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PRACTICAL IDEAS FOR WATER OPERATORS

VOLUME 44, NO. 8 AUGUST 2018

ASSET MANAGEMENT
TAKE A PROACTIVE APPROACH TO REHABILITATE AGING INFRASTRUCTURE

WATER QUALITY
Data Tools Improve Nutrient Monitoring

DISTRIBUTION
Avoid Microbial Contamination of New Fire Hydrants

MEMBRANE TREATMENT
Pretreatment Chemicals Pay Dividends Downstream

Contents

VOLUME 44, NO. 8 AUGUST 2018

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Established in 1881, the American Water Works Association is the largest nonprofit, scientific, and educational association dedicated to managing and treating water, the world's most important resource. With approximately 50,000 members, AWWA provides solutions to improve public health, protect the environment, strengthen the economy, and enhance our quality of life.

Opflow's editorial purpose is to present new and established technologies and ideas that readers can apply to drinking water treatment and distribution, alert readers to possible related problems and solutions, interpret regulatory and technical information in a clear format, and foster and promote innovative ideas that help readers provide safe water to all.

FEATURES

COLUMNS

DEPARTMENTS

On the Cover: Dedham, Mass., has developed a model sewer management program to operate, maintain, and manage its aging collection system. Photograph courtesy of Weston & Sampson Engineers.

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A historic Massachusetts town has implemented a comprehensive rehabilitation program to create a more efficient, less costly, and more predictable wastewater collection system.

BY PATRICK M. COTTON, NATHAN E. MICHAEL, AND JASON L. MAMMONE

TAKE A PROACTIVE APPROACH TO REHABILITATE AGING INFRASTRUCTURE

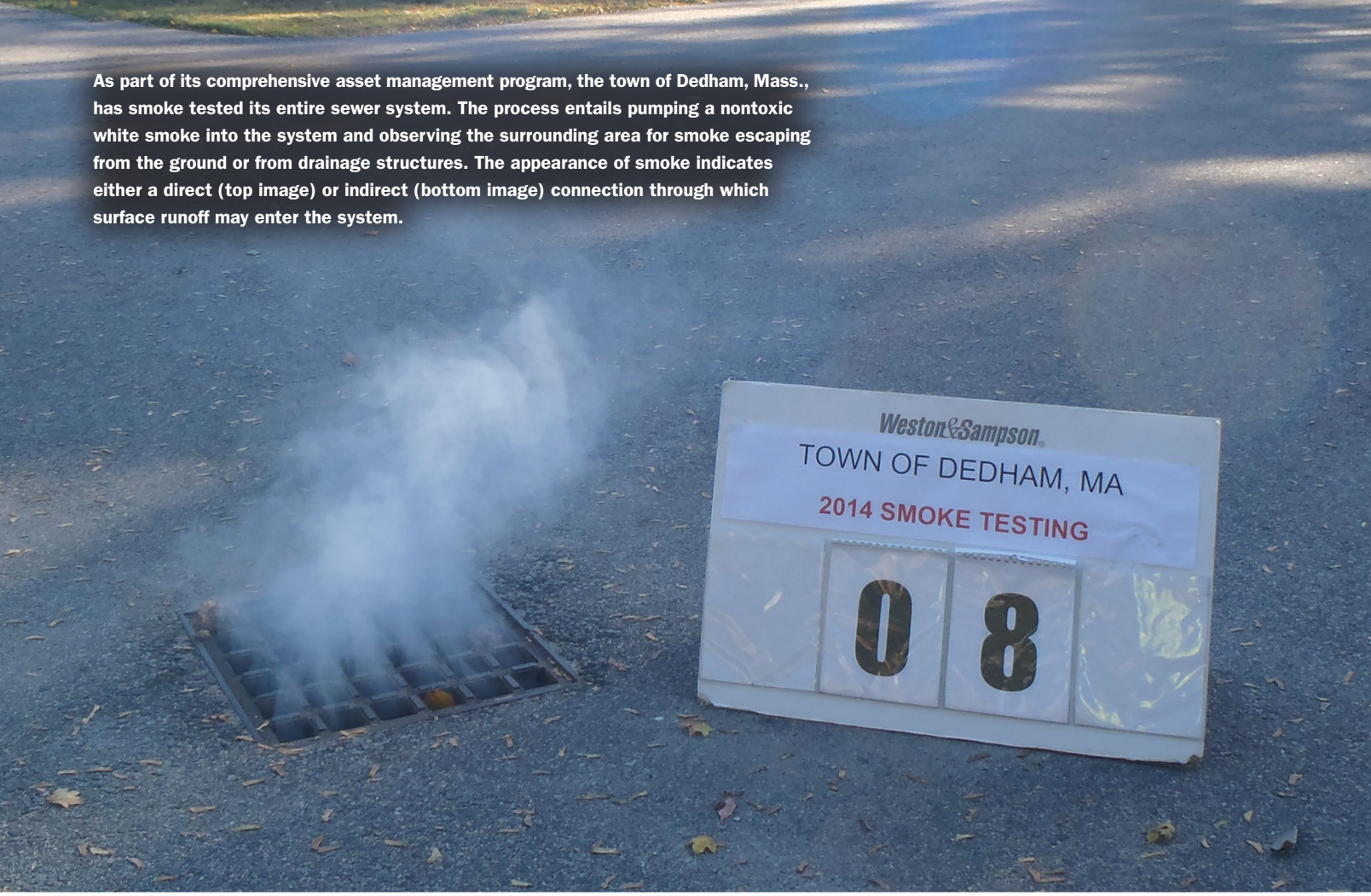
DEDHAM, MASS., is a residential community located southwest of Boston. The town's wastewater drains east to the Boston line, where it enters the Massachusetts Water Resources Authority (MWRA) interceptor and is ultimately treated at the Deer Island Wastewater Treatment Plant.

Dedham's sewer management program (annual program) is used to operate, maintain, and manage its aging collection system; remove extraneous infiltration and inflow (I/I); and keep sewer-related costs low. The annual program is a model tool that supports the community's wastewater collection system and saves money.

In 2006, Dedham faced a neglected sanitary sewer collection system, first constructed in 1901, and increased costs associated with operation and maintenance. The town soon began a comprehensive investigation and rehabilitation program. The approach, incorporated in the annual program, benefits the town by identifying and removing extraneous I/I while repairing structural deficiencies within the collection system before emergency repairs are required.

PHOTOGRAPHS: WESTON & SAMPSON ENGINEERS

As part of its comprehensive asset management program, the town of Dedham, Mass., has smoke tested its entire sewer system. The process entails pumping a nontoxic white smoke into the system and observing the surrounding area for smoke escaping from the ground or from drainage structures. The appearance of smoke indicates either a direct (top image) or indirect (bottom image) connection through which surface runoff may enter the system.



ANALYZING AGING INFRASTRUCTURE

The program began by analyzing the town's entire 94-mile gravity sewer collection system and separating it into 26 sewer basins. The basins then were prioritized for investigation and rehabilitation based on age, known problem areas, amount of work previously completed, and increased flow rates during wet weather.

Repairs were made from 2006 to 2012. The town then developed the annual program in 2013 based on the results of a comprehensive flow metering project in which 24 flow meters were installed during the spring of 2012. The I/I analysis identified 3.4 mgd of peak infiltration and 8.5 mgd of peak storm inflow. The I/I analysis results were used to create the annual program. Each project year includes manhole inspections and television inspections in the project area. Evaluation, design, and rehabilitation of cost-effective and value-effective defects are then completed.

A follow-up flow metering program was performed in the spring of 2016 to identify how the repairs performed between the spring of 2012 and the spring of 2016 affected I/I rates. The same 24-meter program was performed, and the analysis identified 2.7 mgd of peak infiltration and 7.3 mgd of peak storm inflow. The results showed the annual program was benefiting the town by reducing I/I, which in turn decreases the amount of flow being needlessly treated by MWRA.

Every five years, a flow metering project is conducted to analyze the program's success and reprioritize it. This ensures the sewer system is operating efficiently and new I/I sources are identified regularly.

ADDITIONAL ANALYSES

Dedham also has performed several other types of infrastructure analysis.

Sanitary Sewer Overflows (SSOs) and Hydraulic Modeling. Historically, Dedham has experienced only one SSO within the last 10 years, and it wasn't because of a significant rain event. The town experienced five significant rain events during that time, none of which caused an SSO to occur.

In addition to reviewing historical SSOs and rainfall data, Dedham developed a hydraulic model to analyze the effects of a five-year, 24-hour storm event on the wastewater collection system. A scenario was run that included average daily flow, plus the estimated five-year, 24-hour peak inflow as observed at the 24 flow meters during the 2016 I/I analysis. No SSO conditions were generated during this scenario run, which confirmed the sewer system isn't at risk of an SSO during such a storm event.

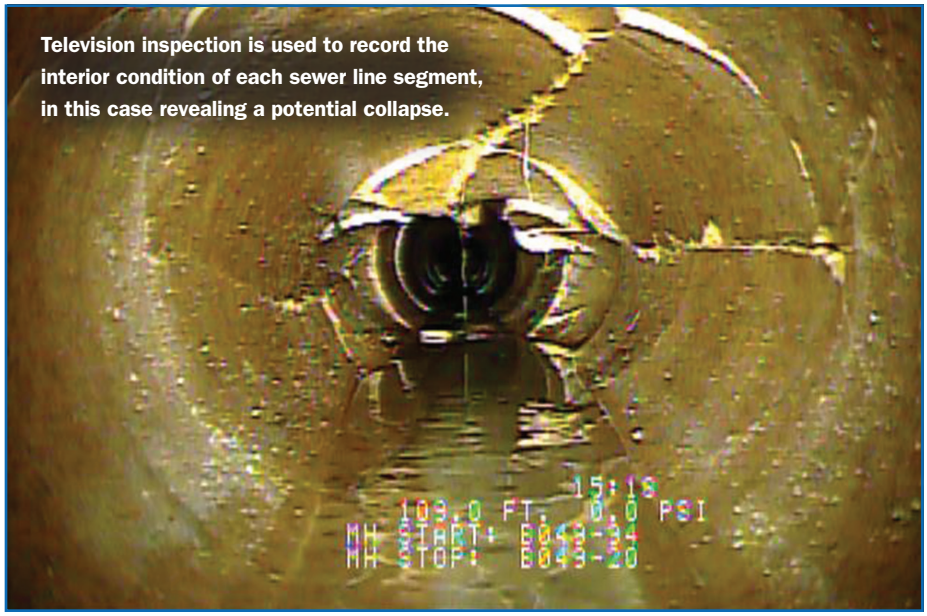
Topside Manhole Inspections. Manhole inspections consist of a topside visual inspection of sanitary sewer manholes and are typically performed during the spring, when peak groundwater conditions exist and allow for visual confirmation of infiltration. Manhole location, diameter, depth, material, and cover casting and size, as well as a flow estimate for all infiltration sources, are recorded for each manhole inspected. Information on inflow sources are also recorded. The inspection also provides information on structural defects in manholes that could be repaired as part of the town's regular maintenance activities. Since 2007, Dedham has inspected all sewer manholes several times, totaling approximately 4,250 manhole inspections.

Television Inspection of Sewers. Television inspection is conducted to locate and document pipeline defects and to directly observe infiltration rates. As with the manhole inspections, television inspection is conducted during the spring to coincide with peak groundwater conditions. A closed-circuit television camera is used to record the interior condition of each line segment. Television inspection logs are completed for each segment, documenting the location of each service connection, joint condition and spacing, debris deposition, pipe defect locations, and infiltration rates. This information is used to specify the appropriate rehabilitation technique and to determine the cost-effectiveness of rehabilitating each defect. During the inspection, a pan-and-tilt camera is used to observe the pipe defects, leaks, and the internal condition of service

A topside manhole inspection revealed wall infiltration and a damaged internal connection.

PHOTOGRAPHS: WESTON & SAMPSON ENGINEERS

It's estimated that the annual program has saved rate payers approximately $10 million during the program's short life.



Television inspection is used to record the interior condition of each sewer line segment, in this case revealing a potential collapse.

connections. Since 2007, the town has completed television inspection of all gravity sewer pipes multiple times.

Smoke Testing. Smoke testing consists of pumping a nontoxic white smoke into the sanitary sewer collection system and observing the surrounding area for smoke escaping from the ground or from drainage structures. The appearance of smoke indicates either a direct or indirect connection through which surface runoff may enter the sewer system. Direct sources include catch basins, driveway drains, patio drains, stairwell drains, or yard drains that discharge directly to the sewer system. It's assumed that rehabilitation can remove 100 percent of direct inflow.

An indirect source constitutes rainwater that infiltrates into the ground before entering the sewer system at a sewer system defect, such as cracked pipes or offset joints in adjacent sewer and drain pipes that create an indirect connection between the drain and sewer systems. It's assumed that rehabilitation can remove only 50 percent of indirect inflow, as the rainwater could enter the sewer system at another defect that has yet to be identified. Indirect inflow sources can occur during a rain event when there's an opportunity for a drainage structure to be hydraulically connected to the sanitary sewer system. An example of this is a cracked service connection located below a cracked drain line. When a rain event occurs, rainwater migrates from the drain line, through the soil, and into the defective service connection. Since 2007, the town has smoke tested the entire sewer system as part of its annual program.

Dye Testing and Dye Flooding. Sources identified during the smoke testing process are confirmed by performing dye testing or dye flooding. Dye testing uses less than 10 gal of water and is conducted by introducing dyed water into a suspected inflow source and observing the surrounding sewer and drain lines for the emerging dye. Dye flooding uses more than 10 gal of water. If dye appears in the sewer system, it indicates the nature of the inflow source's connection to the sewer system. Sources that are inconclusive or unable to be tested are followed up with a visual field or television inspection.

Private Building Inspections. The building inspection process involves a two-person team entering the basement or lowest level of as many buildings as possible within the project area to identify inflow sources to the sanitary sewer system. Inflow sources identified during building inspections have included sump pumps, floor drains that are subject to inflow, and open sewer cleanouts that allow clean water to enter the sanitary sewer system. These sources often are used by the building owner to relieve flooding conditions in or around the building during wet

Sewer System Investigation and Rehabilitation Summary

Since 2007, the town of Dedham has inspected its entire sewer system multiple times as part of its annual program.

Investigation/Rehabilitation	Total
Cementitious Lining of Sewer Manholes (per vertical ft)	7,722
Clean, Inspect, Test and Seal–6 in. to 24 in. (per linear ft)	48,356
Cured-in-Place Short Liners–6 in. to 24 in. (per linear ft)	2,987
Cured-in-Place Pipe–6 in. to 24 in. (per linear ft)	166,086
Grout Service Connections (per service)	557
Cured-in-Place Lateral Liners (per service)	182
Topside Manhole Inspection (per manhole)	4,242
Clean and Television Inspection–6 in. to 24 in. (per linear ft)	1,165,035
Cost ($)	$11,961,157

Dye testing is conducted by introducing dyed water into a suspected inflow source (left) and observing the surrounding sewer and drain lines for the dye's emergence (right).

weather. A public notification campaign is conducted prior to and during the building inspection program.

Cost-Effectiveness Analysis. A cost-effectiveness analysis (CEA) is performed for all identified pipe and manhole defects to determine the merit of rehabilitating each defect. The CEA compares the estimated cost for removing I/I with the estimated savings in transportation and treatment (T&T) costs resulting from I/I removal. T&T costs consist of capital costs to expand and upgrade the wastewater system as well as annual operation and maintenance costs, which are directly related to the quantity of flow being discharged to pump stations and treatment facilities. Increased usage will be reflected by increased operation and maintenance costs for electricity, cleaning, equipment repair, etc.

The present worth of Dedham's T&T costs was calculated using MWRA charges and the town's operation and maintenance and capital costs. The T&T costs have been extended throughout the life of rehabilitation methods.

The CEA can result in one of the following conditions:

- *Excessive* means the cost to rehabilitate the infiltration source is less than the T&T cost. All inflow sources are considered excessive.
- *Nonexcessive* is the opposite, where the cost to rehabilitate the source is more than the T&T cost.
- *Value-Effective* means the cost to rehabilitate the source is more than the T&T cost, but rehabilitation is recommended because of the relative value of the repair. In this case, the T&T cost is within a certain percentage of the rehabilitation cost.
- *Nonexcessive Recommended* means the cost to rehabilitate the source is more than the T&T cost, but rehabilitation is still recommended for structural repairs that are a priority.

Inflow sources identified during building inspections included sump pumps (left) and floor drains (right).

EFFECTIVE RESULTS

Dedham's annual program treats the collection system like a valuable asset that requires routine maintenance. As a result, the town's flow share at MWRA has dropped consistently during the last 10 years by removing extraneous flows. To date, the town has removed an estimated 700,000 gpd of peak infiltration and 1.2 mgd of peak storm inflow as part of the existing annual sewer investigation and rehabilitation program based on the 2016 I/I analysis. The I/I removed from the sewer system is no longer needlessly treated and allows for sewer costs to increase at a rate that's 75 percent less than that of neighboring communities. It's estimated that the annual program has saved rate payers approximately $10 million during the program's short life.