There was a time, going back to Boston’s founding in 1620, when its residents relied on wells, rain barrels, and a spring on Boston Common for their water. An upgrade of sorts came in 1795 when a delivery system was developed to carry water through wooden pipes to Boston from nearby Jamaica Pond.

The Boston Water and Sewer Commission (BWSC) points to 1848 as the year when the city’s first modern water system was begun, using a large new reservoir and a few miles of cast-iron pipe as its foundation. Continuing to count on the strength and longevity of iron pipe, the BWSC system now serves more than 1 million people daily. The BWSC water distribution system has 1,012 miles of pipe, and 995 of that is either cast iron or ductile iron (Figure 1).

Boston was, in fact, built on iron pipe, and many of the city’s iron water mains have averaged well over a hundred years of service. Boston is one of 20 members of the Ductile Iron Pipe Research Association’s (DIPRA’s) Cast Iron Pipe Sesquicentury Club, which comprises utilities that have had cast-iron pipe in continuous service for more than 150 years (Figure 2).

**BOSTON’S INNOVATIVE MANAGEMENT APPROACH**

More than most American cities, 394-year-old Boston has faced aging water infrastructure issues. Although Boston is inextricably linked to the nation’s historic past, the city’s water distribution story is about innovation with an eye on the future. In addition to Boston’s long-ago selection of iron pipe as a sustainable, long-lasting material for its water system, the BWSC has been a leading innovator in the management of this most precious asset.

A study done almost 50 years ago, for example, led to an extensive program of cleaning and cement-lining of iron water mains. The long-lasting iron pipe installed during the BWSC’s earlier days was still in excellent condition at the time of the study, which allowed for the relatively nondisruptive in situ cleaning and lining instead of replacement.

Another study, completed in 1986, called for other improvements in the system and recommended the replacement of a minimum of 17 miles of pipe a year for the next 20 years. Those two studies and the subsequent work they generated resulted in a hydraulically strong water distribution system built with iron pipe, with excellent water quality and overall pipe performance.

Questions lingered, however. The conventional wisdom had been that replacement programs should begin with older mains, but Boston questioned that logic. Water officials asked, for example, if the city was getting the most value from money spent to replace older mains if they, in fact, did not need to be replaced.
It was deemed critical to address such questions through a scientific process so that the resulting answers would stand up to scrutiny by those who approve funding for infrastructure programs. That line of thought led to a complete study of Boston’s water system, which included a detailed analysis of its water pipes. The city chose Camp, Dresser & McKee (CDM Smith) to do the study, which began in 2007.

The four-year study looked at numerous factors, including but not limited to pipe performance, age, location and proximity to important civic and residential activity, past construction (pipe installation) practices, physical and chemical evaluation of pipe samples from different soils and fill materials, the possible impact of stray current from subway systems, and break patterns that would indicate other outside forces affecting water pipes. Among the many facets of the water pipe study was the analysis of an advanced statistical model called LEYP (linear extended Yule process) that uses sophisticated and well-researched multiple regression functions to develop life expectancies of assets. The LEYP model develops life expectancies for a particular pipe or for entire “cohorts” or classes of pipes.

In Boston’s case, the pipe type was broken down into seven classes ranging from pit cast-iron pipe with no cement lining to cement-lined ductile-iron pipe installed since 1976. As a result of this analysis, a range of service-life curves was developed for each of the seven classes of pipe that showed the year when 50% of the pipe in each class would need to be retired.

The service-life data were entered into the KANEW model (a water-main software model developed for North American water utilities based on a model developed in Germany), which looks at the installation date for all of the various pipes in the system and then uses the service-life curves to predict when particular classes of pipe will need to be retired. This
model was used to predict aggregate long-term replacement and rehabilitation needs for the BWSC distribution system.

The KANEW model was further used to develop a series of what-if scenarios aimed at leveling out the volume of pipe to be replaced each year. The final recommendation was to renew 11 miles of pipeline each year, which would sustain the system in the long run. It would significantly reduce the BWSC’s previous goal of replacing 17 miles of pipe per year while maintaining high pipeline performance. After updated information regarding its water mains has been incorporated, Boston plans to run the KANEW model every five years.

The culmination of the water pipe study was the application of a risk-based assessment methodology to determine long-term replacement and rehabilitation needs for every pipe in the Boston distribution system. The Annual Replacement Program model takes all of the prior risk data and weighs and ranks this information to generate prioritized groupings of pipe segments. That provides a flexible and defensible risk-based approach to infrastructure renewal that allows for better-informed decisions and more strategic use of capital funds to minimize the life-cycle cost of infrastructure assets.

According to its capital spending plan, the BWSC maintains a policy—to the greatest extent possible—to coordinate the replacement and lining of water mains with roadway and highway construction, urban development, housing development, and mass-transit work planned by state or local government entities.

If the city’s public works department, for example, plans to resurface a roadway, the BWSC will make every effort to replace the water main in that street before it is resurfaced unless replacement is deemed unnecessary. This further illustrates the asset-management mindset in Boston.

NEW UNDERSTANDING AND CONFIDENCE

According to Boston water officials, the water pipe study opened up a new understanding of the city’s water system. Although many of the conclusions were not a surprise, the depth of detail associated with the resulting analysis provides Boston with the necessary confidence to move ahead in slightly different directions. Armed with new tools and new information, Boston’s decisions can be based on the reality of the condition and importance of each piece of pipe—not on rules of thumb or past practices.

It is no longer a simple matter of replacing the oldest pipes; understanding a city’s system can help authorities prioritize the work that needs to be done based on the true condition of the pipe. Boston’s forward-thinking and fact-based asset-management program directs the BWSC to the appropriate sections of its system for maintenance and replacement, ensuring wise use of funding, resulting in the continued reliability of its strong iron-pipe network. It’s what Boston is built on.

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The content of this article draws heavily and often quotes directly from the report An Analysis of Boston’s Water Distribution System, written by Stephan Shea, director of engineering design for the BWSC, and James Pescatore, senior project manager for CDM Smith.

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