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A Call for Reliability Standards

The catastrophic gas pipeline failure that occurred in California on Sept. 9, 2010, tragically reminds us that a public utility's most important function is the safe operation, maintenance, repair, and management of its infrastructure. As with every other human endeavor, however, it is impossible to reduce the risk of failure to zero. Even approaching that utopian zero-risk state would result in utility service being so expensive that only the privileged few could afford it. The provision of water service is essential for the safe development and habitation of our cities and towns—turning the service into a luxury is neither feasible nor desirable. Neither is it acceptable, however, to allow our infrastructure to deteriorate or to spend money on that infrastructure without understanding the benefits likely to be obtained.

Much has been written by AWWA, its members, and others in the water industry about the broad scope of the infrastructure challenge, the need for asset management plans, and the importance of attempting to minimize the risk of infrastructure failure. Baird (2010) provides a good overview of some of these studies. National studies estimate that water utilities will need to invest tens—or even hundreds—of billions of dollars in water infrastructure during the next 20 years. But no national study can identify the specific assets that need to be repaired or replaced at any particular utility, the appropriate time period for undertaking that work, how the work should be prioritized, or the risks that will be faced if the work is not performed.

After numerous studies spanning 30 years or more, we understand that age alone is not sufficient to identify assets that pose an imminent risk of failure. Age, pipe material, manufacturing processes, installation practices, soil conditions, earth disturbance, and numerous other factors can affect a pipe's useful life. Muhlbauer (2004) identifies dozens of factors that can affect the integrity and life of the components in a water distribution network, including: pipe material and coating, pipe diameter, soil corrosivity (including factors such as moisture content, acidity, presence of chemicals such as chlorides and sulfates), joint type, pressure, tree locations, traffic, nearby excavation, level of activity above ground, cathodic protection, type of joint, land movements, maintenance and inspection practices, and construction methods.

Amid all the studies and talk about asset management and infrastructure replacement, however, one important piece of the puzzle is missing: How do we measure (and improve) the reliability of service to customers?

Simply counting main breaks is not sufficient. The failure of a 36-inch transmission main is not equivalent to the failure of a segment of a six-inch main serving 10 customers. Similarly, measuring nonrevenue water has many pitfalls, not the least of which are the numerous causes of nonrevenue water—some of which directly affect customers (such as main breaks) and some of which do not (such as under-registering meters or water used during hydrant flushing).

Davis and Marlow (2008) suggest that water utilities should focus first on their largest pipelines. Although the management of smaller pipelines is important, those authors note that individual small water mains "can still be allowed to fail because of the relatively low consequences incurred per pipe break, relative to the cost of preventing such breaks across a network. In contrast, because of the higher consequences associated with failure of large-diameter mains, most water authorities would prefer to prevent and/or avoid such failures whenever possible. . . ."

Although that approach starts to address reliability concepts (the failure of a big pipe affects more people than the failure of a small pipe), it is far from being a metric that can be used to set priorities and assess progress toward improving the reliability of service. It also fails to recognize that some customers that have critical needs and an extremely low tolerance for water outages (such as hospitals and nursing homes) may be served by smaller-diameter water mains.

Stated differently: We know that an appropriate goal for a human endeavor cannot be perfect performance. Such a level of performance is neither achievable nor cost-effective. So how much imperfection is tolerable in a public water supply system, and how do we measure it?

Rogers and Grigg (2009) note that a study (American Water Works Service Co., 2002) found that a sample of water utilities averaged 36 main breaks per year for each 100 km (61 miles) of pipeline. More recently, Cromwell (2010) reports that from his work during the past decade, most water utilities experience between 0.1 and

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0.3 breaks per mile, with smaller mains (10 inches or smaller) breaking five to 10 times more frequently than larger mains.

The fact that the average water utility experiences main breaks tells us that water systems are not achieving 100% reliability (as we would expect). But it does not answer two important questions: Are these levels of performance acceptable? How do we measure whether the expenditure of millions or billions of dollars would make things better?

A study by Dandy and Engelhardt (2006) has come closest to grappling with this issue. They characterize the asset management problem as being a trade-off between economics and reliability. They define these two objectives (that is, perfect performance) as follows:

- Economic objective: "minimize the present value of the system cost."
- Reliability objective: maximize "the ability [of the utility] . . . to meet the demands [of customers] at all locations at acceptable pressures" at all times.

Neither of these objectives is fully achievable in reality, but the goal is to approach an optimal solution: achieving an acceptable level of reliability at the lowest reasonable present value of system cost.

Dandy and Engelhardt (2006) suggest that the reliability goal should be based on the number of annual customer interruptions, which they call the total expected number of customer interruptions. Some utilities will have actual data on the number of customers for each pipe segment, whereas others will not have such specific data. Without actual data, the authors made simplifying assumptions based on land-use data, such as a rural road would have three customers per pipe segment and a main supplying a residential area would have 50 customers per segment.

For many years, electric utilities have measured the reliability of service using similar concepts based on the frequency and length of customer outages. Utilities, regulators, and standard-setting bodies have developed indexes, such as the System Average Interruption Frequency Index (SAIFI) and the System Average Interruption Duration Index (SAIDI), to measure the frequency with which customers suffer interruptions of service and the average length of time they are without service. For example, the Pennsylvania Public Utility Commission (2004) defines SAIDI as the average duration of sustained customer interruptions per customer occurring during the analysis period; it is the average time customers were without power. It is determined by dividing the sum of all sustained customer interruption durations in minutes by the total number of customers served. This determination is made using the following equation:

$$\text{SAIDI} = \frac{\Sigma r_i N_i}{N_T} \qquad (1)$$

in which i = an interruption event, r_i = restoration time for each interruption event, N_i = number of customers who have experienced a sustained interruption during the reporting period, and N_T = total number of customers served for the area being indexed. (A "sustained" interruption is defined as one that lasts more than a specific period. The period used varies by jurisdiction and electric utility, but is generally between one and five minutes [Brown, 2008].)

It is time for the water utility industry to develop similar reliability measures and standards. Before we spend tens or hundreds of billions of dollars on water infrastructure, we should have a system in place to measure the reliability of service, quantify the expected improvement in that reliability from infrastructure expenditures, and measure the actual level of improvement achieved. Water utilities should have reliability goals, and those goals should be the end point of utilities' asset management plans.

The potential savings from this type of effort can be substantial. One study estimated that changing the reliability target for a water system by less than 12% (from 1,700 customer interruptions per year to 1,900 interruptions per year) could defer a multimillion-dollar construction program by as much as 10 years (Dandy & Engelhardt, 2006).

Given the public-health implications of a water outage, utilities should consider reliability standards that vary for different types of customers. For example, an industrial plant with access to a private well as a backup water supply for its manufacturing process might require a lower level of reliability from the water utility than a typical residential customer. On the other hand, a hospital or nursing home that must have water to maintain sanitation might require a higher level of reliability than a typical residential customer.

In addition, a water utility reliability measure should be based on the delivery of potable water that complies with safe drinking water requirements. For example, the delivery of water that is unsafe to drink (such as water subject to a boil-water advisory) might be acceptable for an industrial process, but might be considered to be an outage for customers that need to consume the water.

A water utility's asset management plan is an optimization process that attempts to meet the competing objectives of cost minimization and reliability maximization. The goal cannot be to develop a perfect plan or to achieve 100% reliability for every customer. Rather, the goal is to achieve an appropriate level of reliability, given regulatory requirements and the needs of the community, in a cost-effective manner. In order to do so, the utility needs to have reliability goals and a way to measure those goals.

Before the United States commits to spending billions of dollars on water infrastructure, it is essential that we have a way to set priorities and measure progress. An

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essential part of that process is establishing performance goals for water distribution systems. As is common with electric utilities, those goals should be based on the reliability of service received by customers, as measured by outage frequency and duration.

Too much money has already been spent on infrastructure "improvement" in the water industry without a showing that customer service has improved. We must ensure that infrastructure management and investments are improving customer service, and we must have a way to measure that improvement.

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