Reap the Benefits of Minimizing Nonsurfacing Leaks in Underground Pipe Networks

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The water industry continues to face challenges when it comes to managing linear underground assets, including transmission and distribution mains as well as service lines. Consider that AWWA's 2023 *State of the Water Industry* reports that the top issue for water utilities is rehabilitating and replacing aging infrastructure. The 2021 American Society of Civil Engineers' Drinking Water Infrastructure Report Card says that a water main break occurs every two minutes in the United States on more than 2.2 million miles of pipelines. According to the *Environmental Research Letters* March 2022 article, "Untapped Potential: Leak Reduction Is the Most Cost-effective Urban Water Management Tool," real water losses have been estimated at 17% of total delivered volume.

Moreover, in the 2018 Utah State University report, *Water Main Break Rates in the USA and Canada*, more than 300 utilities provided information covering almost 300,000 miles of pipe. According to the report, there are 14 water main breaks for every 100 miles of pipeline. This was an increase of 27% from the university's previous survey conducted in 2012. Both surveys focused on surfacing leaks, and the 2018 report notes that the main causes are circumferential cracks (37% of failures), corrosion (27% of failures), and longitudinal cracks (22% of failures). No data were provided on how many hidden, nonsurfacing leaks there are in a pipeline system and how long they exist before they surface.

To design an effective water loss control strategy, utilities must understand what is happening to their buried pipelines. Knowing how and where leaks are generated and propagate through a system is critical to reducing recalcitrant real water loss.

Determining Nonsurfacing Leaks

Understanding the number of background, nonsurfacing leaks in a system at any point in time entails analyzing multiple data sets. Recently, the results from four fixed-base acoustic leak detection system projects were consolidated and normalized to show leaks per 100 miles of system length. As shown in Figure 1, there were 100 leaks per 100 miles of pipeline length when a continuous correlating acoustic monitoring (CCAM) leak detection system was first installed. This is the baseline level of background leaks for these systems, which averaged a real water loss rate of 25%.

The CCAM system scans the area daily, and leaks are repaired as soon as field crews identify them. As shown in Figure 1, the number of leaks dropped immediately and tracked even lower over time. During the first 12-month period after the initial inspection and repair, a total of 155 background leaks per 100 miles were identified and repaired. Only 33 leaks were found during the next yearly time period. Over time, the number of leaks in these areas approached zero.

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Another data set of 12 projects was analyzed to predict the number of background leaks based on the system's nonrevenue water (NRW) percent as reported by the utility. Data used to calculate this metric included NRW percent, total system delivery, system size in miles, and an estimated average leak size flow rate. The leak size was based on a cohort of more than 88,000 leaks identified around the world. The analysis segmented the leaks by subtype (e.g., main pipe, service pipe, connection, valve, hydrant, curb stop, meter) and assigned a flow rate to leak subtypes as detailed in AWWA Manual of Water Supply Practices M36, *Water Audits and Loss Control Programs* (www.awwa.org/M36). This resulted in an average leak flow rate of 6.4 gpm. As illustrated in Figure 2, the results show that when a system has a 7% NRW, there are approximately 32 background leaks per 100 miles, and when the system has a 29% NRW, it is estimated that there are 77 leaks per 100 miles.

To understand how leaks are distributed throughout a system, two data sets were analyzed. The first cohort contained data on more than 600 projects in which likely system leak locations were prelocated before field crews were deployed to confirm the leaks; this resulted in identifying 2.6 leaks per mile. A second data set of 1,800 projects was developed without prelocation. These projects were performed in a traditional manner by deploying field crews randomly throughout a system and inspecting point to point, which resulted in identifying 0.33 leaks per mile. This study found that there were eight times as many leaks in clustered areas than in an average section of the distribution system. Another difference in the two cohorts was that the prelocation field inspections accessed more than 130 listening points, whereas the traditional method inspected 35 listening points per mile. As more listening points per mile are accessed, more leaks are found.

The long-term analysis of nonsurfacing background leaks calculated a total of 100 background leaks per 100

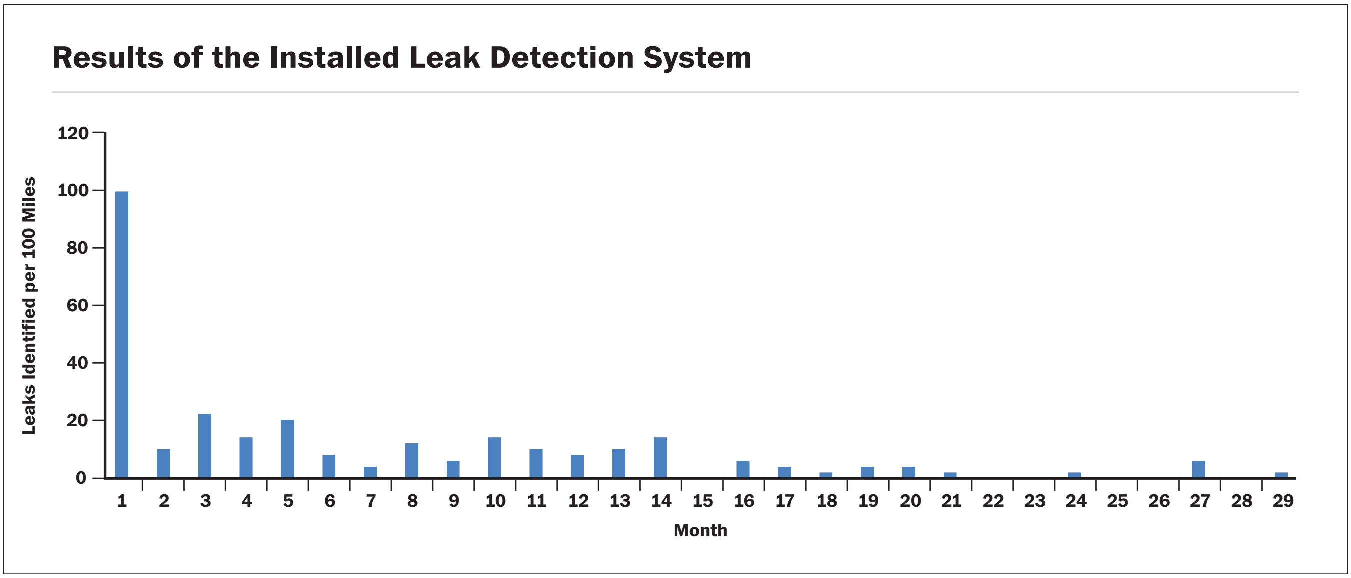
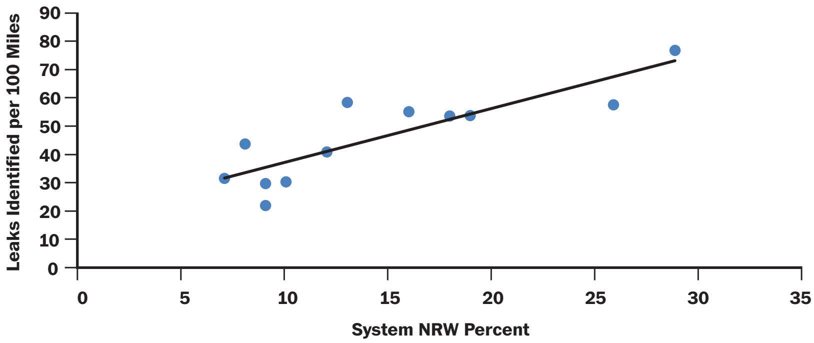


Figure 1

miles of pipe with a 25% NRW. As shown in Figure 2, at an NRW level of 25%, 66 background leaks per 100 miles are predicted. This means that the areas where CCAM systems were used found a 50% higher density of leaks than what would be expected based on an average system with 25% NRW.

Using the Utah State University survey, there are 14 surfacing water main breaks per 100 miles per year, which means there are approximately seven background leaks for every one that surfaces. These leaks are in various stages of development, typically starting small and growing until they are identified by a proactive program—or the pipe bursts and the leak surfaces, although some leaks are catastrophic and burst immediately. That there are many more nonsurfacing leaks than surfacing leaks is a critical fact in designing a successful leak detection program.

Background Leaks per 100 Miles Versus Nonrevenue Water



NRW—nonrevenue water

Figure 2

Addressing Nonsurfacing Leaks

Once areas of leak clusters are identified, they can be proactively targeted for leak detection to efficiently reduce real water loss. Following this approach, eliminating leaks in clusters can lead to wider improvements than addressing background leaks.

As seen from the historical trend analysis, leaks have been almost entirely reduced in these areas over time. As background leaks are identified, newly generated leaks are quickly repaired before they can propagate. However, it is important to understand why leaks can lead to more leaks.

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When water leaks from a pressurized pipe, it typically does not surface immediately, and this can go on for a long time before it is noticed—months or even years. Leaks add significant moisture to the backfill material in which pipes are buried, and they can also cause voids in the backfill material, spaces to generate significant stress around a pipe. These stresses can increase circumferential and longitudinal cracks, which, as previously mentioned, are the two major causes of leaks reported by utilities.

Soil resistivity has the greatest effect on the corrosion of buried pipelines. Soils with poor drainage or exposed to leaking water have high moisture content and low resistivity values. The lower the resistivity, the more corrosive the soil. Buried metal pipelines and tanks usually suffer from corrosion due to low resistivity values and high moisture content.

In addition, the force of the water leak under pressure can generate voids or subsurface erosion, which again can cause differential stress on a pipe, leading to cracks. This means a leaking pipe can have a snowball effect in the area, creating additional leaks or a leak cluster. This cascading effect can be prevented, and leak clusters can be eradicated by quickly finding and repairing system leaks.

Utilities should identify likely leak locations and continuously monitor those areas. Such an approach can dramatically reduce real water loss by eliminating background leaks, preventing new ones, and halting leak propagation to save water resources and minimize the net cost of safe water production.

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