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Comprehensive renewal program addresses aging water and sewer infrastructure

BY TAKING A "FIX-IT-FIRST" APPROACH AND ADOPTING A PROACTIVE INFRASTRUCTURE RENEWAL PROGRAM, THE MIAMI-DADE WATER AND SEWER DEPARTMENT IS MAKING THE MOST OF LIMITED REPLACEMENT FUNDS AND EXTENDING THE LIFE OF ITS INFRASTRUCTURE.

Water and wastewater infrastructure—most of which is reaching the end of its planned life—will be a major challenge for the United States during the next two decades. One industry study estimates that $1 trillion will be needed between now and 2035 to upgrade and renew water and wastewater infrastructure across the United States; most utilities do not have the capital to meet this need.

As industry studies continue to highlight the issues surrounding aging water and sewer infrastructure, policymakers at the local, state, and national levels of government are beginning to recognize the problem and make infrastructure renewal programs a priority.

Aging water and wastewater pipelines are of particular concern within the overall need for infrastructure renewal. In the United States, there are about 650 water main breaks per day, and more than 240,000 per year; 7 bil gal of water is lost each day, and 16% of treated water never reaches the tap; in 1980, only 10% of pipes were in "poor shape." In 2010, that number had reached almost 50% and continues to rise. It is estimated that $2.6 billion in unneeded losses could be avoided by upgrading and repairing the nation's water pipeline infrastructure.

The situation is similarly bleak for sewer force mains across the country that are aging and beginning to degrade in a manner similar to water infrastructure. In addition to the renewal needs, failures of wastewater pipelines can have more catastrophic results than a water transmission main because the structural damage is exacerbated by wastewater being released into the environment and surrounding communities.

The state of wastewater pipelines specifically, coupled with their high consequence of failure, has led to more government regulations surround-

ing inspection and renewal, leaving utility operators with the challenge of finding reliable inspection methods for pipelines that often have no redundancy and thus cannot be shut down.

OVERALL STRATEGY EXTENDS DOLLARS AND INFRASTRUCTURE LIFE

Although the water and wastewater infrastructure challenges facing utilities across the United States are significant, adopting an asset management approach for infrastructure renewal can help utilities work within their capital budgets to identify areas that are most in need of repair. This "fix-it-first" approach ties into an overall renewal strategy by dealing with rehabilitation needs proactively in order to prevent costly system failures and service disruptions, while planning the rehabilitation and assessment of an entire system over the long term.

Implementing a proactive infrastructure renewal strategy is the philosophy of the Miami-Dade Water and Sewer Department (WASD) as the department approaches a critical point in the life cycle of its infrastructure. By identifying and rehabilitating the most critical areas first, WASD hopes to continue providing reliable service to its customers while extending the useful life of its assets in a long-term renewal program.

An electromagnetic tool is inserted into a live pipeline to identify prestressing wire breaks in one of Miami-Dade Water and Sewer Department's prestressed concrete cylinder pipes.

Overview of utility organization. WASD is one of the largest utilities in the United States. The department's water system serves approximately 418,000 retail customers and 15 municipal wholesale customers within Miami-Dade County, Fla. Water is drawn primarily from the surficial Biscayne Aquifer, a near-surface aquifer that underlies an area of about 3,200 sq mi in Miami-Dade, Broward, and Palm Beach counties. The water system consists of three regional water treatment plants and five small auxiliary treatment facilities that service the southernmost area of the county. There are eight major wellfields comprising 100 individual wells that supply raw water to the treatment facilities. Distribution throughout the service area of more than 400 sq mi is performed via seven remote finished water storage and pumping facilities through 7,490 mi of water mains ranging in size from 2 to 120 in. in diameter. In total, WASD provides an average of 312 mgd of finished water to its customers.

WASD's sewer system has a treatment capacity of 368 mgd through three wastewater treatment plants. These plants process effluent from 340,000 retail customers and 12 municipal customers. The county operates and maintains 1,000 pump stations and more than 6,000 mi of sewer mains—900 of which are force mains.

Miami-Dade County has 35 incorporated cities and many unincorporated areas. The northern, central, and eastern portions of the county are heavily urbanized with many high-rises up the coastline; the county also includes downtown Miami. The southern portion of the county includes the Redland and Homestead areas, which make up the agricultural economy of Miami.

As a result of the combination of many cities and regions, WASD has

Nondestructive, free-flowing electromagnetic technology is used as part of an annual leak detection program that assesses pipes without shutting them down.

a complex water and wastewater system with varying degrees of infrastructure quality. Before Miami-Dade WASD was created, political tensions and differing standards throughout the regions caused water and wastewater systems to be highly inconsistent; this posed a challenge for WASD after it acquired smaller utilities and began regional control of water and wastewater collection and treatment. Much of WASD's infrastructure was also built in the post-World War II boom through to the 1970s; many of the assets installed in the postwar period are now coming to the end of their useful life, meaning much of WASD's infrastructure is in need of renewal at the same time.

In 1970, there were more than 40 public water utilities in the county. This has now been reduced to 15 municipal systems, with the remainder being incorporated into WASD. Many of these systems were created in the most cost-efficient manner without significant planning for the future life of the system. Now that WASD operates many of them, it is also responsible for the maintenance and renewal of systems, even if they were not built to WASD standards.

The department operates three water treatment plants (WTPs)—the John E. Preston WTP, the Alexander ORR WTP, and the Hialeah WTP—that supply water to more than 90% of Miami-Dade County. The plants are 45, 56, and 87 years old, respectively, and are expensive and difficult to maintain because the companies that provided replacement parts are no longer in business. Water treatment regulations that are constantly changing are also an issue in older plants, because it is more difficult—and costly—to adapt the archaic technology to changing regulations.

Implementing a proactive infrastructure renewal strategy is the philosophy of the Miami-Dade Water and Sewer Department as the department approaches a critical point in the life cycle of its infrastructure.

Similar to the water department, WASD's sewer operations were highly fragmented during development and didn't become a countywide operation until 1973. Most of its infrastructure was also installed in the post-World War II boom. Until its consolidation into WASD, sewage in Miami-Dade was often improperly treated and disposed of by regional operators into the Biscayne Bay and Miami River, causing significant environmental concerns that led the push for the development of a countywide operator.

Environmental concerns also need to be addressed. In 1995, WASD and the US Environmental Protection Agency (USEPA) drafted a consent decree to guide sewage policy in Miami-Dade County in order to address environmental concerns and improve sewer services. This agreement required the Miami-Dade County government to spend $1.1 billion to overhaul its wastewater treatment system. This consent decree was ratified only shortly after the Florida Department of Environmental Protection and the USEPA required the county to replace its 40-year-old pipeline that carried sewage 5.3 mi across the Biscayne Bay to the Virginia Key Treatment Plant.

These regulations were brought forth so that WASD would upgrade its large wastewater collection system and ensure the safe disposal of wastewater for environmental preservation. In response to additional regulations, WASD started doing assessments on its gravity lines in 1992 and started a program of pressure pipe inspection by human entry in 1995. This program involved the routine inspection of all large-diameter force mains that could be shut down and inspected, but it could not assess force mains that are nonredundant. Although this was an attempt to maintain the structural integrity of sewer pipelines, it was unable to address a large number of force mains because the majority of

force mains in Miami-Dade—and across the United States in general—do not have redundancy.

Because of increasing concerns about aging infrastructure, the Miami-Dade Board of County Commissioners requested a report addressing the county's aged and deteriorating water and sewer infrastructure in 2009 and 2010. The report identified the most deteriorated and vulnerable sections of the water and sewer infrastructure, estimated the cost to rehabilitate or replace the identified parts of the system in each commission district, including pipes, treatment plants, and pump stations, and provided recommendations on whether to repair or replace the identified infrastructure, including possible sources of funding.

WASD's infrastructure report highlighted several areas of concern, including the need for transmission main redundancies to lower the consequence of failure and reduce the dependency on certain pipelines, upgrades to water and wastewater treatment plants and pump stations, and reliable inspection and management strategies for prestressed concrete cylinder pipe (PCCP), which makes up the majority of WASD's large-diameter pipeline network.

All of the projects identified in the report are currently included in the department's multiyear capital plan. For example, after the completion of an engineering analysis with consultants, short- and long-term recommendations were made for WASD's aging WTPs.

Although complete replacement would be ideal, the capital cost estimate associated with a full-scale replacement is extremely high. WASD is currently working to keep the plants operational and effective in the short term, while exploring long-term solutions that allow for the eventual replacement of its major treatment facilities. Currently the construction of a new $577 million WTP is planned to replace the nearly 100-year-old Hialeah plant.

After free-flowing leak detection inspections are completed on large-diameter pipelines, the tools are retrieved and leak locations are recorded for repair and to determine sections with high failure rates.

To fund ongoing infrastructure renewal projects, WASD aims to raise water and sewer rates to offset some of the costs as well as to sell bonds to raise money for the future management of its water and wastewater networks. Although increasing rates in the short term places a burden on ratepayers, successfully preventing costly pipeline failures and improving the efficiency of water and wastewater services will stabilize the budget in the long term. Between 2012 and 2022, the overall capital improvement project budget for water infrastructure is almost $3.9 billion for water infrastructure and almost $9.3 billion for sewer infrastructure.

Although WASD has made strides in planning to refurbish its water and sewer treatment facilities, it has also made significant improvements in pipeline reliability with the adoption of an asset management approach for the long-term management of its large-diameter water and wastewater pipeline infrastructure.

In total, WASD has more than 7,000 mi of mains and service lines, 40% of which are more than 40 years old; currently, these assets are deteriorating at a faster rate than they are being renewed. As the system continues to age, a greater number of pipelines need to be replaced or rehabilitated to preserve the life of the system.

The majority of WASD's large-diameter water and wastewater pipelines are made of PCCP. In total, WASD has more than 250 mi of 48-in. and larger diameter PCCP that has been installed since 1949. Over time—as with all materials—PCCP may deteriorate as the steel prestressing wire used to preserve its structural integrity deteriorates from external corrosion and hydrogen embrittlement.

In 2010, a failure occurred on a 54-in. PCCP water transmission main in Miami, requiring immediate pipeline inspection, repair, and replacement. The failure also caused a massive 40- × 40-ft sinkhole in the middle of an intersection, causing significant collateral damage for WASD. Overall, the incident cost $2.5 million to remediate. Shortly thereafter, a 72-in. PCCP force main also failed in a similar fashion, dispensing wastewater into the environment and resulting in expensive reactive maintenance.

LARGE-SCALE INFRASTRUCTURE RENEWAL PLAN ADOPTED

The predominance of PCCP in its water and sewer pipelines is one reason that WASD has embarked on a large-scale infrastructure renewal

project that includes inspection, rehabilitation, and monitoring of its large-diameter PCCP pipelines.

The pipeline failures of 2010 initiated Florida's Infrastructure Assessment and Replacement Program (IAARP) which strives to find and implement the best available inspection and rehabilitation technologies to address potentially damaging deficiencies in the large-diameter buried pipe of its pipeline network, including a technology that locates broken wires in PCCP that indicate that a pipeline might eventually fail.

Regular leak detection on large-diameter pipelines is an important prescreening function of a pipeline management program because leaks are often a preliminary indication of pipeline failure. Early identification of leaks helps to identify weak areas on a pipeline but also has the additional benefit of reducing the amount of nonrevenue water.

WASD currently conducts an annual leak detection program that surveys more than 8,000 mi of various pipe materials and locates more than 1,400 leaks. The locations are recorded for repair or to determine which areas of pipeline have the highest failure rates.

> These regulations were brought forth so that the Miami-Dade Water and Sewer Department would upgrade its large wastewater collection system and ensure the safe disposal of wastewater for environmental preservation.

Finding these technologies was only part of an overall infrastructure renewal program adopted by WASD to upgrade all of its infrastructure from distribution and large-diameter pipelines to water and sewage treatment plants.

Through the IAARP, WASD hopes to prevent failures to PCCP pipelines and gain valuable information on the condition of its pipeline network to make prioritized rehabilitation and replacement plans.

Four tasks make up renewal program. Within the program, WASD performs four main functions with the help of pipeline engineering consultants to manage large-diameter PCCP pipelines. The functions are regular leak detection on large-diameter transmission mains, electromagnetic condition assessment using advanced nondestructive technologies, structural risk analysis, and ongoing monitoring of PCCP pipelines through acoustic fiber-optic monitoring technology or regular re-inspections.

Advanced technology is a key to program success. To determine the baseline structural condition of its PCCP inventory, WASD uses advanced nondestructive electromagnetic (EM) technology to determine the location and quantity of wire breaks. Although manned inspections of large-diameter pipelines have been done for years, it was important for WASD to find an inspection method that eliminated shut-down time (because of limited access points and pipeline redundancy in the system) and reduce overall labor and costs. In a way similar to pigging performed in the oil and gas pipeline industry, by adopting a free-flowing method WASD is now able to assess more pipelines in a shorter time while collecting reliable data. In addition, nonredundant pipelines are now able to be inspected because the technology operates while the pipeline remains in service.

The primary advantage of this approach is that advanced EM technology provides the wire-break estimates on each individual section of PCCP, which is the best indicator that this type of pipe will fail. This allows for one deteriorated pipe to be identified within an entire pipeline that is in good condition overall and also provides the baseline condition of all pipes in the inspected distance.

Structural analysis helps prioritize repairs. After completing the assessment, WASD has identified all distressed pipe sections in a given pipeline and the position and magnitude of the distress. A structural analysis then provides staff with a recommendation as to which pipes require immediate rehabilitation, which replacements can be delayed until a future date, and which pipes require no action at this time.

Although consultant analysis and recommendations are useful, the WASD staff is the most equipped to make repair, rehabilitation, and replacement decisions. As such, external recommendations, though a key element, are only a starting point in determining what rehabilitative action should be taken for these assets after the WASD staff determines the risk and consequence of a failure for each pipe segment.

The rehabilitation of pipeline assets typically includes one of the following: an internal replacement using a carbon-fiber reinforced polymer, installing a pipe liner, or a complete replacement of the section using new pipe materials. Low or undamaged sections of the pipeline are re-inspected periodically or, if at high consequence of failure, monitored continuously using fiber-optic technology.

Fiber-optic monitoring of PCCP tracks the deterioration of each pipe section by recording wire breaks as they occur. When a prestressed wire breaks, a sound is created, and the resulting mechanical sound wave propagates away from the break. This mechanical wave interacts with the electromagnetic light wave that

is moving through the fiber-optic cable. This interaction is sensed and filtered by the data-acquisition computer system and a notification is made to WASD staff members, allowing them to track deterioration as it happens. The data collected through monitoring is then combined with the wire-break estimates made during the initial EM inspections, which allows WASD to see the total wire breaks on each section and intervene before a pipe section fails.

WASD has considered the complete replacement of some of its PCCP pipelines because the renewal option has the potential to be extremely challenging. In terms of practicality, pipeline replacement is difficult and expensive, and any replacement would require tie-ins to the existing system, shutdowns, and continuing inspection of the sections that were not replaced. The estimate of a complete replacement program for WASD's entire PCCP infrastructure—assuming a replacement cost of $1,500 per linear foot—would be roughly $2.5 billion. Because of the challenges and costs associated with replacing large sections of a pipeline, installing 2 mi of new pipeline per year would be considered a successful and manageable replacement program for WASD. To put this in perspective, replacing WASD's entire PCCP inventory of more than 250 mi would take nearly 200 years. Another factor WASD must address when pipeline replacement is being considered is where to locate new pipelines. Because the county has limited space and many of the pipelines serve a large number of customers in urban areas, replacement projects are difficult to plan and execute.

As WASD inspects its PCCP assets each year, the typical number of segments showing any type of degradation has not exceeded 2.5% on average; less than 1% requires some sort of rehabilitative action with no parts of the system being immune to rehabilitation, regardless of their age or manufacturer. Considering that less than 1% of pipes require immediate action, a full replacement program would end up replacing pipelines that for 99% of the system have a significant remaining useful life.

Getting the most from existing infrastructure. With respect to PCCP water transmission and sewer force mains, WASD's "fix-it-first" approach maximizes the useful life of this portion of the department's critical infrastructure. Ideally, a similar approach can be taken toward other WASD assets so that the capital budget can be maximized and funds are not used on unnecessary rehabilitation.

Although the pipeline management program is only part of the overall infrastructure renewal plan, it acts as an exemplary model of how successful renewal of infrastructure can increase reliability and tackle the problem of aging infrastructure with a manageable capital budget. By beginning an overall renewal program, WASD aims to prevent major system failures, increase service reliability, and extend the useful life of its assets while renewing its entire water and wastewater systems in the long term. WASD has received strong support for the infrastructure renewal project throughout the department, while the recognition of aging infrastructure and support of renewal programs is growing at the different levels of government throughout the United States. In many respects, WASD is ahead of the infrastructure renewal curve because aging infrastructure has only recently become a priority for policymakers at the higher levels of government.

Despite strong support, it will still be difficult to achieve all the funding requirements requested for the program; however, the department is moving toward a structure that has the processes and protocols in place to complete infrastructure upgrades and manage its capital projects in an efficient manner if and when the funding is available.

PROVIDING A MODEL FOR OTHER DISTRICTS

If the pipeline assessment and management program is any indication, the initial reviews show that WASD's water and wastewater systems are in better condition than expected based on their age and operating capacity. Much of this can be credited to WASD employees who have very high standards and always plan for more than they can accomplish in any given year.

As local politicians take notice of the nationwide initiative to address aging infrastructure in the United States, WASD is now able to provide answers of how it can solve specific local infrastructure issues as a result of the early adoption of a renewal strategy. With plans already in motion, the department feels it has a solid grasp on what the renewal process entails and can now plan the program details so that current and future residents of Miami-Dade County have reliable water and sewer service.

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