Conveyance Catch-22

By Carol Brzozowski

Across the United States, our water pipe conveyance system is showing its age:

- An aged, 8-inch cast iron water main break in Dallas, TX, earlier this year flooded lower levels of the downtown Dallas County Records Building and knocked out the building's electrical system.
- Last year, 43 water main breaks hit Los Angeles, CA, within one month, flooding businesses and blocking traffic. One pipe was 90 years old.
- A 79-year-old, 12-inch water main broke earlier this year in the nation's capital, causing a major disruption for northeast Washington, D.C., commuters.

According to statistics from the Pressure Pipe Inspection Company (PPIC), more than 6 billion gallons of water is lost daily through leaks in aging pipeline infrastructure. On average, PPIC inspections have revealed 1.1 leaks per mile of large-diameter pipe in North America, and 2.2 leaks per mile in Europe, England, the Middle East, and Africa. The average volume of a leak is 40,000 gallons per day.

Against that backdrop is the following concern: By 2025, two-thirds of the world's population will live in regions with water scarcity. Yet water loss continues to be a major challenge.

Standards and Practices

"Water loss is devastating to a community, because it causes service rates to be higher, but also creates mistrust with utilities—especially when metered losses occur at a home," points out Domenic DeCaria, a product engineer for Lubrizol Corporation's Corzan Industrial Systems. Plus, water loss adds to the rising financial burden associated with mismanaged and under-funded water systems, says Bob Walker, P.E., vice president of engineering applications for Underground Solutions, which provides PVC-based infrastructure technologies for water, sewer, and conduit applications.

Whether that loss occurs through pipe failure, through exfiltration of a water line, or a sewer gaining groundwater through infiltration, the cost of the water—production or treatment—isn't the only point, says Kimberly Paggioli, P.E., vice-president for marketing and quality control for Hobas Pipe USA.

"Leaking pipes cause damage to the surrounding infrastructure," she says. "Technologies are available to produce leak-free pipes, so why not require it?"

Paggioli points to research conducted by the University of Houston (UH) Department of Civil and Environmental Engineering, funded by a USEPA grant for the Fiberglass Pipe and Tank Institute, which determined that while ASTM (American Society for Testing and Materials) standards existed for certain joint infiltration leak rate tests, they were not universally applicable to all pipe materials or joining methods.

"Further, leak test data was generally not available for joints that were subjected to underground-installed axial, angular deflection, and shear stress conditions," says Paggioli. "Thus, there was a need to develop a universal test method, conduct comparable leak rate tests, and develop test data as input to the life cycle cost models."

The UH research was conducted on two projects: "Sewer-Main Collection Pipe Joint Infiltration Testing" and a "Sewer Main Collection System Infiltration Life Cycle Cost Model", according to www.fiberglasstankandpipe.com/sewer.htm.

The True Cost Conundrum

More than 1 million miles of water pipes and aqueducts are located in North America, with much of it being aged. In 2009, the American Society of Civil Engineers (ASCE) gave the nation's water infrastructure a grade of D-. Additionally, the ASCE pointed out that drinking water systems face an annual shortfall of $11 billion.

"Unfortunately, our infrastructure needs—which tops $2.2 trillion according to ASCE—is only now beginning to be in the spotlight when funding dollars are so problematic," says Paggioli. George Kunkel, P.E., is the assistance chief for the Water Conveyance Section of the Philadelphia Water Department. He points out that while the nation has been "very good" at building a water conveyance system, "there has been a little less emphasis on maintaining it, sustaining it for the future, renewing it, and rehabilitating it.

"Unfortunately, there's a tendency that we get things built, and, eventually, they become 'out of sight, out of mind'. Years go by, the system starts to age and begins to fail in places. We probably haven't kept pace with the maintenance, let alone condition assessments to keep a good handle on it."

Maintenance ignored over time results in leaking pipes. "But, they're leaking in a hidden fashion, and it doesn't get as much attention as some aboveground assets or other issues," says Kunkel.

Additionally, the water industry tends to under-price water despite its value, adding to the challenges of maintaining or replacing water conveyance systems, he adds.

Walker concurs. "Our nation's water systems are generally under-funded and water rates do not cover the true cost of supplying and maintaining dependable water systems," he says. "As a nation, we have failed to provide needed incentives for sustainable utility piping systems. Rather than rewarding utilities for managing and maintaining their pipe systems, our federal government periodically provides funding to assist or bail out utilities whose systems have fallen into the worst states of disrepair.

"This encourages communities to put off making needed repairs and replacements, in hopes of receiving the next round of federal funds," he adds. "Additionally, we need to do a much better job of benchmarking best practices for designing, building, maintaining, and managing water pipe systems."

To that end, quantifiable water pipe performance measures need to be monitored and used to improve decisions regarding new construction, replacement, and rehabilitation practices, Walker says.

"Sustainable water distribution systems require both short- and long-term accountability that is often lacking," he adds.

DeCaria makes the point that, as a nation, "we need to spend efficiently while maintaining the resources necessary to provide clean, healthy water to our citizens.

"Reactive maintenance will always cost more than predictive or preventative measures in the long run, especially when considering the cost of unhealthy water delivery and ultimately higher service charges," he says.

For many municipalities faced with revenue shortages, dealing with their water pipe conveyance system is a Catch-22—many struggle to find the money to make improvements, but to ignore problems creates larger financial implications in the future.

"The conflict is between appeasing people now with spending restraint or protecting our infrastructure for future generations," notes DeCaria.

Walker sees it another way. "Government-run water utilities are conflicted over their need to generate funds for replacing or rehabilitating worn-out portions of their systems and elected officials' needs to keep rates as low as possible while they are in office in order to be re-elected," he contends. "This forces postponement of needed proactive measures that would, in the longer term, actually lower costs and provide for sustainability.

"This short-sighted approach has already cost our nation billions of dollars and is sure to burden generations to come," continues Walker. "Moreover, neither the elected officials nor water system managers are being held accountable for such wasteful mismanagement. They are not bad people, but the system under which they currently operate is a deterrent to sustainability."
Paggioli says she believes that, generally, civil engineers have a long-term proactive goal for the infrastructure, but lack funding to execute their optimal plan.

"Municipalities have other funding needs aside from infrastructure, which is often viewed by the public as more important," she says.
It's the "out of sight, out of mind" concept.

"It is sometimes a tough fight for the public works director to promote allocation of large funds to underground projects of which the general public doesn't have much direct knowledge over—the renovation of a local park in disrepair, for example," says Paggioli.
And yet, should a pipe failure occur down the road, the cost of mitigating is more expensive than taking a proactive approach, Paggioli points out.

"Those costs encompass repair, emergency response, damage to other infrastructure, and possible EPA fines," she says.
Because utilities don't price water relative to its true value, "we end up cutting corners on maintenance or leak detection," adds Kunkel.

Managing and Mending
The first and most important action any utility can do is take an inventory of its system to get a handle on its location and condition and analyze the information through a database, says Gregg Horn, P.E., president of the Ductile Iron Pipe Association.

“Today’s software makes it easier to analyze and prioritize work,” he says.
Kunkel says the American Water Works Association’s Water Loss Control Committee—of which he is a member—has been pushing for annual water audits, much like a utility conducts yearly financial audits.

“The audit allows them to put in rough estimate quantities,” he says. “When you supply so much water in a system, and you count the billing, there’s a difference. Utilities are always supplying more in their actual billing. Some of it leaks away, some is from poor metering or poor accounting; that difference is not only in the water, but it’s also a difference in cost.”
Utilities that audit would see built-in losses not only in terms of water, but also in terms of money, Kunkel says.

“If they quantify ‘X’ amount of leakage, and they know it costs so many dollars per million gallons to produce that leakage, they’ve basically got an inflated production cost in their operation,” he says. “You’re producing 10 units of water, and you only bill for seven, so you have a built-in inefficiency.”

Utilities that audit every year would discover they’re paying extra money in treatment and pumping for a certain amount of leakage that goes into the ground. For example, that extra money may amount to $500,000.

“Now you can start to think about, maybe while you spend $10,000 on a leak survey this year, there’s a cost benefit, because you’re cutting into that $500,000,” says Kunkel. “But, because a utility is not doing auditing, it’s not cognitive of these inefficiency costs.

“It’s even worse on the other side of the losses—what’s called the apparent losses—where there is spilling or metering issues,” he says. “You’re really talking about water that reaches a customer, but you recover the revenue on it. In that case, we’re losing revenue, and revenue is charged the retail rate. What we charge retail to customers is a lot higher than what our production costs are. Utilities are passing along their cost of these inefficiencies to their rate payers.”

Standard annual auditing will help utilities start to quantify these losses, Kunkel says.
“Initially, the values might be a little crude, but over time they’ll improve and start to reflect the cost of these inefficiencies,” he adds. “What they’re going to find, as they move forward in their efforts on managing assets, is they’re going to be pumping capital dollars into their pipeline. But they should also be seeing a drop in their annual losses and the cost of the losses. Every year they do leak detection, but they’re also doing long-term loss replacement by replacing pipes.”
Properly managing inefficiencies and charging appropriately for water will help with funding gaps, Kunkel points out. Asset management becomes more strategic.

“There’s a big funding gap and we have big needs, but we’ve got the tools out there,” says Kunkel. “We need to make an industry mind shift. We’ve got to track our systems a little better, manage them more strategically. We can’t really rely on massive programs.”
His own city of Philadelphia, PA, is a case in point.

Philly's Pipe Tales
Philadelphia's water pipe conveyance system has more than 3,100 miles of piping, most of it installed in phases over long periods of time as the water infrastructure followed development phases.

"We probably have the oldest segments of water piping in the country—we have about one mile of pipe dating from the 1820s," says Kunkel. "We have one segment from 1822, but up to 60% of our system was installed between 1880 and 1930. Our average age of 70 to 75 years is pretty old, whereas many cities and newer communities have only been built in the last 50 years."
Age is not the only factor when considering the condition of water conveyance systems; so is pipe material, standards, and technology, Kunkel points out. "We do see our highest failure rates with online cast iron pipes—that's probably still 45% of our system, especially the smaller-diameter six-inch pipes."

Philadelphia has had an active capital replacement program to replace 700 miles of cast iron pipe system with ductile iron pipes, which has proven successful, says Kunkel.

Controlling corrosion—which may come in the form of corrosive soils or straight currents from underground infrastructures such as subways—is the focus of all new designs. "We have built into the design process an evaluation on the conditions around a new pipeline," he says. "We have an assessment done of each site, and we design into the new pipeline any corrosion protections that are needed. We've found extremely low failure rates on the ductile iron pipes that we've now put in during the last 45 years. It can be argued that while that type of pipe's very new, we're really at a point 45 years into it now, and that history is longer than some newer communities around the country.

"We have a robust process and standards for the piping that has been going in place," he continues. "It's more costly to do those evaluations because we specify pretty strong materials. We're getting a long enough history now to see that's bearing out with a pretty low failure rate."

With respect to the large amount of online cast iron pipe Philadelphia still has in the ground coupled with funding constraints, the city must consider an array of options, Kunkel says. "Is outright pipe replacement a good option?" he asks. "Perhaps that's ultimately what we need to do. You need to renew the pipe, but maybe there are now the newer technologies that don't need the full trench excavation to install the pipeline. That technology is more viable for the larger pipelines. We've not been addressing the larger transmission lines as much as we'd like. The replacement program we have is largely focused on the smaller distribution lines."
Philadelphia water officials want to pursue a more structural solution, Kunkel says. "We want to have it built within the pipe. We want to make sure we're really not getting what I call a lining—we want a structural liner. There are a lot of different products on the market and we have to evaluate them. We will find a way to fund a more robust rehabilitation, and we want it to succeed."

Tools of the Trade
Leak detection and pipe inspection plays a major role in helping to identify problems before they become catastrophic.

“Municipalities must operate like businesses using a reliability program that determines life cycle expectations, risk of failure, severity of failure, and detection methods, and then develop an inspection program that optimizes the resources, while ensuring proper inspection scheduling for each component,” says DeCaria.

Using the latest technology in pipe inspections enables municipalities to make more informed decisions, points out Brian Mergelas, president and CEO of the PPIC.

“The utility has a better use of capital, better allocation of funds, and a little bit of study up-front to get the information needed to make the good decisions,” he says. “A large-diameter pipeline is not going to be failing every week. A water main break is typically in smaller pipes. Even with larger pipes, if you have one failure, it’s normally a pretty significant failure and might lead to damage that could be worth $20 million to $30 million.

“If you use technology like what we deploy, you can pinpoint where you might have damage,” he adds. “Instead of spending $30 million on replacing a pipeline, you might spend a fraction of that on an assessment and pinpointing where it is and fixing it.”

“Most of our clients tend to be people who, in the past, had some type of emergency and transitioned into a more proactive mode,” says Mergelas. “Think of condition assessment as painting a bridge—you’ve got a system with pipe going in every direction, so you start at one end of your system and work your way through, and by the time you’re done in about four years, you have to go back to the beginning of the system again to reassess the pipe. The majority of our clients tend to be proactive, long-term clients, but as people have emergencies they become part of that greater community that does condition assessment.”
In pipe inspection, one should consider a broad asset management approach with an assessment of service needs, says Kunkel.

“You look at all facets of the infrastructure,” he says. “What is the condition of it now? How do we assess that? Is it really deteriorating? We’ll also look at what service it provides. In our city we’ve grown, and since the 1950s the population has reduced, so we actually have more pipe in the ground and in larger sizes than we need.”

That may mean an outright abandonment of certain lengths of pipe or in using trenchless methods to shrink the pipe’s diameter, Kunkel says. “We don’t need the extra capacity. This becomes an issue when you’re being affected by more stringent water quality regulations in the distribution systems, and factors such as how is that water circulating, and is it circulating sufficiently to keep the chlorine residuals adequate? If the pipes are too big for the water, then the water slows down and stagnates to a degree.”

Managing Assets Large and Small
Asset management considers such factors a service needs on a particular part of the system and

whether the pipe needs to be expanded or contracted, the cost of materials used, type of rehabilitation needed, and maintenance.

“Leaks are the most evident sign of some distress in the system,” says Kunkel. “It could be evident of a major problem, or minor in the respect that there’s a long pipeline and one area happens to be in a very corrosive environment, so it’s failing, but perhaps 90% of that line is in good shape, so then it would be a spot repair.”

Asset management requires a strategic approach to consider various technologies such as GIS to catalog the infrastructure or track events more closely. “There are data tools and hydraulic modeling that have never been better,” says Kunkel. “We’re using GIS here. We recently installed a hydraulic model, and we’re working to incorporate a new water management system.

“The biggest management challenge is leveraging that technology, getting the people we need to provide the information, analyze the information, and look at trends. You don’t want to just go out and buy these tools, put a lot of data into them, and not get a good output. It’s that old saying of ‘garbage in, garbage out’.”

Kunkel says he and his colleagues look for trends on certain types of piping and materials: “Can we replace certain fittings or segments of pipe rather than presuming we have to replace whole lengths of pipe outright?”

In assessments that have come out in recent years, different organizations have noted a spending gap. “Their infrastructure needs were not being funding efficiently, and they’re quoting numbers in the hundreds of billions of dollars,” says Kunkel. “I often think those assessments aren’t really strategic; I sense there’s the presumption that many miles or segments or pipes have to be replaced outright. That’s the most comprehensive option, but it’s the most expensive and the most disruptive if you’re digging trenches.”

Strategic assessments may reveal site-specific failures, Kunkel says. “It may not be the entire two miles of that large pipeline, but it’s a few spots here and there,” he says.

Kunkel says he doesn’t believe that the industry is sufficiently engaged in condition assessment or even where there are groups involved in leakage management, he doesn’t believe they’re looking at data efficiently. “There are many new innovations in leakage management,” says Kunkel. “Unfortunately, most water utilities don’t do any leakage management, or they do reactive leakage management—if it breaks and you see it, go out and fix it.”

Most distribution systems have leaks, Kunkel points out. “Many of them are going to start small and build over time and get larger. The deterioration will continue, and eventually they’ll become large enough and severe enough that they’ll cause some visible disruption. They’ll erupt; they’ll flood basements.

“Over the years, more leaks are erupting, maybe slowly, but they’re growing,” he adds. “It’s like a time bomb. It’s going to be like that more or less for every system depending on the age, the

materials in the system, the pressure in the system, and the corrosive condition of the soil. The reactive approach really is not adequate."

It's important to inspect pipe from the time it is installed, Horn says. "Inspection to make sure the installation is done right will give better results in the long run."

Inspection throughout the pipe's lifespan helps confirm a suspected problem, but it's also useful when a water utility taps into an existing line to branch it off to provide addition service to other parts of the system, he adds.

"It gives them an opportunity to look at the pipe when they uncover it to do that," says Horn. Using available technologies such as GIS enables utilities to mount collective data. "In a couple of years, they can have all kinds of information on the condition of the pipes that they've uncovered for one reason or another," he adds. "They could take a soil sample and test it for corrosivity and build a database they could analyze and use as a way of prioritizing."
Horn says while he doesn't believe the nation's entire water system is at risk of failing, "certainly there are parts of it that are going to be in worse shape than others, and a problem utilities have is which pipeline to go to next and what kind of work needs to be done."

While age is often cited as a key factor in pipe failure, the environment into which a pipe is installed is the most important factor with respect to iron pipe, Horn says. "There's a large amount of iron pipe that's been under the ground for a long time that's in real good shape. We are aware of some 630 utilities that have 100-year-old iron pipe in the ground and about 20 of them with 150 years of service. That speaks to the fact that those pipes were put into environments that don't give them trouble over the years."

The Art of Prevention
Municipalities that take a proactive stance have become the exception to the rule, says Chet Allen, a regional manager with Underground Solutions.

The approach is to help them stay ahead of their problems to avoid having issues with water main breaks and doing emergency repairs, Allen says.

"Other towns don't have the money," he says. "What available money they do have, they spend it on expensive emergency repairs."

Inspections allow municipalities to target some of its worst areas and rehabilitate them first. "An all-encompassing inspection and tracking and auditing programs would be nice," says Allen. "A lot of towns don't know the condition of their infrastructure, or even know where it is, so there's value in that. But a lot of municipalities aren't in that condition to spend that kind of money."
Allen illustrates a value of an inspection: "Let's say you had a water transmission main that was put in the ground in 1910. You inspect it and find out that the first 5,000 feet of this line is actually in decent shape, but when you go over to another area, it's worse, so you have to take care of that first. Inspection allows them to target their most needed areas first."
Mergelas says, "Things aren't quite as bad as everyone thinks they are."

While the EPA's infrastructure analysis concludes it will take hundreds of millions of dollars to bring the nation's system up to current standards based on age factors, Mergelas says, "The reality is, from condition assessments on the underground infrastructure, we're finding less than 4% is in poor condition, and of that small percent, only a fraction actually need to be replaced. If you use good 'smart technology' to make good decisions, you can bridge that infrastructure funding gap. You don't have to replace everything—just be smart about what you rehabilitate."
Like many municipal services, there's a delicate balance between deciding whether the work should be done in-house or outsourced. "You need capable people in utilities to take the lead; you need them to be engaged," says Kunkel. "But you also have service providers out there who bring in unique skills, equipment, and consultants. Water loss is no different from managing water quality. Utilities will rely on its own employees and outsourced consultants and services."
DeCaria says maintenance and inspection depends on the needs and resources of the facility. "Generally speaking, the amount of inspection is usually so great and the development and maintenance of the reliability program so intensive, that keeping resources in-house could seem to be more cost effective," he says.

"However," he adds, "using outside resources for maintenance and inspection may allow us to achieve economies of scale with technology, thus making the best technology affordable for most municipalities and thus making inspections less labor-intensive and more automated."

The Three R's: Repair, Retrofit, Replace

The decision to repair, retrofit, or replace is based on a number of factors. "It would be senseless to slip line an existing 42-inch pipe—even if the capacity could be maintained—if what was really needed was a new 54-inch line," says Paggioli. "Certainly, existing infrastructure is an asset and this value should be considered in future decisions, but the long-term need should be the driving force of decision-making."

DeCaria advocates repairing prior to a component breaking down. "That way, its service life is maximized and maintenance expenses minimized," he says. "It depends on the relative cost of each of the components and how long it is expected to last. For piping underground, the mode of failure will likely repeat itself in a slightly different spot after the first failure, so a replacement or rehabilitation is usually best."

Water utilities should evaluate the record of service of given pipelines, and the ones that have the most problems are the ones targeted for replacement, Horn says. "Whether they repair or replace is going to be a function of their track record to a large part."
The cost and frequency of repair or replacement are the primary factors that determine the best course of action, says Walker.

Cost-Benefit Analysis

In a time of tight municipal budgets, how does a municipality convince taxpayers that pipe rehabilitation is money well spent?

Document the cost and risks of not investing in the infrastructure, points out Paggioli. "Overflows cause severe sanitation issues and can have a lasting effect on our natural resources," she says. "ASCE has done a great job of highlighting for the general public the infrastructure needs. I think it is important that this work continues."

Water utilities need to lay out the costs associated with making reactive repairs versus proactive rehabilitation, says Walker, referencing a water main break earlier this year that flooded lower levels of the downtown Dallas County Records Building, knocking out the building's electrical system.

“That break alone has already been estimated to have cost taxpayers more than $10 million,” says Walker, adding that it illustrates the problems created when infrastructure is neglected. “The public must be educated to appreciate and understand that paying the true cost for water now is the best and only sustainable option,” he says. “Safe, reliable water is worth many times its price. Convincing voters to reward politicians for raising their water utility rates is an extremely tall order. Indeed, this is our challenge.”

Allen says when he got into this business nine years ago, he was amazed when he saw a corroded 1940 water main, and he pondered, “How could water get through all that mess and still be drinkable?”

He continues: “The answer is if you hit it with enough disinfectant at the plant—even after it flows through this corroded pipe—when it gets to your faucet, it’s still safe. So you have over-treatment taking place, which is costly and arguably unhealthy to make up for that old water line, let alone how much it’s leaking.

“A lot of cities allow a 20 to 30% leak rate of treated water,” he says. “Show people what the inside of a water main that’s been in the ground for 50 years looks like and show them what happens when a water main ruptures and washes out buildings and roads.”
While Philadelphia’s water utility often communicates with the public through rate increases and consumer confidence reports, Kunkel says he believes that, going forward, the water industry in general needs to create a more targeted public education campaign regarding what really goes into providing services in water, wastewater, and stormwater.

“The public doesn’t understand the amount of effort and infrastructure, and that service is taken for granted,” he says. “The same folks who don’t want to pay an extra dollar in their water bill each month have enough money to buy the latest cell phone, and that’s because those industries market themselves, and we’re the quiet silent service.

“The trade groups might want to consider a campaign for that,” he continues. “We should probably think broader. I remember a colleague say why doesn’t the industry have a one-minute ad in the Super Bowl—what does it take to provide water services, and what’s the value of that?”
Ultimately, there is not one technology that addresses all of the challenges associated with pipe conveyance systems, points out Mergelas. “The technologies we are using today are an accumulation of development over the past few years—not only with our company, but with other people in the industry. There is no magic technology that does everything, even though we assembled a series of technologies.

“You can draw significant value and make important decisions based on technology that exists today,” he adds. “Could there be improvements in technology? Absolutely. But there has been

discussion in the industry and in the EPA about some of the nuances, suggesting there's a need for more fundamental technology before utilities really engage in some kind of program. Even if there are better technologies tomorrow that may refine a decision, utilities really don't have to wait until tomorrow. There are technologies today that can help them drive pretty important decisions."