wastewater, and industrial pipe applications, Amplus was created in response to a need from cities across the US struggling to address the challenges associated with an old and aging infrastructure. At the core, Amplus’ strength empowers cities to strategically plan for the future by offering a comprehensive assessment of the condition of their pipeline infrastructure and producing actionable data to prioritize capital expenditure and improve overall system reliability.

Ultrasonic technology, coupled with HD CCTV and acoustic sensors, can determine pipe wall thickness, identify internal and external corrosion, calculate life expectancy, provide high-resolution visual video footage, and accurately locate leaks in real time. The system is inserted into live pipelines 8 inches and above through existing system assets causing no disruptions to service and has a 3300-foot inspection capability upstream and downstream of the insertion point. With Aquam’s Amplus, clients can get a deeper understanding of the overall health of their linear assets and make defensible remediation decisions regarding repair, replacement, and rehabilitation, enabling them to allocate funds intelligently. Amplus is set to be deployed by Aquam service providers with commercial, residential, utility, and municipal customers in the US and UK effective within the summer of 2018.

Aquam’s global team designs novel technologies that solve some of the most challenging infra and external structure problems safely, ethically, affordably, unobtrusively, and sustainably. Risks are largely mitigated through a three-step process: monitor, repair, and remediate the transmission and distribution of water and wastewater pipelines. The award-winning approach provides a combination of actionable data utilizing key performance indicators to ascertain the overall condi-
tion of pipes, such as leakage, pipe wall thickness, internal and external diameters, and visual intelligence.

Emma Quail, VP at Aquam Pipe Diagnostics sales and marketing, promotes preventative methodologies and technologies for condition assessment, pipeline diagnostics, and non-revenue water (NRW) assessment and reduction in the US. According to Emma Quail, “My passion continues to be about increasing awareness of sustainability and conservation of one of our most precious resources. Therefore, I am proud to be at the forefront of a progressive and innovative company who are committed to offering quality services and advancements in pipeline assessment technologies. As a volunteer on the AWWA Water Loss Control Committee and a contributing author of the new M77 Manual of Practice: Condition Assessment of Water Mains, I am proud to play an active role in the water and wastewater industry here in the US.”

Aquam’s technology is also uniquely qualified to handle aging and iconic structures. For example, in the aftermath of Hurricane Sandy, when many of the historic buildings in New York City suffered damage to their pipes, roofs, and drains. St. Thomas Episcopal Church—an iconic west side Manhattan cathedral completed in 1914 and an institution for Gothic Revival architecture—is one of those buildings. Buried behind layers of stone in hard-to-reach areas of the wall, the church’s pipes were clogged with dirt and sediment. Water leaked from the pipes and threatened to damage parts of the wall in the church’s sanctuary. Utilizing non-invasive diagnostic and remediation procedures, NuFlow, a subsidiary for Aquam Corporation, successfully assessed the problem with a specialized camera and coated the corroding pipes with an epoxy liner to prevent further damage and leakage into the wall.

Angel Estrada, St. Thomas facilities manager touches on the experience: “After being the facilities manager for more than 30 years, the challenges of this building still surprise me. Once I eventually realized that the pipes could be rehabilitated in a matter of weeks, and without disturbing the church’s regular worship services, I wondered why we had waited so long to tackle the seemingly impossible task. I believe in innovation, which is why my biggest takeaway coming out of the experience was to keep an open mind about partnering with private sector entities and out of town specialists.”

Daniel P. Duffy, P.E., writes frequently on the environment.

At the end of the day, inspecting and rating pipes is all about risk management, specifically minimizing risk.
Looking for Leaks
Technology for locating and addressing water leaks efficiently
By Lori Lovely

Water loss can be attributed to unbilled authorized consumption such as firefighting or flushing water mains, unauthorized consumption, and real losses due to leakage. All are examples of non-revenue water loss.

Utilities can conduct system-wide water audits to assess leakage by estimating consumption and loss through the use of performance indicators, metrics, and benchmarks. Or, they can use technology to locate leaks. Most use sound to identify the location, although increasing use of smart technology can also help.

The key to success in maximizing savings and minimizing water loss depends on the early detection of leaks to reduce their duration, with the goal of repairing them before they progress to costly water main breaks.

It’s no secret that the country’s water infrastructure is aged and, in many cases, deteriorating. Leaky pipes can cause service disruption and can have a severe economic impact from the loss of treated water, increased maintenance budgets, interruptions, and property damage. Even before the situation deteriorates to the point of leaks, pipes can suffer from reduced flow capacity and pressure.

An essential factor used to quantify the condition of underground pipe is water main break rates, which are calculated for all pipe materials used to transport water in order to judge performance and durability, as well as to aid in asset management decision making.

SURVEY SAYS...
Utah State University’s 2012 and 2018 water main breakage studies, which reviewed almost 13% of the total length of water mains in the US and Canada, reported that during that six-year period, water main breaks increased by 27% from 11 to 14 breaks per 100 miles per year, with smaller utilities experiencing break rates more than twice as high as larger utilities suffer. Significantly, the break rate of cast iron and asbestos cement pipe, which make up 41% of the installed water mains, have increased by more than 40% over

The survey, one of the largest conducted on water main failures, collected information from 308 utilities covering 197,866 miles of pipe. It recorded 23,803 failures that needed to be repaired. The report is used to update the average estimated service life predictions for pipe materials when considering asset management pipe repair and replacement decisions.

Pipe material differs by geographic region. The four most common types include cast iron (28%), ductile iron (28%), PVC (22%), and asbestos cement (13%). The remaining percentage consists of HDPE, steel, molecularly oriented PVC, concrete steel cylinder, and other materials.

The empirical data in the two Utah State studies compare changes over time regarding water main break data in order to benefit water asset management planning, but the American Water Works Association also conducts studies to formally track issues and trends. As long ago as the 1990s, the AWWA indicated that aging infrastructure was a concern and water main replacement was inadequate, an issue that remained a concern in their 2016 and 2017 surveys.

The Utah State study found that 16% of water mains are beyond their useful life, but utilities don’t have the funds to replace them. An Environmental Protection Agency study in 2002 indicates that the number of pipes in need of immediate replacement is growing, but only 0.8% of installed pipes are replaced annually. At the current replacement rate, the expected service life of pipe is 125 years; however, the average age of failing water mains is only 50 years.

In addition, state and provincial regulatory agencies across North America are bringing forward requirements for water utilities to report on current non-revenue water levels and take action on improving data reporting and lowering water losses. States such as California, Georgia, Texas, Tennessee, and the Canadian province of Quebec are among some of the leaders in regulating utilities to control system water losses to economic levels.

With more than 286 million Americans getting their water from a community water system, it is imperative to maintain water pipes and minimize water loss. The Utah State survey states, “It is believed that at many utilities, pipe replacement levels are inadequate to keep up with the rate of deterioration. Maintaining an obsolete system can cause severe financial hardship for cities as well as increase public health risks.” It suggests managing assets at an acceptable service level at the lowest life-cycle cost.

GOING DIGITAL
Based on the studies, it’s clear that the key strategy for maintaining a working water system is to locate and repair leaks, documenting the information for future analysis. “The last step is

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missing from many utilities,” says Kelly Olson, senior manager of business development, Core & Main, the largest national distributor of water, wastewater, storm, and fire protection products. She is a proponent of core asset management—the collection and repository of data such as GIS locations, as-builts, field inspections, repairs, conditions, performance, and monitoring.

Olson is also a proponent of using a mobile format in the field. “It’s important to get digital information… to collect data so you can do mapping and historical analysis.” She also advocates using GIS mapping to actively maintain assets and suggests using InfraMap, a software conducive to asset management. “You can use a tablet [in the field] to digitally record the location, the type of crack, the type of pipe, and what was done to fix the problem.” In addition, it can help predict future leaks.

Finding a leak underground is difficult, Olson explains, because no one knows where it is. The use of leak listening devices like those from SubSurface Instruments can aid in leak detection. They attach to the valve of the hydrant and listen to the pipes for clues like higher velocity, a whistle, or a loud rush. “You have to keep moving around the system to pinpoint the leak between valves. It’s very labor-intensive.”

However, when the amount of water being pumped doesn’t match the amount of water being billed, a leak is the possible culprit. If the water loss is more than 10%, it’s not getting to the customer, Olson says. At that point, “you need to find the leak and fix it. A listening device will help, and a leak listening system will document it correctly.”

Proper documentation is a critical step in asset management communication. “The younger generation speaks a different language, but as the older generation retires, they are taking knowledge with them,” observes Olson. “Documentation can be an important aspect of succession planning.”

The only downsides she notes are a technology buffer and the cost. Nevertheless, she sees a changing of the guard. “Digital leak listening is the way of the future.”

CAN YOU HEAR ME NOW?
A leak sensor on the pipe next to the community module that is connected to the meter listens to flow in order to find leaks. This acoustic system pinpoints leaks by listening to water volume, explains Mike Scarpelli, director of product management and customer quality North America, Itron Inc. “The more leak sensors you have, the more you can pinpoint a leak.” He says that other technology requires a lot of coordination to pinpoint leaks. “Our product is smarter because the solution is connected. Our system works with all connected devices.”

He considers leak sensors an important part of asset management for detecting apparent and real loss. With non-revenue water loss at 30% globally, the real-time reporting and real-time alarms are key to catching leaks early. “If you pinpoint it, trucks don’t have to hunt [for a leak],” explains Scarpelli. “That saves time and is a more efficient use of resources.”

It’s one of the innovative ways in which utilities and cities manage water,
Once the data is collected, the utility can act on it by prioritizing which leaks to go after.

Scarpelli continues. Software and smart networks provide visibility and information to empower the customer to conserve water and use resources more wisely. Satellite imagery and traditional use of AMI can also uncover leaks, particularly if the leak is a continuous flow, like a running toilet.

Once the data is collected, the utility can act on it by prioritizing which leaks to go after. Baltimore Water, for example, has discovered 180 leaks a month, according to Scarpelli. The data allows them to rank their leaks by urgency and address as needed or as time permits. By arming itself with this information, a utility saves water, electricity, manpower, and time.

Itron recently launched a new meter. The Intelis water meter is part of the company’s end-to-end smart water solution: network, community, back office, meter, community module, and leak aerator. No moving parts means lifetime accuracy without hardware maintenance. Real-time alarms and flow data from the meter, coupled with an OpenWay Riva water module, alert utilities to leaks, theft, and backflow.

**IT’S 3 A.M. DO YOU KNOW WHERE YOUR WATER IS?**

The 3 a.m. hour is very important to detect leaks, says Aaron Beasley, vice president of sales, Water Signal LLC. “You have to break down usage per unit [in multi-family dwellings] and middle-of-the-night usage. If use is over 3 gallons at 3 a.m., there’s a problem.” Similarly, in an office building where there should be no usage at night, if you see usage, you have a leak somewhere.

It could be a running toilet or an icemaker line. Whatever it is, Beasley says it would show up on the data collected by their device, which is non-invasively attached to the meter to turn it into a smart meter with a water signal graph that allows the customer to see and quantity water usage.

The key in leak detection is benchmarking: tracking usage to record a history. The daily snapshot is an important aspect of data collection. Then an algorithm is applied to break down overall usage per unit average.

“Our solution is data collection,” says Beasley. “We monitor and look for anomalies. Then we send alerts by text or email.” Hourly alerts indicate a major event that needs attention immediately. Daily alerts—usually sent by email—are used for high-usage or abnormal days. “The building response is to find the leak and make decisions based on the data, not an assumption based on the water bill.”

He says multi-family dwellings can save an average of 14% annually by benchmarking, and he has seen commercial offices experience a 30–40% reduction, although he says the difficult aspect for them to get around is the cooling tower. In addition to those savings, he says the return on investment sometimes includes sewer credits from the city.

The intent is to be proactive. In addition to sending alerts based on established parameters, Water Signal grants clients access to a dashboard so they can look at the data. “Everyone can see, from the CEO and president on down,” indicates Beasley, adding that some school and university systems let their students see in order to engage them in water usage and conservation.

Some customers want more, Beasley says. Water Signal trains them to use the system and perform data analysis. Smart technology is intuitive, he believes.

Education is the future, he believes. “We are barely scratching the surface now. Energy is at the forefront with LED; gas and water are just starting to come to the forefront.” It’s an important change at a time when 50% of irrigation is run-off and just one Houston company uses 70,000 gallons a day. “Water has an end date; we must manage usage.” That’s why his company, while geared to detection, is focused on conservation. “We want to save the world, one thirsty property at a time.”
GO WITH THE FLOW

Saving the world through water conservation is a noble and vital objective, but the short-term goal for many utilities is reducing costs. “Private water companies are loss-conscious,” says Barry Spiegel, director of sales, municipal markets, McCrometer. “Every wasted drop is revenue they can’t charge for.”

Clean water is expensive—and it’s also expensive to uncover leaks. “You need equipment and manpower to dig,” continues Spiegel. But there was a time, he says, when “no one cared about water loss” and “a lot of rural communities didn’t even have meters.” Over the years, however, the cost of non-billable water loss grew. “Now, it’s rare to find a community not billing—at least at a flat rate.”

One way for utilities to achieve “significant savings, depending on the cost of water” is to incorporate flow meters. “Water treatment plants filter things out of the water,” explains Spiegel. “Valves control the flow.” A flow meter can indicate a potential leak by recording flow measurement.

McCrometer is not a leak detection company. Spiegel explains that the company is the “only large pipe manufacturer of flow meters that can talk to AMI.” Their device connects to the utility’s AMI system to record the flow. “Our meters hook up to automated meters.”

McCrometer offers a full profile insertion meters for large pipe—their specialty—that don’t require shutting off the water to install. “There’s no cutting. You just insert the meter and go,” indicates Spiegel.

They provide around-the-clock coverage and their alarms and controls help utilities find water loss, whether due to poor accounting, theft, or leaks. “We find the general area of the problem. It saves time by pinpointing areas.”

They are particularly useful in cases in which one town sells water to another town. A meter is placed at the interconnect to record the amount of water sent and billed. It’s also convenient in areas where there are no power lines because it’s battery-operated.

Spiegel believes that a combination of flow meters, sound detection, and other devices allows for the rapid deployment of people to find a leak.

NARROWING DOWN THE NOISE

American Leak Detection Inc., an international franchise company for residential, commercial, and municipality water management, uses a wide variety of tools to locate leaks. “Trimble has new technology to record sound files from the hydrant onto a cell phone,” says Jim Carter, senior director of corporate field services. “The water districts like it.”

The company also manufacturers a microphone and leak finder that produces a GPS recording on the logger location. “With sound information on a computer, it can be difficult to determine if it’s ambient and background noise or leak noise,” says Carter.

The way to determine the type of noise is to rely on experience and use a wide range of tools to help identify the size of the leak, low or high pressure on the line, soil type, and...
whether the pipe is wrapped, which can muffle noise. Sometimes pipes are wrapped in a 20 mil plastic sleeve that makes detection difficult. He relates an instance of water ballooning into the coating, preventing spray and noise. “It was hard to find the leak. Sound changes when a pipe is not metallic or is wrapped in a coating.”

Traffic, wind, and ambient noise also affect detection of leaks. So can soil content—sand and rock are especially tough. Other underground infrastructure can complicate leak detection. Buried steam lines, water lines, and high-voltage lines produce noise that causes interference. “You can pick up a 60-cycle electric hum that looks like a possible leak,” admits Carter.

Different sized leaks produce different sounds. GIS location, diameter, and type of pipe material also affect the sound. That’s why experience is so important. “You need knowledge of the equipment,” insists Carter, adding that it typically takes about five years to become proficient.

This is why water districts need to be proactive, Carter believes, by incorporating metering with leak indicators and adding more loggers. “Hydrant loggers allow you to see sound and pressure and provide better data.” He says the use of this technology reveals 15–200 small leaks per survey. Finding them early saves energy, treatment, wear on pumps, and money.

**SEEING IS BELIEVING**

Problems with drinking water systems are mainly associated with the age of their pipes, reiterates James Perry, vice president of business development for Utilis Corp, a data provider to water utilities that has developed a new way of detecting NRW leaks by analyzing images from satellites. “Most metal pipes last 75 years at the most; newer systems built with plastics last 25 years.” In both cases, these systems have surpassed their usable lives. Due to this infrastructure breakdown, leaks are occurring with greater frequency.

That means the response by utilities has been reactive. A quick assessment of management in cities worldwide indicates that most utilities react to anomalies in their water management systems, such as measuring a pressure drop via a district metered area or smart water management system or responding to a flood from a pipe that has already burst. This results in significant water loss and expense.

“More and more breaks are occurring, [but] the cost to replace these pipes is too prohibitive,” Perry observes. The two methods most commonly used by utilities for managing non-revenue water are smart water management systems and acoustic leak detection. According to Utilis, most water managers use

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**Satellite remote sensing technology can identify the signature of drinking water underground and help utilities pinpoint leaks before they surface.**
these methods because they are currently the best solutions available on the market. However, they are time-consuming and expensive, delivering a very low ROI.

“The older methodologies of simply ‘listening for leaks’ is inefficient and takes years to survey an entire system of pipes. Newer technologies are a huge capital expenditure, work on only a limited portion of the system, and [are] very expensive to install and maintain. A better way must occur.”

He believes Utilis has found a better way. They use satellite remote sensing technology that sees the signature of drinking water underground. It covers a vast area of land in one image (1,300 square miles) and provides points of interest to utilities, who, in turn, use their field leak detection teams to pinpoint leaks, fix, and repair before the leaks surface. “This avoids the damage that occurs with surfaced leaks,” elaborates Perry.

This full-system survey is a digital approach to field leak detection that he considers a more efficient use of resources. “By finding more leaks per day, we are the lowest-cost-per-leak-found in the industry today.”

Utilis detects leaks in water supply systems by analyzing satellite images and presenting results as a data layer within a web-based application. The satellite’s sensor sends electromagnetic waves to Earth that penetrate the first few meters (depending on soil conditions) and then scatter. A portion of the waves are reflected back towards the satellite where an onboard sensor receives and measures the energy. Utilis translates this energy into a unique signature that is based on the interaction of the electromagnetic wavelength and the material it is hitting.

Utilis remotely senses under- and aboveground water leakage using a primary algorithm that detects treated water through the analysis of satellite imagery and filters out all other signals. A large area can be assessed all at once, within minutes, with the ability to triangulate a leak to a small region. Unlike other satellites that are limited by daylight or good weather, the Utilis system is based on microwave reflectometry. Microwaves travel through atmospheric interference such as clouds, dust particles, and aerosols. Therefore, they work in any light.

The process works by a microwave sensor onboard a satellite acquiring images and processing a corrected image. Treated water leaks are identified by use of the proprietary algorithm, which removes undesired “noise” such as reflections of buildings, vegetation, and other topographical features. Data is then presented graphically as a GIS data layer. Teams in the field receive information enabling them to locate, confirm, and repair the leaks.

The system can survey large areas all at once in a single screening, as opposed to taking years. Other benefits include ease of use in any GIS system, remote operation, no installation required, and consistent results. It doesn’t require equipment on the ground; it uses electro-acoustic techniques to mark the location of the leak.

**STILL LISTENING**
From the most basic early non-amplified aquaphones and geophones to more modern electronic amplified acoustic listeners and ground microphones, acoustic leak detection has been conducted through labor-intensive surveys of the distribution systems, relying on human expertise. However, says Alain Lalonde, Echologics director of business development for Mueller Water Products, periodic surveys are no longer considered best practice due to the rising costs associated with water, aging infrastructure, the shrinking workforce, and increasing regulations. "Real water conservation and loss prevention require ongoing and sophisticated monitoring."

Echologics uses acoustic technology to find and monitor leaks and assess the
condition of water distribution pipelines without breaking ground, inserting tools in the water line, or disrupting service. Acoustic sensors are attached to existing contact points such as fire hydrants, valves, or directly on pipes. A sound wave is induced in the pipeline and a pair of acoustic sensors capture data, which is analyzed using their proprietary algorithms to identify leaks and assess the integrity of the lines.

Each of their products focuses on a different aspect: LeakFinder-ST accurately pinpoints leaks before they become detectable by conventional methods. EchoShore-TX provides continuous leak monitoring for large diameter water mains while EchoShore-DX provides continuous leak monitoring for smaller distribution mains. EchoShore-M provides mobile leak detection that can be easily operated by utility crews and ePulse provides condition assessment of both distribution and transmission mains while simultaneously searching for leaks.

By identifying leaks at or near their inceptions, the runtime can be reduced, lessening the labor and costs needed to repair them. Lalonde mentions a UK company that manages 35,000 kilometers of water distribution network, supplying water to 4.3 million customers and water recycling services to 5.5 million customers. “Our client was due to replace 402 kilometers of water mains to optimize financial returns for its pipeline replacement program; ePulse condition assessment was used to help determine if and when certain sections of pipe needed replacement. We found that a 198-meter section on the replacement plan was actually in good condition and did not need to be replaced.

As this section ran under an environmental protection area, the complexity of the work and risk of negative environmental impact would have added to the cost. This led to a direct cost saving of over $150,000, along with the added benefits of reducing the environmental impact, carbon footprint, and disruption to local customers’ daily life.”

The company’s first project in Southeast Asia was installed in Malaysia to survey more than 3,000 kilometers of pipeline. Within the first 17 months of deployment, they identified and located 252 leaks and were able to save more than 25 million liters per day. The utility expanded its leak detection program to survey an additional 1,500 kilometers of trunk mains at an average rate of 40 kilometers per week, accurately pinpointing 120 leaks and saving a further 7.9 million liters per day. “That’s a savings of 32 million liters per day—enough water to supply an additional 152,000 residents every day,” calculates Lalonde.

He believes that the automation of data collection and reporting is a key component to developing smart cities. “Monitoring smart water infrastructure gives utilities the ability to not only identify leaking pipes before they cause issues, but also [to] create significant operational efficiencies through optimized capital investments.” Through early detection of leaks, utilities can better manage their water main assets and help avoid costly and potentially disastrous events such as a major pipe burst on a bridge or near a hospital or a school.

However, he also thinks that the adoption of new digital technologies has not been fast enough in the water industry, in part because of the non-competitive nature of the industry and an “out of sight, out of mind” mentality. Nevertheless, when it comes to acoustic leak detection, the results and savings are realized right away. “Utilities are able to stop the loss of NRW, better prioritize maintenance, and know precisely when pipes need replacing,” states Lalonde. “Any one of these alone can result in huge savings, which is why leak detection and monitoring is an affordable necessity.”

He views the market opportunities that lie ahead in fixed leak detection and pipe condition assessment as “already huge” and thinks they will increase in conjunction with aging infrastructure and population growth. “Utilities and water distribution companies are becoming more proactive because it’s cost-effective.” Knowing the condition of pipe systems and finding leaks to fix is vital for this approach.
he water industry has been “data-rich and information poor,” notes Graham Symmonds, chief knowledge officer for FATHOM.

“That will continue without a reconceptualization of how, where, and why we’re using this data,” he adds. “A lot of work has to be done on utilities to be able to collect, curate, and analyze this data. There’s a lot that’s literally coming down the pipe for utilities to deal with and data management is a little bit lagging.”

Companies like FATHOM and others—as well as the

Accessibility and Analysis
Enhancing utility operations with data management
By Carol Brzozowski
utilities—seek to change that.

Today when it comes to data management for water utilities, look to the cloud.

That’s where data is increasingly being stored and water utility directors now have many options for how to leverage that data.

John Fillinger, director of utility marketing for Badger Meter, notes that historically, the water industry has moved at a “slow and steady pace” toward disruptive technologies, “conservative and slow to adopt” them.

“We’re starting to see things change in the way utilities look at how they want to solve problems, especially on the meter reading side,” says Fillinger, adding that ties into Badger Meter’s “smart water” solutions.

Flexibility is important to water utilities, says Fillinger.

“We’re seeing new technologies come in for fixed network that are low-power, wide-area network technologies,” he says. “The true definition of smart city and smart water is that they’re utilizing technologies that allow the utilities to purchase from multiple suppliers and they’re not locking themselves into a single supplier arrangement like a traditional fixed network system does.”

Among such technologies on the market is Badger Meter’s cellular technology.

Fillinger says Badger Meter’s approach with cellular technology enables water utilities to focus on their strengths of managing their water systems and allows other companies such as Badger Meter to handle the tasks of managing networks and gateways in order to obtain more data and leverage it to their advantage.

For instance, Badger Meter’s system offers 15-minute interval data from its meters. Using that data to drive proactive decisions for a utility means transcending the receipt of that data to a transformational process to be able to get intelligent information for the utility to utilize, says Fillinger.

The benefit of cellular technology is that the infrastructure is already in place for the utilities, Fillinger points out.

“They’re not having to wait for a third party to install something,” he says. “If they wanted to get started tomorrow, they could buy endpoints. They’re all set and ready to go. It gives them the utmost in flexibility moving forward.”

Another strength of a low-power, wide-area network is demonstrated in Badger Meter’s BEACON AMA software, which resides in the cloud “so it allows utilities the flexibility and the ability with any internet-connected device to be able to access the data in a very secure and reliable system,” says Fillinger.

The Badger Meter “smart water” approach also enables utilities to do a “surgical” deployment, in that if a water utility wanted to deploy the technology in a fraction of its overall number of meters, it can do so, says Fillinger.

“It can be as few as one endpoint and the deployment could be done or it could be as many as the entire population because it grows and scales with the utility,” he adds.

Case in point: Santa Fe, NM, depends on a scarce water supply. Five years ago, it became apparent to the city’s water division that its drive-by meter reading system was failing, with meters reading wrong or becoming unresponsive.

The system was operating at 60 to 65% capacity, resulting in thousands of gallons of water loss, forcing the division’s technicians to manually read the uncommunicative water meters.

Nick Schiavo, public utilities department director, and his team sought a solution to provide actionable data that the water utility could use to regularly monitor consumption patterns, detect and fix leaks, and identify inefficiencies in the water system.

Through a request for proposal (RFP) process, the city selected Badger Meter’s BEACON Advanced Metering Analytics (AMA) managed solution with ORION Cellular endpoints as well as E-Series Ultrasonic meters.

Schiavo notes that his utility had, for the first time, the ability to track at all times how much water was produced and how much went through the meters instead of manually reading them once a month and guessing about unaccounted water as well as being able to identify and address system leaks.

Santa Fe’s Water Division implemented the BEACON AMA managed solution with ORION Cellular endpoints using cellular networks to transmit information from the meters to the water utility to eliminate the need for fixed-network infrastructure.

“When you turn on BEACON AMA, it tells you exactly how many meters in your system are leaking,” notes Kyle Sager, project manager for the city of Santa Fe. “It was startling at first—we had 1,200 to 1,400 leaks. But when we

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started drilling them down, some of them were tiny leaks and easily fixable. For the big leaks, we’re finding them within 24 hours instead of a month like we had with our old system and we’re taking care of them right away.”

The system also enables Santa Fe customers to have access to a smartphone/web-based consumer application, EyeOnWater, enabling them to take a hands-on approach to their water usage via regular notifications and timely data.

“The EyeOnWater application has had a huge impact on our customer service capabilities and has been a great success for our residents,” notes Caryn Fiorina, utility billing division director.

“The application provides consumers with the capability to see consumption daily, hourly, monthly, and annually via their smartphones, computers, or tablets.”

The application also enables customers to set alerts notifying them of a potential leak or high-usage period and allows them to communicate with the utility on issues of concern.

Symmonds notes he has no doubt there is an increasing amount of data becoming available for water and wastewater utilities that’s a function of sensors and improvement in measuring technologies and meters.

“The opportunity to collect data has always been a bit of a challenge for utilities and it’s becoming more of an issue as we snap on these new devices,” he points out. “Now you can get distributed sensors for a distribution system, you can get pressure from your meters, you can shut off your meters remotely now,” he says.

Small utilities don’t have the resources to handle that type of infrastructure by themselves, so the availability of cloud storage and services that take advantage of it will be fundamental to water utility data management programs going forward, says Symmonds, adding, “We have always been a big believer in the ways that the cloud technology has democratized the availability of solutions.”

To that end, FATHOM looks at the billing vertically and allows utilities to access technology and services they might not otherwise be able to afford “because it’s a subscription model where those technologies no longer require massive investments in infrastructure or implementation at the utility end,” says Symmonds.

As business models and acceptance of these new strategies evolve for utilities, they realize there are opportunities to modernize their existing processes by accessing new services through new companies, he adds.

The opportunities for utilities transcend billing to all of its elements, including asset management systems that are available in a cloud services model in which utilities can assess pipeline monitoring, leak detection, and event monitoring and management, Symmonds points out.

“The services model allows utilities to get around this conundrum of data management and makes it that much easier to access modern tools to manage existing infrastructure,” he adds.

FATHOM also offers the Smart Grid for Water.

“It’s a term we coined a few years back to introduce the concept of how data was going to change the operational philosophies of utilities. Done correctly, there are ways to service both capacity and dollars in data,” says Symmonds.

The Smart Grid for Water is a combination of consumption (AMI), customer (CIS), and location (GIS) data, designed to create actionable information.

“With sensing technology, you can pin down exactly your average daily flows, peak month flows, and peak day flows, and become better at managing the actual distribution of water,” says Symmonds.

“Once you know what your real-time demand is, you can use that to essentially tap what is committed capacity within your system but is actually never used.”

Symmonds points out many components of water infrastructure are designed with constant demand built into them: lift stations, distribution systems, pump pressure stations, and tanks.

“Everything has some committed demand that is actually never used,” he adds. “We have this ability to extend the life of existing systems to serve more people and that’s all a function of getting better, more granular, and more time-relevant data.”

Symmonds adds that FATHOM’s Smart Grid for Water “is a way to communicate the value of that data. It also highlights the importance of intersecting different data sets: metering data, sensor data, building department data, customer information data, GIS data, operational SCADA data, and even social media data and combine or cross-compare them and get interesting insights.”

Most utilities do not have to install infrastructure to get the information, but already have it, Symmonds notes.

“Most utilities are going to AMI or at least AMR on the metering side,” he adds “Most of them have customer information billing systems, SCADA systems, and most of them have ways of communicating with their customers.”

A case in point is the ability to be able to cross-compare data to understand the state of contaminants in a system to the point where its propagation can be modeled throughout the
distribution system in such a way that it can be contained and flushed out and customers in its path can be notified, Symmonds says.

“That’s a more proactive operational philosophy,” he says. “In order to realize that, you have to have the ability to intersect the data.”

Addressing non-revenue water (NRW) loss is a key, driving factor in data management as water utilities grapple with fiscal austerity, water scarcity, aging infrastructure, and increasing expectations from consumers and regulators, Symmonds writes in a white paper on the subject.

He points out that the American Society of Civil Engineers estimates that by 2020, the capital infrastructure funding gap for water and wastewater will be $84 billion.

Closing the gap will take a concerted effort that will include going beyond the norm to seek efficiencies, especially when there is “very little appetite for massive rate hikes,” Symmonds adds.

“One efficiency yet to be fully exploited by utilities is monetizing the entire utility water cycle,” he says. “Ensuring that all water produced, treated, pumped, and distributed is actually delivered and actually billed is vitally important—environmentally and fiscally.”

Utilities are leaking money through non-revenue water, says Symmonds, adding that the USGS reports that US water systems lose 1.7 trillion gallons of water annually through 240,000 water main breaks, with some parts of the country experiencing larger numbers as the infrastructure nears the end of its service life. The US Environmental Protection Agency estimates the cost of NRW to be around $2.6 billion annually, he notes.

“An equally important component of NRW is not leaking drops, but leaking data,” says Symmonds. “The fundamental business tools used to ensure the utility’s financial health are decoupled from the physical infrastructure. The result is that many utilities are not only leaking physical water but are also leaking the data associated with the production, treatment, distribution, and sale of that water.”

To correct this problem, utilities must move to a “smarter” approach such as AMI “with substantially increased data granularity and direct integration with customer information systems under a geo-temporal data mode. Such a system will plug leaking data from time disparity, billing system errors, and meter degradation,” says Symmonds.

While a “utility can tell you to the millisecond when a booster pump is turned on, in many cases it cannot tell you until next month—or the month after, or six months later, or in some cases never—where that water went,” he points out.

In various cases, when utilities have adopted FATHOM’s Smart Grid for Water, they begin to derive significant water loss reductions and financial benefits, Symmonds says.

Other technologies leveraging data are coming to the US after having been proven successful elsewhere. Itron recently announced its first solid-state, end-to-end water meter for North America: Intelis. When coupled with Itron’s multi-purpose network, the solid-state intelligent water meter enables utilities to harness the power of data to improve water management and resourcefulness through tracking flow usage patterns at the meter level.

The meter also offers AMI and additional management capabilities with Itron’s OpenWay Riva and Gen5 networks. Itron’s open standards networks are designed to enable water utilities to support smarter, more efficient operations and deliver actionable insights.

“Research indicates that over 80% of utilities in the US are looking to invest in smart water infrastructure with a clear trend toward two-way communicating meters over one-way. As water utilities continue to embrace smart water solutions, the introduction of new market offerings such as the Itron Intelis water meter is great news for the sector,” said Ben Gardner,
president of Northeast Group, a market intelligence firm with expertise in the smart infrastructure sector.

Itron Intelis water meters have no moving parts and are designed to maintain accuracy throughout their lifetime without the need for hardware maintenance while meeting American Water Works Association standards for residential meters. Real-time alarms and flow data from the meter, coupled with an OpenWay Riva water module, enable utilities to respond quickly to backflow, leaks, or theft.

Made of polyphthalamide polymer, the meters exceed the durability demands of the industry’s traditional metal-based meter bodies.

Gavin van Tonder, president of Itron’s Water Business line, notes that with the roll-out of the Itron Intelis water meter, utilities can add more efficiency to their smart infrastructure and better address customers’ needs with real-time metering data.

“By tracking flow usage, utilities can improve the efficiency of their water distribution systems and detect leaks to reduce wastage and improve resourceful water usage,” he says.

Mike Scarpelli, director, Itron product management and customer quality, points out the meters are designed like a mechanical meter in that the flow and usage can be viewed.

“It also has various alarms that are created throughout the usage for high flow, low flow, temperature, and low battery,” he adds. “It also depicts flow through a faucet.”

Part of the Intelis design focuses on a flooded installation application. The meter was designed as a “very reliable and robust solution for crimping and sealing that canister with the register and the lid together” to address water intrusion challenges, says Scarpelli, noting that 85 to 90% of North American installations in residential areas are in pits.

The meter brings together existing Itron technologies. When put together with Itron’s end-to-end solutions — whether it be OpenWay Riva Network in the fourth quarter of 2018 or Gen5 in the first half of 2019 — it adds to the clarity and the data sets a utility can utilize, Scarpelli notes.

“Through collection management or any of those applications, you’ll get actions to go work on to prioritize,” adds Scarpelli.

Leak detection and how it couples with NRW is another significant criterion in getting data out so customers can benefit by utilities stopping leaks, notes Scarpelli.

Scarpelli sees smart metering in the water sector starting to catch up with where the electrical sector started 15 years ago.

“It started the slow take over in solid-state metering, getting more data, and delivering that data to utilities so that the end-customer gets faster service, prompter reaction,” he says. “It will take the water industry probably five to seven years to cross over the threshold from mechanical meter to solid-state to adopt a technology that is available for utilities to make better and faster decisions and become more efficient so they don’t roll a truck at $120...”
an hour to search for something. “They have actionable items to go work on because their data sets have been prioritized through applications and an in-depth solution.”

Another system being piloted in the US is offered by EMAGIN. HARVI (Hybrid Adaptive Real-time Virtual Intelligence) is designed as an artificial intelligence-driven platform to enable utility operators to intelligently manage their infrastructure in real time.

EMAGIN’s AI platform exploits data-driven technology to learn the nonlinear dynamics of both industrial and utility-scale water and wastewater systems. HARVI is designed to enable utility operators to quickly detect, learn about, and manage emerging issues in their system hours before they occur.

HARVI is also designed to help utilities hit operations, maintenance, and environmental targets with minimal capital expenditure to maximize savings through proactive management.

It clones a utility’s physical infrastructure on the cloud. It is equipped with an elegant dashboard that helps operators create, monitor, and visualize their key performance indicators in real-time.

HARVI’s Virtual Assistant enables users to conduct scenario-based analyses in simple text.

The data-driven and cloud-based architecture is designed for a seamless integration and automated process with minimal staff overhead.

In implementing HARVI into a water utility system, staff from Emagin meets with utility managers to identify challenges and goals and explore historical data, plant specifications, and the project scope.

Historical data is used to train HARVI to site-specific data and internal models are built and validated.

HARVI is then integrated with the utility’s SCADA system and staff members are provided administrative access to the platform.

Jon Grant, EMAGIN chief strategy officer, notes that the data-driven HARVI system allows utilities to see what’s going to happen within their systems 24 hours in advance, making recommendations on how to operate assets.

In a network distribution system, for example, HARVI looks at pump schedules to enable a utility to reduce energy by using the pumps that are the most energy-efficient to meet demands.

“It provides a guide to operate the system through a web-based dashboard that makes recommendations and has analytics to explain why those recommendations were made,” says Grant.

End-users can customize certain features such as proactive alarms based on forecasted conditions.

Grant says using HARVI is akin to using a map application in which a traveler inputs destination information and the application offers options for getting there, including course correction in response to conditions.

Leak detection depends on sensor placement.

Becca Fong, business development
manager at environmental software developer KISTERS North America, indicates that recently, the UN Global Environmental Monitoring Water Program went public with its water quality database known as GEMStat (www.portal.gemstat.org).

“The site is meant to inform economic development, capacity building, and training initiatives,” she adds. “Since data is reported by public agencies and NGOs worldwide, the underlying database features automated quality assurance while water data managers perform manual quality control. Other basic functionalities like analyses and state and federal reporting also are conducted. A growing number of US clients are implementing the technology to educate their residents and make them aware of flood risks or beach closures.”

Fong adds that two flood forecasting systems also are in place.

“The US-focused National Water Model portal is not made public,” she says. “The technology behind it is similar to the Flemish Water Portal, which has been public since 2014 at www.waterinfo.be.

“The system takes in radar rainfall data, other rainfall forecasts, and in-situ observations and integrates them with more than 1,000 models in order to generate forecasts for the next two to 10 days. The real-time system affords flood control professionals more time to plan and respond to threats.”

Fong described how her company’s technology coordinates collected data and forecasts that inform Merced Irrigation District (MID) operations.

“The district is still experiencing population growth and thus, balancing ag and urban water demands,” she adds.

In what she calls a “whiplash” of wet and dry years in California, Fong says the Merced Irrigation District in California’s Central Valley has come to optimize operations through real-time forecasting that predicts short-term reservoir inflows and supports operational decisions.

“The fully automated MIDH2O decision-support model pulls quality-control data from its water information system, computes, and every six hours reports on past, current, and estimated future conditions that may impact operations,” she says.

The deployment of the MIDH2O Hydrologic and Hydraulic Optimization Model was a collaborative effort including KISTERS, water resource modeling firm Resource Management Associates, and consulting engineering firm Dewberry.

The District operates reservoirs for irrigation, flood control, water supply, and hydropower generation as well as environmental stewardship and public recreation. It ranges from the central Sierra Nevada mountain range’s western slopes to the San Joaquin River, with a total drainage area of 1,266 square miles. Elevation ranges from 52 feet to 13,090 feet above sea level.

With increasing inconsistencies in precipitation and snowmelt, MID wanted to predict short-term and seasonal reservoir inflows and take appropriate action.

Every six hours, a generated report covers precipitation and snowpack, the status of reservoirs, diversion demand, and forecasted flow for key downstream locations. The appendix includes the current San Joaquin Valley report from the National Weather Service and historical plots for San Joaquin Valley basin precipitation, California snow water content, and Lake McClure storage, as well as a Merced Watershed Report featuring historical snow water equivalent time series for Ostrander and Tenaya lakes during years identified as critical.

Data sources include flow data from a network of stream gauges and SCADA data from the District itself. Information from the California Department of Water Resources, California Data Exchange Center is imported into the water information system developed by KISTERS, which is called WISKI.

Automated and manual quality assurance tasks are performed before data is passed through to a sequence of Hydrologic Engineering Center models: Hydrologic Modeling System (HMS), Reservoir System Simulation (ResSim) and River Analysis System.

The first model output becomes input for the subsequent model, says Fong.

After all models have run, resulting information is distributed back to WISKI and the report is generated, she adds.

“The District uses two weeks of observed data in order to simulate one week into the future.”
observed data in order to simulate one week into the future,” says Fong. “From observed streamflow data and soil moisture deficit computations, HMS provides reservoir inflow and elevation releases, supplemental release, and irrigation demand data to the ResSim model.”

Scripts and KISTERS’ web interoperability services ensure secure transfer of information and in a format appropriate for the decision-support system, says Fong.

The HEC model has an interactive GIS-based interface.

“However, a headless implementation may be integrated with other interfaces,” she says. “The District uses the HEC Decision Storage System interface custom configured with the web services to quickly and easily plot or visualize and tabulate data with the click of a few icons.”

Fong points out that HEC Real Time Simulation is the free public version of the US Army Corps of Engineers’ Corps Water Management System Control and Visualization Interface.

“As such, all HEC models, including those implemented in the MIDH2O optimization model, are free to the public. WISKI integration is a standard feature available in HEC-RTS version 3.1,” she adds.

Dewberry also will develop a long-term planning model to support new and refined delivery strategies for the district, says Fong.

Currently, the development of an on-farm efficiency and conservation program is underway, she says, adding that Merced is “another jurisdiction balancing population growth and its ag-based economy.”

As data technologies evolve, so too intensify security concerns.

“From a security standpoint, the data on a cellular system transfers from point to point through the network so the endpoint sends data up to the cellular gateway,” says Fillinger. “From there, it’s transferred on a private network line to a data security warehouse for the network carrier and from there it goes directly through another secure channel—a private network into the BEACON-hosted application. Nowhere does any data touch the public internet.”

That acts to help eliminate the risk of vulnerability to someone hacking into the system, Fillinger points out.

Addressing security concerns, Symmonds points out that utilities have been reticent to put anything out on the web.

“Getting people to have a SCADA system in the cloud has been a tough sell, but the reality is most of the cloud services systems have entire teams of people working on security and ensuring that systems are not breached.

“There’s a definite need to be aware of security, but I also think we should take advantage of existing platforms that do security very well and work with them. We have to recognize we’re dealing with public health and the primary duty of a water utility is to protect public health. There can and should be some extra precautions and considerations that we take.”

Carol Brzozowski specializes in topics related to water resource management and technology.
Pump Maintenance 101
Strategies to ensure consistent operation and efficiency
By Daniel P. Duffy

Maintenance will never be exciting. But it’s necessary work required to ensure that a pumping system operates when you need it. If pump operation was a football team, maintenance would be the offensive linemen who do the grunt work in the trenches of the scrimmage line and make possible the exciting plays and athletic prowess that make the quarterback so famous. But no quarterback, no matter his athletic prowess, would be anything but a defender’s tackling dummy without a strong offensive line in front of him. So, let us for once shine the limelight on repair operations and examine their requirements. Let us take a close look at pump maintenance. What are the essentials? What practices are recommended by manufacturers?

PUMP OPERATIONS AND ENGINEERING
Two characteristics define a pumping operation and flow rate: the pump’s performance and the system’s resistance. A pump’s performance determines the flow rate the pump can produce for a given pressure head. Flow rates are typically measured in gallons per minute (gpm), while pressure heads are measured in equivalent feet of water column. Water at standard pressure and temperature weighs about 62.4 pounds per cubic foot (pcf). At 144 square inches per square foot, the pressure exerted by a 1-foot-high column of water is equal to 0.433 psi. The relationship between a pump’s operating head and its generated flow rate is called a pump performance or characteristics curve. This curve is drawn on a grid with the y-axis being head (in feet) and the x-axis representing the flow rate (in gallons per minute). The curve inflects downward from a maximum head at the y-axis (when the flow rate is zero) to maximum flow rate at the x-axis (when the head is zero).

In addition to the pump’s performance curve, there are three other curves that define a pump’s operating characteristics: the efficiency curve (measured in percent), the brake horsepower (BHP) curve (typically measured in watts), and the pump’s Positive Suction Head (NPSH). The first two are roughly parabolic and help to define the pump’s recommended operating range (as defined by its flow rate). The efficiency curve starts at 0% at the point of zero flow and zero head (the grid’s origin point) and continues to a peak that determines the pump’s Best Efficiency Point (BEP). From there it curves down again to 0%. BHP is represented by a shallower parabolic curve that starts at the minimum BHP associated with maximum head and zero flow of the performance curve, peaks near the BEP, and declines again to the minimum BHP required for maximum flow and zero head. BHP is defined as “the available power of an engine, assessed by measuring the force needed to brake it.” Peak BHP occurs within the pump’s recommended operating range.

There are two definitions of NPSH. The first is available head (NPSHa) and the second is what is required (NPSHr) by the pump without being subject to potentially damaging cavitation and resultant reduction in pumping output.

The system resistance curve compares the system’s resistance head, measured in feet, to the allowable flow rate, measured in gallons per minute. Total resistance head is the sum of the elevation head difference between the pump’s Grinder pumps send wastewater to the sewer treatment system.
outlet and the pipe system's discharge point (the static head), the friction head lost as a result of water flowing along the surface of the pipe's interior walls, and the head loss from the water's flow velocity through the pipe (determined by dividing the pump's flow rate by the pipe's cross-sectional area). Since the static elevation head is a constant, the system resistance curve intercepts the y-axis (where the flow rate is zero) at a point equal to the static head. Static head is positive when the discharge point is higher than the pump outlet, zero when the two are at the same elevation, and even negative should the discharge point be physically negative (in this last case, the total system head would require large values for friction and velocity head from a complicated and long plumbing system to even require a pump in the first place). From the y-axis, the system resistance curve inflects upward to a maximum head value associated with the maximum flow rate that can be generated by the pump.

So how do these curves define the pump's operating state in terms of flow and head? This occurs at the point where the system resistance curve intersects the pump performance curve. To maximize operational efficiency, it is best to choose a pump whose performance curve results in an operating point that coincides with the pump's recommended operating range (flow rate) as defined by the efficiency curve.

**TYPES OF PUMPS**

While pump engineering is based on standard performance characteristics, pump mechanics are highly variable and utilize a wide variety of methods to move water through a pipeline. There are two major types of pumps: centrifugal and positive displacement.

Centrifugal pumps use a set of rapidly spinning impellor blades. As these impellor blades spin around an axis, centrifugal force causes the water to travel along the surface of the blades to the outer rim of the impellor assembly. Water enters the impellor unit through a port in the axis, and in effect, the spinning blades fling the water outward. The force imparted by the rotation forces the water out of the impellor casing via a discharge port built into the pump's outer housing. In general, centrifugal pumps generate high flow rates with relatively low operating heads. The lower operating heads result in lower operating costs, making centrifugal pumps a cost-effective choice for high volume water removal. There can be many variations of the impellor design. One option is a pump that utilizes flexible impellors instead of stiff, fixed vanes or blades. The centrifugal force of the rotation also distorts these flexible blades, allowing them to trap a larger amount of water and expel it from the pump. Fixed, stiff impellors can use complicated curved lobe shapes or simple flat fan blades, with a tradeoff between cost and performance.

Some centrifugal pumps do not use blades or impellors at all, but instead rely on rapidly spinning enmeshed gears. Similar to a peristaltic pump (see below), the enmeshed gears trap, squeeze, and pinch water to a space between the gear teeth and use the rotary motion and centrifugal force of the spinning gears to expel water from the pump. Centrifugal pumps also come in submersible (designed to be placed below water level) and extraction (which operate from above the level of water being pumped) varieties. Submersible centrifugal pumps get their power from a vibrating drum, which can operate underwater without the need for direct electrical power. While operating underwater is not considered a harsh environment, certain applications and fluids definitely are. These include water with high turbidity (high amounts of total suspended solids), unfiltered groundwater, water with large suspended objects such as rags or green waste, raw municipal sewage, leachate from solid waste and hazardous waste landfills, industrial water pollution and spillage, and diesel and gasoline, as well as unrefined oil, viscous fluids and oil, heavy slurries, and sludges.

There is a direct correlation between the size of the objects suspended in the water or other liquid being pumped and the amount of energy required by the pump, as well as an inverse relationship between object/particle size and pump head. For suspended objects up to the size of fine gravel (diameter of 0.375 inches) sump pumps are used. For the range between fine gravel and medium gravel (0.5 inches), there are effluent pumps. For objects between medium gravel and cobbles (up to 2.0 inches in diameter), sewage pumps are utilized. Larger than this, specialized grinder pumps are required that will crush these objects down to a finer particle size prior to actual pumping, resulting in a thick slurry. Furthermore, the flow rates decrease with increased size. And as the object sizes increase, the amount of energy needed for pumping increases and the pumping head falls. The final result is the grinder pump, which requires very high horsepower and creates a low

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flow and low head pumping operation.

Positive displacement pumps "push" instead of "fling." They utilize a reciprocating mechanical device, such as a piston inside of a cylinder, which pushes water out of a chamber and propels it out through the discharge pipelines. Other types of reciprocating mechanisms include bellows cavity, vibrating diaphragm, or drumhead squeezing a peristaltic with a pair of pinch rollers and syringes. This last type differs from pistons in that they operated at low flow rates but high-pressure heads. In fact, displacement pumps in general are capable of operating at high operating heads while generating low flow rates (the opposite of typical centrifugal pump performance).

No matter the mechanical design, performance characteristics, or operational applications, all pumps have one thing in common: the need for an exterior power source. This power source is either mechanical (from a reciprocating internal combustion engine) or electrical (from a battery or turbine power source). How much power any pump requires is relatively simple to calculate. Power requirements are a function of the pump's mass flow rate (cubic feet per second or cfs), the density of the fluid (62.4 pounds per cubic foot or pcf, for water at standard temperature and pressure), the differential head (measured in feet), and the acceleration due to gravity (32.17 feet per second squared). Multiplying these values together and a conversion factor and the result is power requirements expressed in horsepower. This is referred to as the pump's brake horsepower, the power actually used to perform the work. The pump's rated horsepower is larger than this value depending on the pump's efficacy rating. For example, a pumping operation requiring 120-brake hp to pump water would require the use of a 150-hp pump operating at 80% efficiency.

**MAINTENANCE VS. REPAIR, AND AVOIDING DAMAGE IN THE FIELD**

It is easy to get maintenance and repair confused. Even experienced operators can make that mistake. Maintenance is performed so that repairs can be avoided. Anything with moving parts requires maintenance, while repairs are completely avoidable. Maintenance is planned as part of a regular operating schedule; repair events are unwelcomed surprises. Maintenance is a cost of doing business, no different than the cost of labor or fuel needed to operate a pump or other piece of equipment. The costs associated with repair extend far beyond the direct costs of labor and parts involved in the actual repair work. Repair creates opportunity costs in terms of schedule delays, lost production, even safety violations and potential property damage or personal injury. In short, maintenance saves money and repairs cost money. Any attempt to skimp on maintenance is a classic example of a false economy. Shirking on maintenance makes major repairs almost inevitable.

"An ounce of prevention is worth a pound of cure" goes the old saying. So, the first step in proper maintenance is setting up the pumping operations to prevent damage in the first place. Damage typically results from either cavitation or clogging. Cavitation is defined as "the formation of bubbles or cavities in liquid, developed in areas of relatively low pressure around an impeller. The imploding or collapsing of these bubbles can trigger intense shockwaves inside the pump, causing significant damage to the impeller and/or the pump housing" (Source: Crane Engineering, "What is Pipe Cavitation?", www.blog.craneengineering.net/what-is-pump-cavitation). These bubbles, as small as they are, can cause a series of micro-explosions and impacts with the pump itself. The shocks and vibration created by cavitation can over time damage the pump housing, impellor blades, seals, bearing packages, and pipeline connections. In the end, the pump loses both flow and pressure until it fails completely.

![A DH071 Grinder pump](image1)

![E/One’s DH152 duplex grinder pump station](image2)
Cavitation can occur at either the suction or discharge end of the pump. Suction cavitation results when the pump is left to operate in a low-pressure regime (caused by poor pipe system design, not meeting the pump’s NPSHr standards, or partial or complete blockage of the intake and its filters) resulting in the pump not receiving enough water inflow. Air bubbles then form at the impeller inlet and travel along the vanes to the discharge—all the while impacting the blade surface. This can cause pitting and scarring of the impeller blade surface, and even the formation of holes that resemble Swiss cheese. The resultant rough surface further degrades pump performance and leads to increasing damage and further cavitation. Conversely, high pressure at the pump’s discharge point can cause discharge cavitation. Excessively high pressure at the receiving end makes it difficult for water to exit the discharge pipe which in turn makes it difficult for water to exit the pump itself. Bubbles then form along the interior surface of the pump housing walls, creating the same impact and shockwave damage caused by inlet cavitation.

In addition to avoiding those system characteristics and operational settings that make cavitation more likely, active measures can be taken to minimize the potential for cavitation. First and foremost, the filters and strainers at the pump’s intake should be checked and cleaned on a regular basis. Clogging of any kind can create the pressure imbalances that lead to cavitation. In many cases heavy filtration including mounds of filter stones and layers of geotextile are required in the field to prevent suspended solids from entering the pump. The pump’s operation should be monitored to ensure that it is working within the acceptable zone and preferably at the pump’s best efficiency point. Conversely, the piping system receiving discharge from the pump can be modified to eliminate the pressure differentials that can lead to cavitation.

In addition to clogged intakes, clogging and biological buildup can affect the operation of a pump’s control switches. This is true of both pressure transducers located in the nose of a submersible pump or a floater switch. Dirt, plant growth, floating objects, mold, and bacterial scum can affect the linkages and connects that turn a pump on and off. Failure to turn a pump on can lead to overflow and flooding. But failure to turn a pump off when the water level has dropped below an acceptable head level can cause the pressure differentials that lead to cavitation. Lastly, there is the problem of ice formation, which can be considered to be a special type of floating debris. Ice clogging, either partial or complete plugging, can damage a pump during operation by preventing discharge and causing cavitation to reduced discharge flow rates.

**MONITORING, INSPECTIONS, AND MAINTENANCE**

In short, there are a half-dozen pump operating parameters that have to be monitored to ensure proper pump operations: intake pressure (feet), outlet pressure (feet), flow rate (cubic feet per second), pump speed (revolutions per minute), and motor temperature. Monitoring, along with scheduled mechanical inspections, can help prevent cavitation and related damage. A common inspection is to look for signs of cavitation wear on the impeller or other components. Additionally, monitoring the motor temperature can help catch overheating before it leads to damage. If cavitation is suspected, it should be addressed promptly to prevent further damage to the pump and system.
per minute), pump efficiency (percentage), and power requirements (watts). In addition to direct monitoring of the operating pump, vibration and noise levels should be checked along with any service fluids such as the fuel tank (and fuel consumption rates) and oil reservoir levels. Monitoring of these parameters is the next best thing to performing actual maintenance. It is less costly in terms of labor and time (no need to dismantle, maintain, or clean the pump) and does not require the pump to be temporarily brought offline. Furthermore, the accumulated data from this operational monitoring can be used to better plan the frequency and type of maintenance required to keep the pump functioning.

Pump inspection schedules typically follow routine, quarterly, and annual cycles. Routine inspections (weekly to monthly) should examine oil level and operating temperature. Quarterly inspections include checking the mechanical seals, changing the oil, and shaft alignment. Annual inspections include checking the pump’s capacity, pressure, and power requirements.

Maintenance regimes require a certain standard set of procedures. These include:
- Lock-out and tag-out of all power sources, including shutting off of all power switches, removing electrical fuses, shutting down the control panel, closing off all valves, and disconnecting or otherwise shutting off any fuel or oil service lines to the pump. In other words, disconnect anything carrying any kind of electrical, hydraulic, or mechanical power from the pump. Rotating parts (couplings, belt pulleys, external fans, spinning axles, etc.) especially have to be shielded from contact by people or clothing.
- Examine the pump’s foundation and ensure that the anchor bolts are tight and firmly in place.
- Make sure that pump vibration has not caused it to misalign with its power source, intake piping, or discharge piping.
- Key lubrication points (such as the ball bearing package) need to be inspected to ensure that they have sufficient lubricant and that their moving parts have not been subject to wear and tear along their contact points. Similarly, shaft seals need to be examined in order to ensure that there has been no leakage or loss of lubricants.
- Often the pump requires a complete internal examination requiring disassembly and reassembly. This time-consuming process usually requires that the pump be temporarily replaced with a backup pump during the inspection process. Furthermore, a ready supply of spare parts should always be kept on hand to minimize the wait time to get the pump back online. Not having to order parts greatly reduces any delays caused by delivery times.

**MAJOR SUPPLIERS**

Environment One manufactures a series of different pump product lines. Their D-Series is available in a range of station heights to accommodate shallow to very deep burial requirements. Completely assembled stations are available with one or two grinder pumps. The W-Series provides flexible applications with a variety of basins, covers, discharges, inlets, and panels and completed stations with up to four grinder pumps. The Upgrade is a replacement grinder pump engineered to fit into virtually any grinder pump wet well. Universal design allows easy drop-in conversion and easy connection. The Upgrade is a complete replacement with all components of a centrifugal pump, including slide rails, pump/motor, float switches, piping, and motor control devices in one package. It comes with its own self-contained level control system, eliminating the need for float switches.

For more than 80 years, Gorman-Rupp Company has manufactured high-performance, high-quality pumps and pumping systems for the municipal, water, wastewater, sewage, industrial, construction, petroleum, fire, and OEM markets. They do so with a product line...
as varied as the markets they serve: self-priming centrifugal pumps, standard centrifugal pumps, submersible pumps, trash pumps, priming assisted pumps, rotary gear pumps, and lift stations. Complete lift station and booster station packages are also available and include pumps, motors, controls, piping, accessories, and enclosures. These ReliaSource lift stations include above- and below-ground pumping stations. Their Prime Aire and Prime Aire Plus venturi priming system offers automatic priming and repriming for sewage bypass operations and construction site dewatering.

Since 1981, the Vertifl ow Pump Company has concentrated on manufacturing vertical process pumps, sump pumps, end suction pumps, and self-priming pumps in cast iron, stainless steel, and special alloys. Vertiflo Pump Company’s vertical, horizontal, and self-priming pumps offer up to 3,000 gpm, 250-foot heads, and 26-foot depth.

There are a half-dozen pump operating parameters that have to be monitored to ensure proper pump operations.

The horizontal end suction pump line offers up to 3,000 gpm and 300-foot heads. Their seal-less vertical pumps are designed for service in water, chemicals, sewage, and slurries. The Series 2100 industrial trash- and solids-handling self-priming centrifugal pumps have an oversized, tapered bore, a self-flushing seal chamber, and an optional external flush, resulting in greatly extended seal life. The Vertiflo Stormwater Vertical Immersion Sump Pump Series 800 is designed for sump drainage, flood control, and process drainage while operating with heads to 230 feet, 3000 gpm, and 350°F.

Sulzer Pumps provides a wide range of products for engineered, configured, and standard pumping solutions as well as essential auxiliary equipment. Sulzer offers a complete range of low and high pressure, horizontal and vertical axial flow pumps (also known as elbow or propeller pumps, they are used in high flow and low head applications) especially designed to handle severe pumping conditions. Their CAHR pump range has been designed for high flow and low head pumping applications. Submersible drainage pumps J and XJ are used for pumping water and dirty water mixed with light abrasives. Pumps with built-in AquaTronic unit will always have correct direction of impeller rotation, ensuring peak performance and reduced wear. Their HPH and HPL are multistage ring section pumps, designed for operation at two or four pole motor speeds. They are suitable for pumping clear or slightly polluted water with abrasive particles.

Daniel P. Duffy, P.E., writes frequently on the environment.

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How one city transformed its water system to maximize resources.

LOCATED 20 MILES outside Cleveland, OH, the City of Avon is now one of the fastest growing communities in northeast Ohio. The city is situated next to Lake Erie and is home to more than 20,700 residents. Its water utility serves approximately 10,500 residential and 1,000 commercial accounts with clean and reliable water.

Because of the city’s rapid expansion in recent years, Avon’s water utility has faced challenges. For years, the water and wastewater system had a history of obsolete accounting records and meter reading technologies, meaning the outdated system could not keep pace with the city’s changing needs.

The utility had also used several different meter reading technologies over the past decade, which added to inefficiencies because the various systems and technologies did not always work together. While Avon had years earlier invested in Badger Meter’s TRACE drive-by/walk-by automated meter reading system and ORION Classic (CE) endpoints, the utility was also still using handheld meter reading solutions that required manual reads for approximately 200 to 300 meters every month. As a result of the inefficiencies in its legacy data and the variety of meter reading technologies, the system overall was not operating effectively or efficiently.

“We were estimating,” explains Anthony Lorenzo, utilities superintendent for the City of Avon. “Using our old system, we could only read one-third of the city’s meters each month. So, we had to estimate the reads for the other two-thirds of the city. That meant every account was only read accurately once a quarter. We lost time and money, and our customers were upset. We needed to make a change.”

FINDING THE RIGHT SOLUTION

In February 2016, the city of Avon’s water utility team began putting together a request for proposal (RFP) for a fixed-network meter reading solution to address their challenges. Around the same time, they learned of new cellular endpoint technology being deployed by Badger
Meter. This technology—the industry's first endpoint using existing cellular networks—eliminated the need for the utility to own fixed-network infrastructure. Seeing the potential of this technology, Avon switched gears and issued an updated RFP for a hybrid fixed and cellular-network meter reading solution.

After its brief search, Avon's water utility team selected Badger Meter's BEACON Advanced Metering Analytics (AMA) managed solution with ORION Cellular endpoints and Badger Meter's E-Series Ultrasonic meters. BEACON AMA is a cloud-based software analytics platform, which allowed Avon's water utility to utilize both the new ORION Cellular endpoints as well as its traditional fixed-network technologies. By bringing its meter reading and analyzing technologies into one solution, the Avon utility team had timely access to its data, making it much easier to see and understand the state of the water system.

"With BEACON AMA, we were able to move to 24-hour meter reads across our entire system. We are now monitoring more precisely, and more importantly, billing our customers more consistently, using actual meter reads rather than estimates," says Natalie Cifranic, billing clerk for the City of Avon.

Avon's old infrastructure-based meter reading solution required utility technicians to spend more than 160 hours every month monitoring the water meter reading system, manually rechecking meters, and acting on the data. By implementing the BEACON AMA managed solution, Avon cut that time down nearly 88% to about 20 hours per month.

**NEW, MORE ACCURATE METERS**

Before the City of Avon installed Badger Meter's E-Series Ultrasonic meters throughout its system, the utility faced a series of challenges surrounding meter locations. The previous meters had been operating for many years—sometimes well beyond their lifespan. Specific meter locations were known by individual utility technicians rather than stored in a central database that the accounting department could access for billing purposes. "The legacy data system was not always accurate and did not contain important information on the meters and their locations," says Lorenzo.

After selecting Badger Meter, Avon installed both new meters and billing software to replace the many varieties of meters previously in the ground. Utility staff were able to find and map the locations for the new Badger Meter E-Series meters and incorporate them into a new geographic information system (GIS), so that meter readers could easily obtain meter readings, even during the snowy winter months in Ohio.

The E-Series Ultrasonic meters also significantly improved the water utility's meter reading accuracy. A relatively new metering technology, ultrasonic meters use high-frequency sound waves to measure water flow. Within each meter, electronic transducers send high-frequency sound signals consecutively in forward and reverse directions. Then, an onboard processor turns this data into actionable information for the water utility. These technologically advanced meters can also result in increased accuracy up to 1.5% over the normal operating range of the meter, and 3% at extended low flows. Since ultrasonic meters use solid-state technology and have no moving parts, they help improve reliability and increase the life expectancy of the meter compared to traditional mechanical meters.

Prior to implementing the new meters, Avon found that some of its water meters were reading flows at 60–80% accuracy. With the E-Series Ultrasonic meters in place, accuracy improved to nearly 100%, making Avon's water system one of the most successful hybrid systems in the nation.

"Our new managed solution, paired with our new meters, has allowed us to be more efficient with our time and effectively respond to leak detections or issues for our customers," says Lorenzo. "We know that the data coming in is reliable and accurate."

**WORKING WITH THE CUSTOMER**

In addition to improving its data accuracy and reliability, as well as meter reading efficiency, the City of Avon's utility team has worked diligently to encourage customers to be more accountable for their water usage. As part of the BEACON AMA solution, water utilities can offer their customers access to EyeOnWater, a smartphone and web-based application that provides customers with hands-on information about their water usage via regular notifications and personalized, timely, and accurate data. Consumers have the capability to see water consumption data daily, hourly, monthly, and annually on their smartphones, computers, or tablets. This means that while the City of Avon water utility team monitors for leaks throughout its system, its individual water customers can also monitor for unexpected increases in their usage and notify the utility. The application also provides users with suggested actions to conserve water.

Currently, about 1,500 Avon residents are utilizing the EyeOnWater app, and that number continues to grow as the utility continues its education efforts throughout the city. By using the application, water customers are actively monitoring their water consumption patterns and reaching out to Avon's water utility billing team with questions and concerns. The application has also helped Avon's customer service team reduce time spent handling billing disputes. With accurate and reliable data at their fingertips, the customer service team can simply show a customer the data in question upon request.

**BUILDING A SUCCESSFUL SYSTEM**

"This solution has been transformative for the City of Avon. We now know that we will receive timely and accurate data every day. It has also helped us improve accountability with our customers and our rate-payers. With the pace of Avon's population growth, this will be especially critical for our future," says Lorenzo. "Working with the Badger Meter team has been highly successful, and we know we can trust this technology to be effective for years to come." [M]

*Kristie Anderson is marketing manager for Badger Meter.*
EMBALSE LA FE is a freshwater reservoir in Medellín in Colombia. The lake measures 1.1 square kilometers and is used to supply drinking water to about 55% of the people in Medellín. In addition, the reservoir is also used for recreational purposes. Unfortunately, the reservoir was suffering from frequent algal blooms, hampering its uses for both drinking water production and recreation. The problematic algal species primarily consisted of blue-green algae, along with diatom growth.

Blue-green algae represent a group of ancient bacteria known as cyanobacteria. They give rise to a distinctly foul odor and are known to produce toxins. These toxins can cause various illnesses in humans, such as skin irritation and paralysis, and some are even suspected to be connected to occurrences of liver cancer. When surface water is used for drinking purposes, blue-green algae in the water may also endanger the water supply by releasing toxins and cyanobacterial metabolites, such as geosmin and 2-methylisoborneol (MIB), which can dissolve in the water and escape conventional water treatment. In the World Health Organization's publication guidelines for drinking-water quality, the guideline value for total microcystin-LR is 1 gram per liter in drinking water.

The MPC-Buoy system helps control algae blooms at Embalse La Fe.
Empresas Públicas de Medellín (EPM) is the company responsible for the treatment and quality of the water from Embalse La Fe, making it the main provider of drinking water, potable water, and wastewater services in Medellín. The company has been searching for a chemical-free and environmentally friendly solution to control algae in the reservoir.

For the last 100 years, the main practice of water treatment plant operators and lake managers to remove algae from their reservoirs has been the addition of chemicals. Chemicals that have been dosed in our waterways include copper sulfate and other algacides, as well as metals (iron, copper, gold, aluminum, calcium). Although these methods are considered fast working and economical, their impact on the ecological balance of a waterbody cannot be disregarded. Effects of chemical algal control may include toxicity, lysis of algal cells, and non-target responses, which results in a degradation of overall water quality.

Continuous dosing of most metal-based chemicals to a lake for a long period of time can also alter the composition of micro- and macro-organisms in the water. Beneficial bacteria in the sludge that are in charge of nutrient removal may cease to grow, along with benthic plants, which results in reduced dissolved oxygen concentrations and a reduced capacity of the lake to deal with inflowing nutrient pollution.

**MONITOR AND CONTROL ALGAL BLOOMS**

In order to deal with these algae problems, EPM installed 8 MPC-Buoy systems in Embalse La Fe, provided by the company LG Sonic from the Netherlands.

The MPC-Buoy stands for Monitor-Predict-Control and can reduce algal concentrations by 70–90% in an environmentally friendly manner. LG Sonic has been researching the effects of ultrasound on specific algal types, different types of water bodies, and variations in water quality since 2005.

In collaboration with several European universities, LG Sonic has created a database that defines optimal ultrasonic parameters for different algal species and water quality characteristics. By continuously updating these ultrasonic parameters, the system prevents algae from becoming resistant to ultrasound.

For the collection of in-situ water quality data, near real-time sensors are used to measure pH, chlorophyll a, phycocyanin, turbidity, dissolved oxygen, and, optionally, nitrogen and phosphorus. Based on this information and algal bloom forecasts, the MPC-Buoy automatically alters the ultrasonic parameters that it sends out. This is called interactive algae control.

**HOW DOES ULTRASOUND CONTROL ALGAE?**

The MPC-Buoy systems use low-power ultrasonic algae control. This specific ultrasonic mechanism does not cause algal cells to lyse and does not affect multicellular organisms. Algae rely on their buoyancy to float close enough to the water surface to take up sunlight. This allows them to outcompete other organisms in the water, such as plants,
ALGAE CONTROL

MPC-Buoy systems use low-power ultrasonic algae control.

that are also depending on sunlight intake. The ultrasound used by the MPC-Buoy system fixes algal cells in the water column, preventing them from absorbing sunlight at the surface.

RESULTS IN EMBALSE LA FE
The MPC-Buoy systems were installed in La Fe on May 5 and 6, 2015. Before installation, as well as during the project, the water quality was tested. EPM used the water quality sensors provided with the MPC-Buoy systems, as well as their own water quality monitoring protocols, to verify the technology.

During the first months of the project, the photic area in the lake had already increased due to a decrease in algal concentrations. EPM’s own water quality tests also indicated a drastic reduction of diatoms and cyanobacteria throughout the water column of La Fe reservoir.

In addition, since the system installation, algal blooms have been con-

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trolled effectively, even in the extreme environmental conditions of “El Nino” from 2015–2016. The interactive algae control systems allowed treatment to be adjusted for a highly dynamic and fast-growing algal population. This reduced treatment cost.

Santiago Barrera, Biologist EPM, says about the equipment:

“The algae and cyanobacteria control has been an excellent investment. We achieved by means of an environmentally friendly technology to improve the water quality and decrease the treatment costs. Furthermore, we have today a monitoring and control which is more adjusted to the behavior of our reservoir.”

LG SONIC
LG Sonic is a company active in the water quality management of large reservoirs and water surfaces. They supply innovative, chemical-free, and environmentally friendly solutions to the water industry.

The company is currently active in 55 countries worldwide and works together with water companies all over the world, such as EPM, American Water, and many more. The objective of the company is to reduce or eliminate harmful chemicals in our environment. To accomplish this, they have developed a chemical-free technology that controls algae without disturbing the natural balance within water ecosystems.

Microbiologist Lisa Maria Brand is the chief technology officer at LG Sonic.

MPC-Buoys can reduce algal concentrations by 70–90%.
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**READER PROFILE**

**Matt Corson**

**THE FLINT, MI, water crisis has amplified the importance of water quality issues for water utilities and their consumers on the national front as well as the criticality of the work of people such as Matt Corson, director of environmental compliance and stewardship for American Water. Corson is responsible for directing the overall environmental compliance and stewardship program across more than 300 drinking water systems and nearly 200 wastewater operations owned or operated under contract by American Water throughout the country. He assists with the overall vision and strategy for American Water, coordinating with the United States Environmental Protection Agency (USEPA) and water industry organizations on national water quality issues and to help shape future drinking water regulations. He credits "strong teams at the state and local level that do the hard work" in helping with that effort.

Corson also educates the public about water quality through an American Water blog, *Water Street*. Through educating water consumers, Corson seeks to partner with them in the effort to conserve water and protect its quality. In a recent blog regarding lead, Corson points out that American Water takes lead in pipes "very seriously" and he endeavors to educate water consumers about their role in monitoring lead in their own household plumbing and service lines. "Lead is seldom found naturally in source water and is rarely present in water coming from the treatment plants," he writes, adding that lead gets into water from lead solder used in household plumbing before the 1986 EPA ban, in faucets manufactured before 2014, or in a lead service line extending from the utility’s water main in some older homes. Households on private wells may have similar household plumbing, he adds. Corson has called upon water consumers to flush the taps in their homes, use only cold water for cooking and drinking, routinely clean faucet aerators and screens on a schedule similar to changing smoke detector batteries, follow manufacturer recommendations for replacing water filters in home appliances, and seek lead-free labels when replacing water fixtures.

**What He Does Day to Day**

In directing American Water’s environmental program, Corson engages in activities that focus on environmental compliance, or "what we need to do to meet the rules and regulations," and environmental stewardship, or "what do we need to do to protect the environment and the resources upon which we rely," he says. "I work with a lot of great people both in my office and across American Water on a variety of issues such as compliance sampling. American Water collects and analyzes more than one million water quality samples each year." Corson’s daily tasks focus on concerns regarding lead, source water protection, backflow protection, emerging contaminants, wastewater, greenhouse gas and climate change, and water conservation. He also reads up on regulations, develops guidance for American Water’s operations, attends meetings, and sits in on internal conference calls as well as those with the EPA and water industry organizations.

**What Led Him Into This Line of Work**

Corson earned a B.S. degree in chemical engineering from Lehigh University and is a licensed Professional Engineer in the state of Delaware. "I went to work for the New Jersey Department of Environmental Protection in the Bureau of Safe Drinking Water doing operational oversight, which gave me my first taste of the drinking water industry, and then moved to Washington DC, which gave me the broader, national view, which really hooked me," says Corson of his time as the regulatory affairs manager with the Association of State Drinking Water Administrators. Corson has been employed by American Water for more than 13 years.

**What He Likes Best About His Work**

"It’s never boring," says Corson of his occupation. "Drinking water is such a unique industry. When you think about it, our customer ingests our product. That’s putting a lot of trust in us, which makes it really easy to take pride in what you do."

**His Biggest Challenge**

"There is always something new and exciting going on, something to challenge you: lead, algal toxins, legionella," points out Corson. "The bottom line is that my job is to protect public health and the environment, which I find to be extremely worthwhile and rewarding."
IT’S ALL ONE WATER

Our need for water has collided with the realities of reduced water supply and increasingly threatened sources. In many areas, our water management policies and practices are no longer sufficient, costs are rising, and our legal and regulatory framework is out of alignment with current and future hydrologic and climatic conditions.

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