TRENCHLESS TRANSFORMATION

To repair a major sewer pipeline in a politically and environmentally acceptable way, the Massachusetts Water Resources Authority chose a cured-in-place liner system.

Stephen A. Calabro, P.E., and Meredith R. Norton

A young boy is cutting the grass in his backyard near a fence that abuts a sewer easement. He feels a ground tremor and backs away from the fence, just in time to see part of it disappear into a 16 ft (5 m) deep hole in the ground. It sounds like fiction, but this incident actually happened—and propelled a sewer pipeline rehabilitation project to the top of the Massachusetts Water Resources Authority's priority list.

The Framingham Extension Sewer (FES)—the pipeline that lay behind that backyard fence—was constructed of reinforced-concrete pipe in the mid-1950s as part of the wastewater collection system for the Greater Boston area. It varies in diameter from 42 to 54 in. (1.07 to 1.37 m) and is approximately 5.9 mi (9.5 km) long. The FES receives wastewater from the towns of Framingham, Ashland, and Natick and transports these flows to the Wellesley Extension Sewer for eventual conveyance to the Deer Island wastewater treatment facility, in Boston Harbor.

The FES has reported structural problems and inadequate capacity issues for a number of years. Various degrees of deterioration have occurred in the FES over the years because of age and hydrogen sulfide corrosion. In several instances the sewer has collapsed as a result of severe deterioration, creating a dangerous condition in the residential areas along its route.

The Massachusetts Water Resources Authority (MWRA), which maintains the FES, serves approximately 2 million customers in 43 communities in the metropolitan Boston area. It maintains approximately 240 mi (386 km) of interceptor sewers, various pumping stations, headworks facilities, and a 300 mgd (1,140 ML/d) wastewater treatment facility. It also operates the potable water system for approximately the same area. The $3.5-billion Boston Harbor project, which includes the new Deer Island wastewater treatment facility with its 9.5 mi (15.3 km) deep rock effluent outfall tunnel, is the most visible of the MWRA's current efforts to improve water quality in the region.

The MWRA retained the firm Anderson-Nichols/Goodkind & O'Dea (A-N/G&O), located in Boston and headquartered in Rutherford, New Jersey, to implement an estimated $50-million program to repair the FES and to build new facilities to increase its capacity. The program consists of five construction contracts as part of an

ANDERSON-NICHOLS/GOODKIND & O'DEA, ALL

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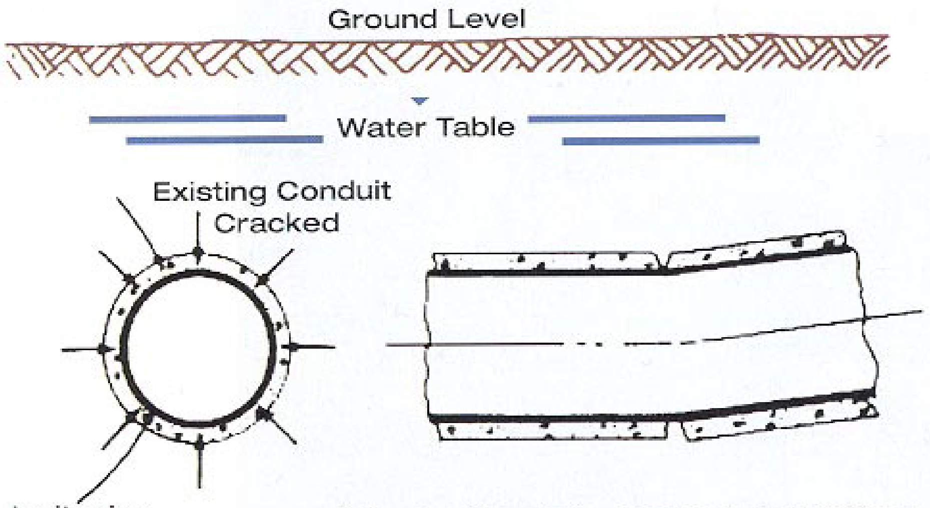
The Repair Concept



Circular Conduit—cracked and leaking but offering firm side support to Insituform

overall capital planning program. Two of these contracts concerned the complete rehabilitation of the FES using trenchless construction technology.

The FES parallels a railroad line that is used by CSX Transportation and the Metropolitan Boston Transit Authority. The pipeline traverses wetlands, is adjacent to sites contaminated by oil or other hazardous materials, crosses under several brooks and the Charles River, and passes through the Elm Bank Reservation, a major source of freshwater for the communities of Natick, Dover, Needham, and Wellesley. It also passes through many residential backyards. Facing these conditions, the MWRA concluded that open-trench rehabilitation would be extremely costly, as well as politically and environmentally unacceptable, and that the project should be completed using trenchless construction.

The FES was built through open country to extend sewer service to the town of Framingham, one of the westernmost communities in the service area at that time. During the late 1950s and the 1960s, as families moved to the suburbs, many homes were built with backyards abutting the sewer easement. Gardens were planted, sheds were built, swimming pools were installed, and the easement land became a natural green space as it acquired more and more trees and shrubs. The consequences of having to completely clear this area for open-trench excavation and the concomitant mitigation measures that would be required greatly influenced the decision to choose trenchless construction technology.

The engineers carried out investigations to determine the most cost-effective method for rehabilitating the FES. Consideration was given to pipe-bursting; microtunneling with directional drilling; a liner plate with a gunite coating; a shotcrete coating inside the existing pipe; slip-lining using a new pipe with a smaller diameter; and cured-in-place pipe liners. The team ultimately selected the last method because of its overall durability and resistance to future corrosion, favorable hydraulic characteristics (that is, minimum diameter reduction and improved coefficients of friction), reasonable constructibility with minimal disruption to sensitive areas, and cost-effectiveness based on a life-cycle cost analysis.

Initially, rehabilitation of the FES was to be completed in one contract, but the extremely poor and unstable condition of certain sections of the pipeline required the MWRA to fast-track the rehabilitation of the worst sections. As a result, the overall design was divided into two contracts. The first involved rehabilitation of the 1.5 mi (2.4 km) of the FES pipeline known to be in the worst condition and in danger of collapse. The second contract involved rehabilitation of the remaining 4.4 mi (7.1 km) known to be deteriorated through age and the effects of hydrogen sulfide corrosion. The MWRA expedited the first contract because of the health and safety ramifications; the second contract was the final component of the overall program.

Highlights of the design included formulating detailed survey plans, determining areas requiring rehabilitation, developing detailed specifications for the rehabilitation process, determining bypass pumping and temporary piping requirements, settling upon staging areas and pipeline access points, obtaining easements to facilitate constructibility, and determining measures to mitigate any adverse consequences of construction. For the second contract, the design had to address additional issues, among them wetlands, effects on traffic, access for residents, controlling odors, and limiting noise, especially at the 24-hour-a-day bypass pumping setups.

The issues related to design, mitigation, permitting, and construction were all worked out in a cooperative effort between engineers from the MWRA and their counterparts from A-N/G&O. Much time and effort were spent in meeting with property owners, local officials, and other interested community residents during the design to explain the project, build consensus, and determine the necessary mitigation measures.

A cured-in-place liner system for rehabilitating the FES was selected

BECAUSE THE *pipeline runs through such sensitive areas as wetlands and even residential neighborhoods, the MWRA decided to avoid open-trench excavation.*

180°F (82°C) and sent back through the tube. The hot water remains inside the pipe liner, causing the resin-impregnated felt liner tube to harden and form a new pipe inside the existing one.

After the tube has cured, which takes approximately eight hours, the ends of the new liner are cut to fit the repaired pipe ends. A remote-controlled robot cutter is then inserted into the pipe and used to open any tributary pipe connections. Finally, the line is inspected by TV. When all are satisfied that the installation is correct and complete, the contractor places the pipeline back into service.

Insituform of New England, of Charlton, Massachusetts (now a branch office of Insituform Technologies, Inc.), was the successful bidder for the first contract at just under $5 million, compared with the engineer's estimate of $5.2 million. The project was successfully completed in nine months for a final cost of $4.81 million—$190,000 less than the contractor's bid price and $455,000 less than the engineer's estimate.

During the construction and rehabilitation process for the FES, as many as three 18 in. (457 mm) polyethylene pipes were used to reroute the sewage flow in some of the sections being rehabilitated. Each of the environmentally sensitive areas of the project where the bypass pipe was installed had to be constantly monitored to ensure that there were no harmful effects.

With the design and construction on the first contract completed, the

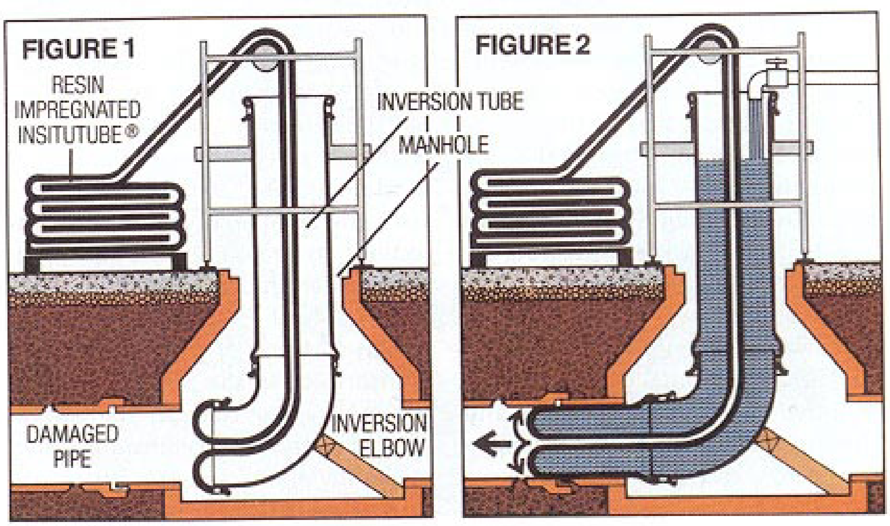
during the study phase of the project and incorporated into the design. The process, which was selected by competitive bid for both contracts, uses a polyester felt tube impregnated with a liquid thermosetting resin. The resin is custom designed for the diameter and length of the pipe that is to be rehabilitated. The thickness of the liner can also be varied to meet the final condition requirements. By varying the type of resin, the resulting liner can be made to resist corrosion from different types of effluents.

Before the liner is placed in the existing pipe, the latter is cleaned of all debris and deposits. It is then inspected by remote TV to ensure that no foreign material is present and to locate all tributary pipeline connections. In rehabilitating an active sewer line, the wastewater must be piped around the section being worked on using a temporary bypass pump setup. When the preparation work is complete, the liner tube is fed into the pipe through a manhole by hand and then with the aid of water pressure, as shown in figures 1 and 2.

The water pressure causes the inverted tube to turn inside out and forces it against the wall of the existing pipe, as shown in figure 3. The smooth side of the liner tube then becomes the new interior pipe wall. When the tube is fully installed, the water used to install the tube is heated in a portable boiler to approximately

The Repair Process

TO REPAIR *the pipeline, workers insert a resin-impregnated, inverted liner tube into the pipe,* right; *use water pressure to force the liner against the inside of the pipe,* far right; *and then heat the water to harden the tube in place,* opposite.



MWRA authorized A-N/G&O to proceed with the second.

The design work for the second contract was completed in March 2000. The engineer's estimated construction cost is $13.2 million, with construction on the project scheduled to take two years.

All land takings, easements, permits, and approvals have now been obtained, and the project was let in June. Three bids on the work were received, ranging from $21.37 million to $11.95 million.

The MWRA is planning far in advance to upgrade and maintain the wastewater collection system infrastructure under its jurisdiction. Not satisfied with simply correcting the deterioration of the FES, the MWRA is also working to determine the factors that contributed to the deterioration and to develop a plan to prevent its reoccurrence. The new plastic resin lining material that is being installed as part of the rehabilitation process will be very resistant to the hydrogen sulfide corrosion that is believed to have caused the excessive corrosion in the FES. But how can hydrogen sulfide corrosion and the odors that such corrosion occasions be minimized and controlled? To answer this question, the MWRA commissioned an extensive odor and corrosion control study for the FES and its tributary areas. The results of this study have led the MWRA to pursue several projects.

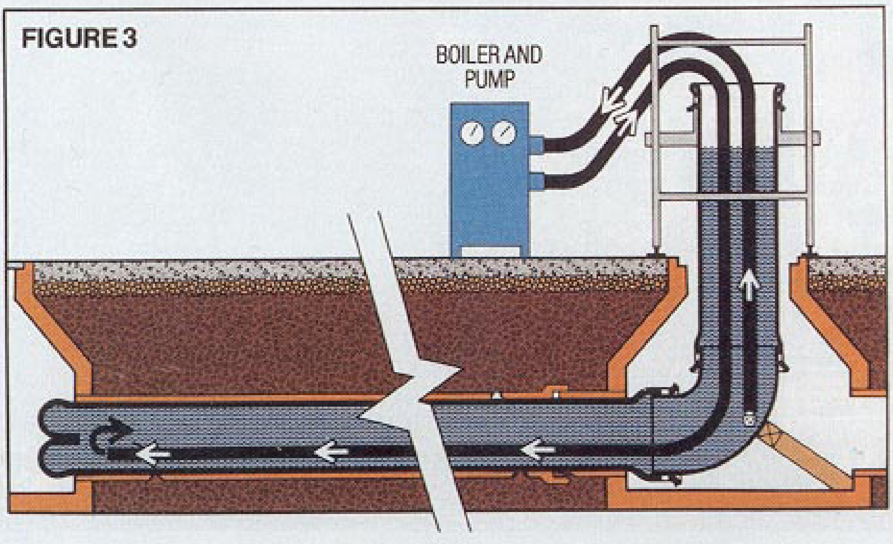
One project is a study to update the local wastewater discharge limits that set the allowable chemical constituents and limits of concentration that can be included in the wastewater discharged to the interceptor sewer system. The intent is to limit the discharge of chemical constituents that foster hydrogen sulfide corrosion while being sensitive to the needs of communities and industry.

Other projects include a program to work with the communities to decrease the formation of hydrogen sulfide in local sewer systems, the goal being to reduce the amount of hydrogen sulfide discharged into the MWRA's interceptor sewers. Another program, this one in the planning stage, will control potential odors from the FES and associated pipelines.

DURING CONSTRUCTION, *as many as three 18 in. (457 mm) polyethylene pipes were used to reroute the sewage flow in some of the sections being rehabilitated.*

The FES rehabilitation project stands out as a success for a number of reasons. First, it uses an innovative approach—trenchless technology consisting of a cured-in-place liner system. This technology has the potential to save the MWRA and its ratepayers up to $10 million compared with the more traditional open-cut and pipe replacement approach. Second, the project demonstrated flexibility based on actual needs, with the overall rehabilitation of the FES divided into two contracts to address an emergency condition. Third, it demonstrated sensitivity to the community and individual homeowners and families in the area of the construction by implementing mitigation measures. Finally, the construction cost for the first contract was less than both the engineer's estimate and the bid price. The second contract is expected to be similarly cost effective. Ultimately, the MWRA will regard this project as one of its many successful efforts to improve the wastewater infrastructure in the Greater Boston area. ▼

FIGURE 3



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