

FIGHTING THE TIDE

by

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Installing and Rehabilitating Sewers Using Trenchless Techniques

Fighting the Tide

Introduction

The Charlestown Navy Yard Project was undertaken as the result of extensive metering of the Boston Water and Sewer Commission's (BWSC) facilities, which identified extensive infiltration into the sanitary system within the Charlestown Navy Yard (CNY). The CNY was partially decommissioned in 1974 as a result of military cuts by the Federal Government, after nearly 175 years of active military operations. A majority of this facility was turned over to the Boston Redevelopment Authority to convert the existing structures into various uses, the oldest being constructed in 1805. During the past twenty years, much development has occurred including million dollar residences, commercial buildings, daycare facilities, office buildings and various recreational areas. (See **Photo 1**) During



Photo 1. Residential Condominium complex

The conversion process many of the utilities were evaluated for adequacy in size and the projected demand. Much of the infrastructure was replaced with new PVC sanitary sewers, separate storm drains and new water mains. The CNY is also the home of the oldest naval frigate, the USS Constitution (See **Photo2**) and the USS Cassin Young, a naval destroyer.



Photo 2. USS Constitution

(See **Photo 3**) Millions of tourists come to the CNY as part of Boston's historic Freedom Trail and needed to be addressed in the daily scheduling of work and access.

During the renovation of the buildings new service connections were made to the sanitary sewers, storm drains and water mains. In some instances the development required the extension of new systems as well. As the development neared completion the BRA approached the BWSC to take ownership of the system. Prior to accepting any private system, the BWSC requires television inspection of the sanitary sewers and storm drains to



Photo 3. USS Cassin Young

determine the adequacy of the service connections, quality of joints for infiltration and to ensure proper slope within the system reaches. The television inspection was scheduled and could not be performed due to sur-charged conditions in the system. Upon further investigation it was noted that the system was only surcharged at high tide, which was confirmed by inserting a camera into the system at low tide and observing major infiltration as the tide increased. Further television inspection confirmed that the infiltration occurred at many joints and at many service connections. The Commission then decided to meter the system to determine the amount of infiltration. The study determined that 380,000 gallons of tidal water entered the system each day. This infiltration entering the sewer system would be transmitted to the Massachusetts Water Resource Authority's (MWRA) treatment facility at Deer Island. The Commission would be charged treatment costs for this tidal water twice a day and annually would cost the Commission \$275,000. This was not acceptable. Therefore removal of this infiltration was required.

It appears that during the construction of these facilities, proper inspection and construction supervision was not acceptable. In many instances the infiltration was entering at open joints, lacking proper seals. Other location, a PVC wye was not used for a new service, and was punched through the system. In other locations major infiltration existed at the manhole connections. The extent of the infiltration far exceeded anyone's reasonable expectation for a system, which mostly had been replaced over the past twenty years.

The sanitary sewer and drainage system is comprised of over 10,000 feet of sanitary sewers ranging in size from 8" to 15' and over 10,000 feet of storm drains ranging in size from 12" to 60'. (See **Figures I & 2 on pages 6 & 7**) Many of the buildings in the CNY com-

prise an entire city block and have more than one lateral. Oftentimes the buildings were converted and had new connections made to the system. The average daily flow from this area is approximately 0.5 million gallons per day, of which 380,000 gallons per day is projected to be infiltration.

The BWSC also observed major infiltration and surcharging of the drainage system as well. This infiltration was not an immediate concern because it discharges back into Boston Harbor, however it does take away from storage during a major storm event. (See **Photo 4**) The Commission is presently designing a tide gate on the storm drain to reduce the recharge of the groundwater from the infiltrations of the storm drain.

Whereas the BRA still controlled and owned these utilities, the BRA and the BWSC decided to enter into an agreement for the remediation of this system. The BWSC has staff and procedures in place to plan, design and construct major infrastructure improvements. It was agreed that the BWSC would oversee the rehabilitation or replacement of the sanitary sewer system and the BRA would reimburse the BWSC for the value of the work. In addition, the BWSC submitted an application with the MWRA for funding under the MWRA local sewer infrastructure rehabilitation program.



Photo 4. Major Infiltration

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Under this program the MWRA provides 25% of the funds as a grant and the remaining 75% as an interest free loan. The loan will be paid back by the BRA in five equal payments over a five-year period.

Planning & Design Process

The BWSC proceeded with the planning and design of the system. With the well-known historical nature of the area and the influence of the tide, the construction methods evaluated quickly disclosed the need and desire of using trenchless technology methods. It became readily apparent that the system not only needed rehabilitation of the main sewer system, but the laterals as well. In addition, the structural integrity of the system was not the primary design criteria, which further made trenchless methods the obvious choice. The BWSC investigated many liner systems and lateral liner systems. It was decided that several criteria were needed to ensure that this project was successful and included:

- An experienced contractor was necessary
- The process to be used needed to be a tested system with a positive track record.
- The system selected needed to be able to remove 100% infiltration

In order to meet these criteria, the Commission opted to prequalify the contractors that could be used as the lining and lateral-lining contractors. The criteria set forth in the prerequisite sites were as follows:

- The installation of the main line sewers needed to be installed without excavation, using the existing manhole structures
- The liners needed to be able to withstand hydrostatic pressures up to twelve feet
- The liners must be sealed tightly at the connection to the manholes.
- The lateral liner shall be installed from an excavation at the connection to the main sewer without requiring a cleanout.

- Contractor must be able to rehabilitate several manholes.
- Contractor must be able to remove 100% infiltration at high tide at the completion of the project and one year from acceptance of the project.

To ensure adequacy of the system to be used and as well as the ability of the contractor, several areas needed to be responded to. The criteria set forth to evaluate the credentials of the contractors were:

- Name of contractor and number of years in contracting.
- Number of years contractor has been a cured in place or fold-in-form liner contractor, noting that grouting or other nonlining methods would not be allowed.
- Type of business organization.
- Evidence of at least five projects, last four projects in the United States and one project within the last year
- Evidence that at least one project was undertaken in a high groundwater table to at least the crown of the pipe
- Description of the projects required above, including project location, owner, type of lining, subcontractors, litigation and claims and relevant information
- Description of sewer bypassing and ground water control and monitoring
- Project superintendent and foreman experience, substantiating at least four years of experience for the superintendent and two years for the foreman
- Means and methods to be used have a four-year track record
- The lateral liner shall extend from one access location and be able to line a minimum of twenty feet and be able to withstand the same hydrostatic pressures as the main line sewer
- The main line sewer shall not leave a gap or annular space between the liner and the host pipe

Upon receipt of all complete applications an evaluation team was formulated and consisted of the Chief Engineer, the Director of Design Engineering, the Director of Construction, the Design Engineer and the Construction Project Engineer. Of the ten applicants, five were found qualified. These contractors were specified in the contract documents as authorized contractors to perform the work. The contract bid, required that the main line sewer and lateral liner contractor be stated in the bid and only could be changed to another listed contractor. The five contractors found to be qualified were:

- Am-Liner East Inc.
- Insituform Technologies, Inc.
- Miller Pipeline Corp.
- Philips Utilities Management Corp.
- Pipelining Products, Inc.

Project Scope

The project entailed the rehabilitation by trenchless lining of approximately 10,000 feet of ten inch to eighteen-inch sanitary sewers, as well the rehabilitation of 26 manholes, excavation of eight point repairs and investigation of 45 sewer laterals. The sewer system consists of some clay and the remaining polyvinyl chlorides pipes and is circular in shape. Inspections of the sewer manholes also identified infiltration and would need to be rehabilitated as well. In February, 1999 the project was advertised and bids were opened on March 3, 1999. The low bid was \$981,769.00, which was 20% below the engineer's estimate of \$1,221,460.00. The contract was awarded to the low bidder, Miller Pipeline Corp., an approved prequalified contractor, and was the contractor for the rehabilitation of the mainline sanitary sewers. Miller Pipeline identified that Performance Pipeline would be installing the lateral lining system and Vermont Pipeline would be performing cleaning, televising and manhole rehabilitation.

Background Information

The sewers and drains in the city of Boston can range over 100 years old and generally 75 to 100 years old. Many of the sewers and drains are constructed of brick or clay pipe and are in various stages of structure decay. However, a majority of the sewers in the CNY had been replaced with new PVC pipe. The television inspection that had been performed did not identify any major collapses, except at eight locations the system did have significant degradation from improper construction necessitating excavated point repairs. A considerable amount of infiltration was observed in the inspection, which would have to be reckoned with during the construction process.

The project area is adjacent to the harbor and at high tide, a majority of the system is tidally influenced. At a full moon, spring tide, the tide is generally around elevation 11. At low tide, the tide ranges from elevation -2 to 2. However, during storm surcharges, the tide has been observed as high as 13. The sanitary sewer ranges from elevation 8 to elevation 3, therefore providing limited time to access the system with minimal tidal influence. (See Photo 5)



Photo 5. -Tidal Influence at Excavated Point Repair

Design Options

There are several trenchless technologies that can be used to rehabilitate sewer and drains. Two technologies are cured in place pipe and fold-n-form pipe. These technologies are practical in the rehabilitation of pipes that have experienced cracking provided that no more than 15% of the pipe's diameter has collapsed. Trenchless technologies are advantageous because:

- Street opening permits are not required because manholes are used as insertion points.
- In the City of Boston an extensive permit fee is required for excavation.
- Upon completion of the project, permanent paving is installed by the Boston Public Works Department at a unit cost of \$5.25 per square foot, which results in additional costs. Trenchless methods save this cost because paving is not required.
- Generally, sewer lining is a lower unit cost. A typical 15-inch pipe can be rehabilitated at a cost of \$55.00 per liner foot. The same 15-inch pipe would cost \$90.00 per foot to replace using PVC pipe as well as the cost of paving restoration.
- The deficient pipe can be completely replaced with a structural liner or PVC pipe using these trenchless technologies generally within 24 hours compared to the weeks required for an excavated repair.
- Traffic disruption is minimal and generally can be effectively managed. (See Photo 6)

Process Description

The installation process of a Cured in Place Pipe or a Fold N' Form Pipe is similar even though the technologies are conceptually very different. Each technology requires a pre-installation video inspection, by-pass piping, insertion, cooking, forming, service reinstatement, and post-video inspection.

Pre-installation Cleaning and Televising

Prior to the installation of the pipe, it is important to clean and televise the sewer in order to reconfirm the condition of the pipe prior to the liner installation. The videotape of the pipe allowed the engineer and contractor to observe the structural integrity of the pipe, confirm active services, which at times requires dye testing, document obstructions, such as protruding laterals and document the distance to laterals requiring reactivation. If during this inspection the integrity of the system has degraded, the installation of a structural liner in a pipe may not be feasible, such as in a pipe that has substantially collapsed. At the CNY Vermont Pipeline Services performed the cleaning and television inspection. The scheduling of this work was driven by two criteria; 1. The work needed to be performed at low tide to ensure that the services could be visually inspected and documented and 2. The work was performed when the buildings were occupied, whereas dye testing may be required. Extensive coordination with the abutters was necessary. The confirmation of services was difficult because many of the buildings did not have visible cleanouts or the connections entered the basement floor and were not visible where they exited out of the building.

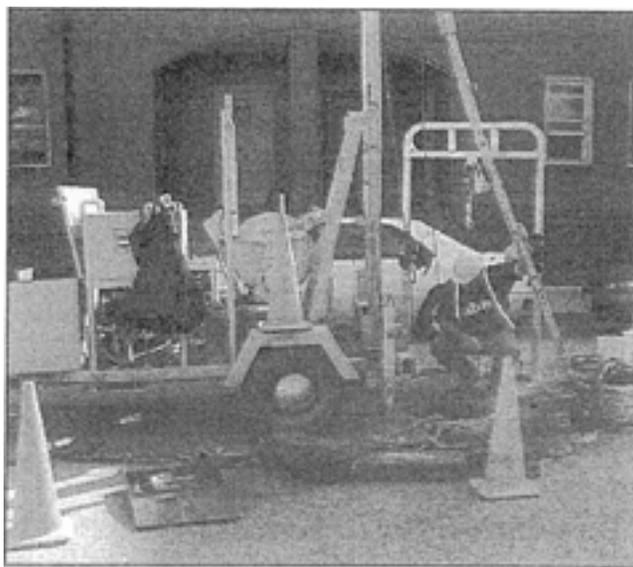


Photo 6. Traffic Management

During the planning and design stage, inspectors had gained access to each building in an attempt to ascertain the location of each active lateral, however this was not always feasible. The age of some of the buildings date back to 1805 and building plans or record documents were not available.

By-Pass Pumping

With the television inspection complete, the contractor and subcontractor were required to become familiar with the flows in the tributary sewers and lateral connections. There were many customers that had substantial flow and individual bypass was required. (See **Photo 7**) The duration of the main line sewer liner as well as the time for the lateral liner needed to be evaluated. The failure to properly evaluate the flow could adversely affect the buildings by back-ups resulting in property damage. In addition to the sewer flow, the contractor and subcontractor had to evaluate the impact of the infiltration from both upstream and downstream, because the bypass pumps would need to consider the tides while the system was curing. In addition to the bypass pumping, the contractor installed weirs to control the flow. Lastly, the contractor needed to address flow while performing the manhole rehabilitation.

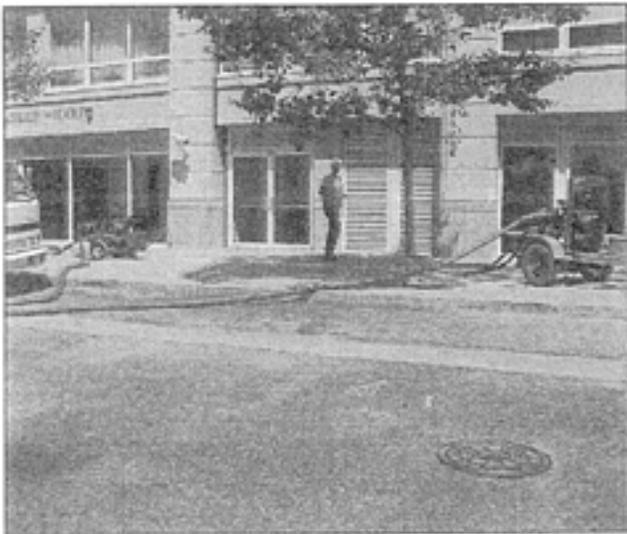


Photo 7. Bypass Pumping

Liner Installation

The contract identified the installation of 6,400 feet of ten inch lining, 1,800 feet of 12' lining, 1,000 feet of 15" lining and 100 feet of 18' lining. The longest run was 482 feet of 10" lining and the shortest run was fifteen feet of 18' lining. The contract allowed the installation of either a fold-n-form liner or a cured in place liner. The most critical element in the selection of the liner by the contractor was the criteria that 100% infiltration removal was required. This criteria would be checked twice, the first time at the post liner television inspection and one year from the completion of the contract both occurring at high tide. In order to properly select the best method, the following summarizes each process.

Fold N' Form Pipe

Miller Pipeline Corp. selected the EX Method of pipe rehabilitation. The polyvinyl chloride (PVC) resin pipe is deformed for insertion by heating in the pipe warmer trailer. Once the pipe is warmed the liner is prepared for insertion into the sewer system. (See **Photo 8**) Generally the liner was winched from one manhole to another, depending upon the length of the run, the longest being 500 feet. (See **Photo 9**) Once the liner reaches the destination point,

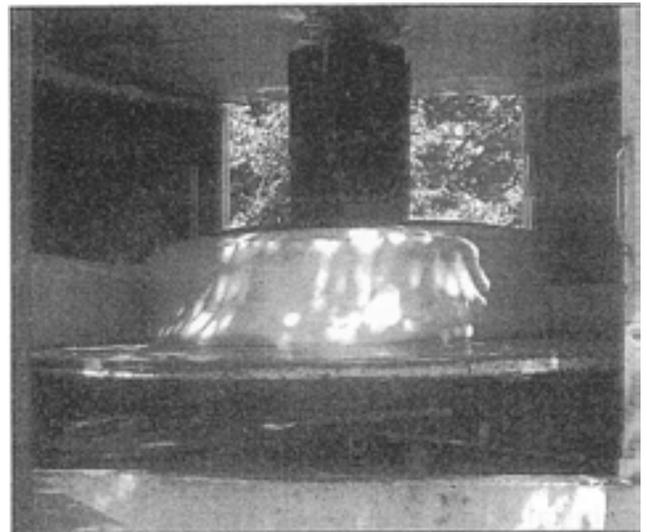


Photo 8. Liner Deformed in Truck



Photo 9. Liner Insertion

generally another manhole, steam and pressure are introduced into the liner for expansion of the liner, which deforms to the shape of the conduit. **(See Photos 10 & 11)** Once totally deformed, the steam is stopped and pressure continues until the conduit cures and the PVC cools. Once completed the excess liner is cut and removed from the insertion and reception manholes. The liner is now ready to introduce flows. Depending upon the volume and the time required for the curing it may be necessary to deactivate the bypass system and

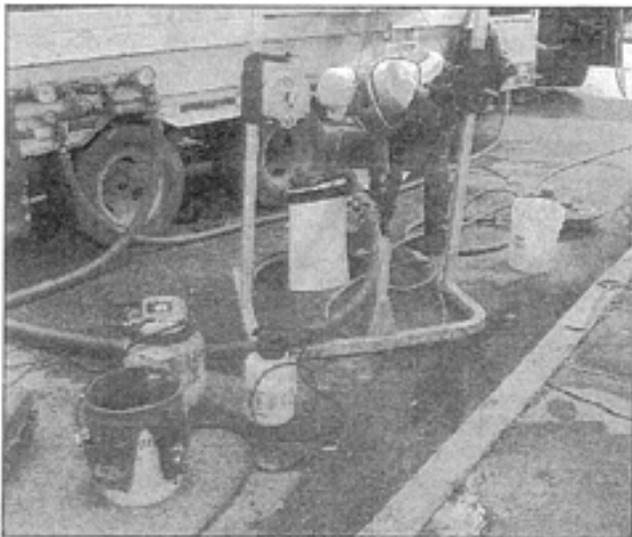


Photo 10. Preparation of Liner for Curing



Photo 11. Steam Curing of Liner

allow the system to be activated. This was complicated by the need to reopen the active services, which were also still subjected to the tidal influence. Both evaluation of the tidal influence was necessary in determining who required bypass. Each active service was reopened by remote controlled cutters, guided by television inspection. **(See Photo 12)** At times the activation of the services was delayed because of the tidal influence as well, which only heightened the importance of coordination. In larger systems, oftentimes the services are reinstated by workers entering the system.

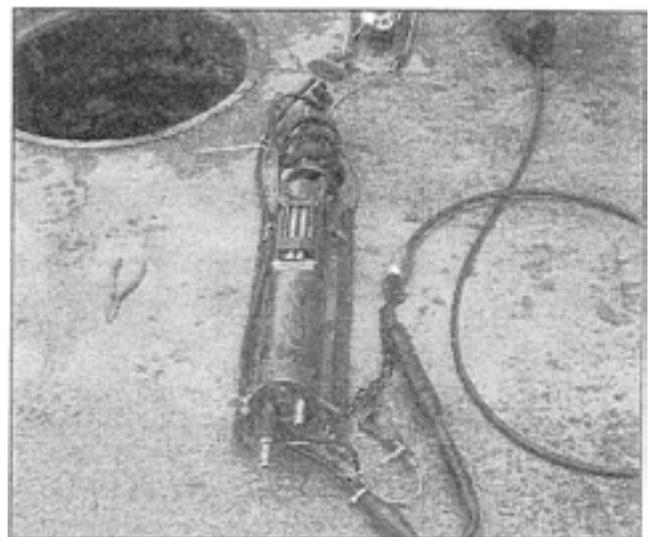


Photo 12. Reinstatement of Services

This was not feasible for the sizes on this project and would not have been safe due to the tidal influence of the system. Lastly, at times the volume of infiltration was so great that the contractor grouted a crack or joint separation prior to the lining process to optimize success.

The PVC liner was designed for the following criteria:

- Soil Depth - 14.5 feet
- Fully deteriorated
- Hydrostatic Pressure - 14.5 feet Live loads
- Allowable deflection - 5%

The other method that could have been selected for the project was a Cured-in-Place Pipe (CIPP) rehabilitation process. This process utilizes a thermosetting polyurethane resin impregnated felt lining material that is cured in the host pipe to form a new structurally superior pipe. The resin in the liner is activated at a calculated predetermined temperature. The curing time of the liner is determined by the size, length and thickness of the liner. Hence the liners are delivered to the job site packed in ice aboard a refrigerated truck. The liner is loaded from the truck onto a conveyor system, and mounted on a mobile staging platform. The end of the liner is sealed to prevent water from exiting and then inverted. The liner is inverted in order to expose the resin-coated side of the liner. The liner is filled with cool water and the height of the staging is adjusted so that the proper amount of hydraulic head is used to extend the liner through the entire length of the host pipe. Once the liner is in place, water that has been heated to 180 degrees F in a mobile boiler is circulated into the liner via perforated rubber hoses that were previously inserted into the liner. The resin's curing temperature of 180 degrees Fahrenheit is maintained for

several hours to ensure that the pipe is properly cured. After curing is completed the circulation water temperature is slowly lowered to ambient temperature. It is critical that the circulation water temperature be properly monitored during the curing stages because the new pipe may fail to cure if the temperature fluctuates or if the pipe is cooled too quickly. If the procedure is not properly followed the liner could collapse and would need to be removed by open excavation. After the water temperature is properly lowered, the sealed end of the liner is opened in order to drain the curing water from the pipe. The services are cut out as discussed in the fold in form method.

Post Installation Video Inspection

After the services are opened, a post installation video inspection is performed. The post video inspection confirms that all active services have been properly restored as well to confirm that the liner has been installed satisfactorily. A proper liner installation includes the following conditions:

- The liner should be homogeneous and properly impregnated.
- The pipe should not have extensive wrinkles, especially in the invert where it could impact flow characteristics.
- A proper seal against the host pipe has been obtained, if deflection is noted a mandrel should be pulled through to determine the severity of the deflection.
- Infiltration should not be observed, especially at the entrance and exit to the manholes and at each service.

Lateral Lining

In addition to the rehabilitation of the main line sewer, it was apparent from prior television inspection that considerable infiltration existed within the sewer laterals. As a result the contract identified that every sewer lateral below elevation 11 was to be lined. The design elevation criteria is based upon the normal high tide elevation.

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Miller Pipeline Corp. selected LMK Enterprises, Inc.'s T-Liner as they're proposed method. As required in the contract, the contractor excavated at each requisite liner and accessed the sewer lateral. (See Photo 13) The contract identified that the liner at a maximum would be twenty feet. It became apparent at a few locations that the lateral, generally six inches in diameter, would need to be extended because the depth at twenty feet was still tidally influenced. A unit price for each foot beyond the twenty feet was negotiated and agreed to and paid under a change order.

The T-liner is a relatively new technique as compared to the history and time frame associated with cured in place liners for main line sewers. The advent of rehabilitating sewer laterals has provided an opportunity to expand on the successes of main line CIPP. The process materials and techniques for sewer lateral lining is very similar in design to main line CIPP, however it does require additional challenges, not typically found in main line sewers.



Photo 13. Access to Sewer Service

The lateral liner consists of a non-woven fabric tube, generally of one or more layers of flexible felt or an equivalent non-woven material, depending upon the use and specification for the project. The liner is a continuous section and the thickness is uniform. As a result of the flexibility of the liner, bends, offset joints and sags can generally be lined through, if desired. The liner is impregnated with a resin, consisting of polyester or vinyl ester and activated with catalysts. To properly ensure a watertight connection at the junction point of the lateral with the main line sewer, a comparable liner is attached to the lateral lining for adherence to the main line sewer, thus making the 'T' liner.

The procedures required to install the T-Liner are very similar once again to the process required for main line sewer lining. The following procedures were necessary for the CNY project.

Each known lateral was investigated and required extensive investigation by both television inspection and actual connections in the buildings. As previously discussed many of the buildings infrastructures were constructed in or at the turn of the 19th century. As a result records were at times not readily available. To complicate matters, many of the buildings have undergone extensive renovations as part of the redevelopment and many of the lower levels now are finished areas and thus many sewer stacks are hidden behind walls. To further augment the problem, many of the laterals were visible however entered the basement floor without a visible cleanout, and as such the actual depth of the lateral was not known. After an exhaustive combined investigation, a list of known active laterals was compiled. As part of this investigation, flow characteristics were also identified, noting peak usage, non-peak usage and available access times to buildings.

A preliminary schedule was compiled to determine the appropriate time for the insertion, comparing non-peak flow times with low tide.

The contractor needed to determine which locations required bypass based upon the anticipated peak flow during the lining process and the potential for tidal influence if the process took longer than anticipated. Oftentimes this necessitated the excavation at the lateral upstream of the lining process to bypass the flows especially where access to the lateral in the building was not feasible. This also required investigation of discharge locations for each building because of vehicular and pedestrian concerns and requirements to comply with the Americans with Disabilities Act.

A pre-television inspection of the main line sewer and the lateral was performed to ensure that no new blockages, debris, collapses, size variation or degradation of the lateral were present which could impede the process. At this time if the lateral was deemed to have excessive root intrusion or debris the process may be abandoned and rescheduled. It should be noted that all protruding laterals had been previously addressed in the main line sewer lining and did not cause any concern at this point in the project.

The actual process was now ready to commence. The liner is inspected for defects and for proper size. The liner was inspected to confirm there were no defects or rips. The length of the liner was final checked to ensure that the requisite length was provided whereas no seams are allowed. The liner was now impregnated with the resin. The resin was introduced at one end and pressed through the liner with a roller to ensure that it was uniformly applied. **(See Photo 14)** The resin was thoroughly impregnated by a vacuum process removing all air and pulling the resin into the liner. The main line portion of

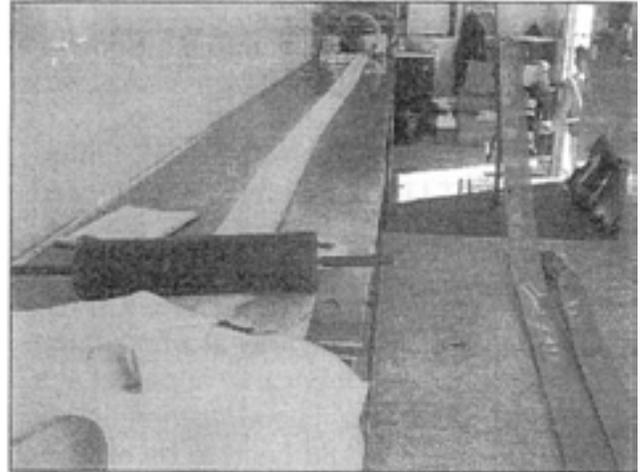


Photo 14. Sewer Lateral Liner Impregnated

the liner was also impregnated with the resin to ensure full saturation. **(See Photo 15)** This is critical to provide the requisite bond within the system. The color of the liner, originally white is now tan as a result of the impregnation, a visible way to inspect the full penetration of the resin into the liner.



Photo 15. T-Line Impregnated

The liner assembly was now ready for installation into the lateral. The liner was attached to the inversion bladder, which was attached into the system by a winch, previously installed and ready for the process. **(See Photos 16 & 17)**

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As part of this assembly the launching mechanism for the lateral insertion was integral. The insertion commenced and watched via two remote television cameras, one in the main line sewer and one in the lateral. (See **Photo 18**) The assembly is brought to the lateral and aligned with the lateral. The liner had been previously marked to assist in the alignment process. (See **Photo 19**) The assembly was protected during the pull by the rotating skid system. It was important that the liners are not contaminated by dirt or debris as part of the insertion; the dirt could impact the integrity of the bond to the host pipe. (See **Photo 20**)

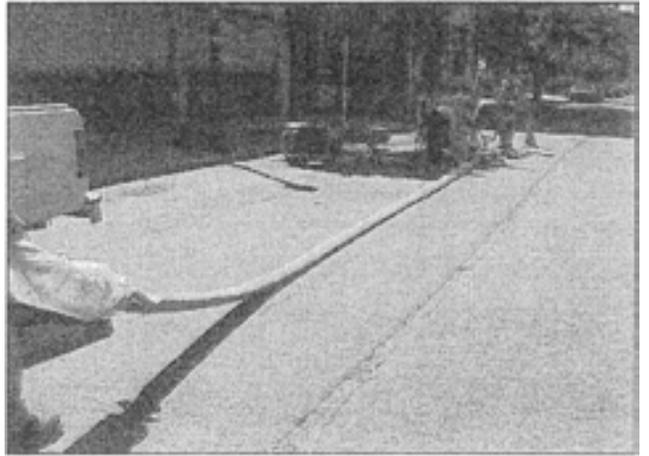


Photo 18. Inversion

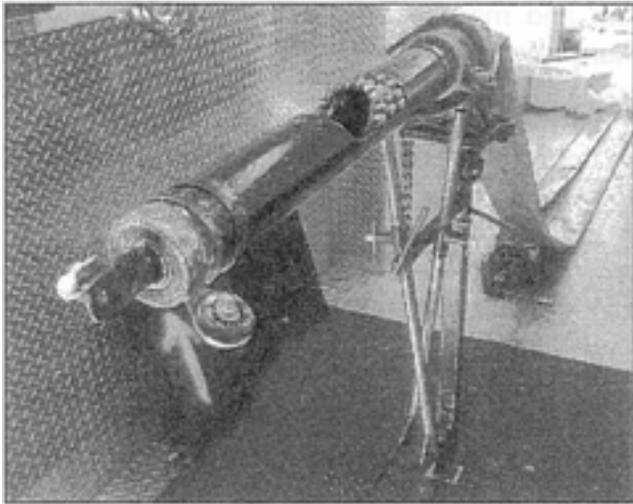


Photo 16. Lateral Liner



Photo 19. Lateral Mark



Photo 17. Main Line T-Liner Attached to Lateral Liner



Photo 20. Insertion Unit

The exact alignment is controlled by the internal television inspection with the camera in the lateral, upstream of the end of the liner. The mainline camera ensures that the main-line, or T connection, was properly curing as well. Once the cameras confirm the proper location, the mainline liner was expanded against the wall of the cleaned pipe and the lateral liner was inverted with either air or water pressure. The camera allows for continued inspection throughout the process and, if needed, the process can be stopped, up until the time the liners were cured.

The curing process commenced by pressure. Upon completion of the cure, the bladder and launching mechanism were removed via the winch system. Upon removal of the system, the television inspection was performed to ensure proper adherence of the liner to the main line sewer. The lateral liner was inspected as well. In addition, the lateral connection can be tested to ensure water tightness.

Upon completion, the bypass pumping initiated during the process can be removed and the lateral connection repaired or the cleanout cap replaced.

Issues During Construction

This project was unique and complex because of the issues associated with the tide. The project necessitated extensive coordination with the tide. On several occasions the contractor's schedule could not be met due to the amount of time anticipated to complete the work and the timing of the tide. The lateral lining was also impacted by the tide. In a few instances the process was abandoned and had to be rescheduled. In addition, there were several required excavated point repairs. These repairs oftentimes took three or four days because the tide would come into the excavation and it is impossible to pump the Atlantic Ocean! The project has not been totally completed. A few lateral connections

have not been lined. The reasons for this varied from excessive bends that the liner could not negotiate and others where the connections go under the buildings and are still below the designated elevation and exceed the maximum length of the liner installation. These laterals will probably require excavation to make the final repair.

Another major issue has been the most downstream portion of the system where the invert elevation is around elevation I and the tide's influence has been monumental. In addition, the system has been observed to be surcharged at almost all times during the day. The system beyond the CNY ties into the MWRA's trunk main and may be influencing the flow with other projects on the system.

As with any major project coordination with the impacted residents and businesses adjacent to the project was paramount. The CNY not only is a historical complex, it houses many affluent Bostonians who do not want to be inconvenienced. The MWRA's headquarters are also within the CNY as well as other major businesses and offices. As a result of these mixed uses, the allowed time frames for work was not only influenced by the tide but by traffic impacts. Any delay in any of the stages could result in the stoppage of the work for the day because the tide did not provide a wide window of time to perform the work. There were many times when delays were encountered that did result in work stoppages and no work being completed.

While performing the cleaning and lining process, infiltration was found in additional manholes. These manholes were not in the original scope of work to be rehabilitated but once the infiltration was noted in these inverts, the Commission authorized these manholes to be rehabilitated as well. Originally the infiltration was not visible because it existed in the invert of the system, which always had flow.

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Once the majority of the work was completed the Commission reevaluated the system by metering the flow. The first phase removed 350,000 gallons per tide and the system is being carefully evaluated to ensure that the remaining infiltration is removed. It has been estimated that the liners not installed at the downstream sections as well as the laterals still requiring work, will account for the

majority of the remaining infiltration.

To date, the Commission is satisfied with the work performed and the technologies utilized. The system will continue to be monitored and if acceptable, a model for other projects. To ensure a high level of quality, a set price of \$50,000 was identified for the final inspection one year later.