Overcoming Challenges While Rehabilitating a Corroded Aerial Sewer in a Tidal Marsh

Wayne Miles, PE, CDM
Frank Styers, PE, Cape Fear Public Utility Authority
Chris Bowling, PE, Cape Fear Public Utility Authority
Christine Nesbit, PE, CDM
Michael Sloop, PE, CDM

ABSTRACT

Following a proactive process of identifying high risk sanitary sewer lines, the Cape Fear Public Utility Authority retained CDM to conduct a condition assessment of a 48-inch aerial gravity sewer located in a tidal marsh. The condition assessment, which included conducting ultrasonic pipe-thickness testing, revealed significant interior and exterior corrosion of the steel pipe. This prompted the need for a fast-track rehabilitation project to avoid any failure, which could have significant environmental impacts. The process of completing construction of this pipeline rehabilitation project within as short a period of time as possible required tenacity and creative thinking, especially given several challenges that arose during construction.

KEYWORDS

Pipeline rehabilitation, condition assessment, cured-in-place lining, pipeline corrosion, ultrasonic testing.

INTRODUCTION

The Cape Fear Public Utility Authority was formed in July 2008 by combining the water and sewer utilities formerly owned and operated by the City of Wilmington NC and New Hanover County NC. The Authority has approximately 65,000 customers and serves a population of approximately 140,000 people. The core principles of the Authority are stewardship, sustainability and service, and its mission is to provide high-quality service in an environmentally responsible manner while maintaining the lowest practicable cost.

In keeping with these principles and mission, an early objective of the Authority was to begin assessing the condition of its key assets and identifying priorities for where rehabilitation may be needed. To accomplish this, the Authority leveraged and continued work begun by the City of Wilmington with CDM to develop and apply a decision-making process for setting priorities for subsequent condition assessment and pipeline rehabilitation projects.

SETTING REHABILIATION PRIORITIES

There are many potential objectives of a sewer rehabilitation program including restoring structural integrity, reducing infiltration and inflow (I/I), and reducing maintenance costs. Identifying which of these objectives is the highest priority or has a higher potential for beneficial results can be difficult and sometimes controversial. Setting priorities for which areas of the community to focus rehabilitation funding can also be difficult and can include political implications.

The purpose of the priority setting process applied by the Authority is to identify where to focus resources to inspect, maintain, and rehabilitate different areas of the system so that the most beneficial results can be achieved. Immediate investigation and rehabilitation of every pipe and pump station is cost-prohibitive for most utilities. A more appropriate use of finite resources is to focus immediate rehabilitation on higher priority areas of the system and to monitor areas that are lower priority. In addition to this short-term plan, it is important to create a long-term rehabilitation strategy that can be updated regularly and that results in phased rehabilitation of all system components. The goal of the long-term rehabilitation strategy is to proactively identify potential problem areas and fix the problems before they result in a system failure that would cause significant impacts

To accomplish this, the Authority applied an approach to identify pipes and other facilities that should receive immediate inspection or rehabilitation by ranking them in terms of their criticality (or consequence of failure) and condition (probability of failure). Under this approach, assets whose failure creates a large impact on the community and environment and whose condition is the poorest will receive immediate inspection and/or rehabilitation. Pipes and facilities that receive a lower criticality and condition rating will receive some level of continued monitoring but no immediate action or rehabilitation. A more detailed explanation of the process applied and the outcomes of this process have been public previously (Miles et al, 2007).

The result of this process was assigning a condition rating and a criticality rating to each system asset, including all sewer collection system pipes and manholes. This allows each asset to then be plotted within a decision matrix as shown in Figure 1 to determine the recommended course of action. Through application of this process, the Authority identified the Burnt Mill Creek sewer outfall as an immediate action priority requiring further field condition assessment and possible rehabilitation. This priority was confirmed by Authority field who recently had expressed concerns about observed manhole corrosion along the Burnt Mill Creek outfall.

		Criticality				
		1	2	3	4	5
Condition	5	Mid Priority Program Rehab	High Priority Program Rehab	High Priority Program Rehab	Immediate Action	Immediate Action
	4	Mid Priority Program Rehab	Mid Priority Program Rehab	High Priority Program Rehab	Immediate Action	Immediate Action
	3	Low Priority	Low Priority	Regular Monitoring	Frequent Assessment	Frequent Assessment
	2	Low Priority	Low Priority	Regular Monitoring	Frequent Assessment	Frequent Assessment
	1	Low Priority	Low Priority	Regular Monitoring	Regular Monitoring	Regular Monitoring

Figure 1. Matrix of Recommended Courses of Action Based on Condition and Criticality Ratings

BURNT MILL CREEK OUTFALL DESCRIPTION

The Burnt Mill Creek outfall is a 48-inch gravity trunk sewer that is located in a coastal, tidal marsh area. It receives wastewater from an approximately nine square mile service area. It consists of a combination of reinforced concrete pipe that is buried as well as several sections of 48-inch steel pipe located on piers and/or at grade and secured by helical anchors.

The portion of the Burnt Mill Creek outfall addressed by this project begins immediately south of a CSX railroad corridor and flows in a northerly direction, paralleling alongside and within Burnt Mill Creek, for approximately 630 feet, as shown in Figure 2.

The initial 70 feet of 48-inch diameter pipe from Junction Box #1 to Junction Box #2 is located predominately below ground and runs under the CSX railroad bridge, as shown on Figure 2. The following 280 feet of 48-inch diameter pipe is located above ground between Junction Box #2 and Manhole #1 and is supported by retainer straps, installed in 2006, spanning approximately every 20 feet. Figure 3 below shows the pipe looking downstream, with Manhole #1 and the Lovegrove Tide Gate in the background. Fluctuations in the daily tide level result in the pipe being completely above the water level to being completely inundated.

From Manhole #1 to Manhole #2 is an additional 280 feet of 48-inch diameter pipe located aboveground. The pipe is supported by concrete piers, installed in 2006, spanning approximately every 20 feet. There are three locations where retainer straps were installed in place of concrete piers along the pipe. Fluctuations in the daily tide level range from the pipe being completely above the water level to the pipe being completely inundated. Figures 4 and 5 show photos of the pipe and associated piers during low tide conditions and high tide conditions, respectively.

CONDITION ASSESSMENT APPROACH AND RESULTS

Initially, a zoom camera inspection and manhole inspections of the Lower Outfall were conducted, which identified some corrosion of the inner, upper half of the pipe and corrosion of a majority of the manholes. In addition to corrosion, fractures were identified in the upstream manhole. Subsequent field condition assessment of the pipe was performed consisting of visual observation and ultrasonic thickness testing to determine the potential loss of pipe material due to external and/or internal corrosion. The result of this investigation showed the outer bottom half of the pipe to have experienced considerable degradation due to corrosion, likely resulting from the exposure to brackish water and fluctuating tide level. The inner top half of the pipe had experienced considerable degradation due to hydrogen sulfide (H_2S) corrosion. In addition, City staff indicated that there were approximately 18 to 24 inches of sediment accumulated in the pipe.

In addition to pipe corrosion, field assessments revealed considerable structural degradation and corrosion in the junction boxes and manholes along the pipeline. Specifically several cracks were identified on the outer portion of the junction boxes. From internal inspections it was apparent that the portion of the interior wall that could be observed had been subjected to H_2S corrosion. The extent of corrosion could not fully be determined through a visual observation because of high water levels in the box, but is believed to be significant as exhibited by the exposed aggregate and the presence of yellowish stains and soft surficial layers that are indicators of H_2S attack.

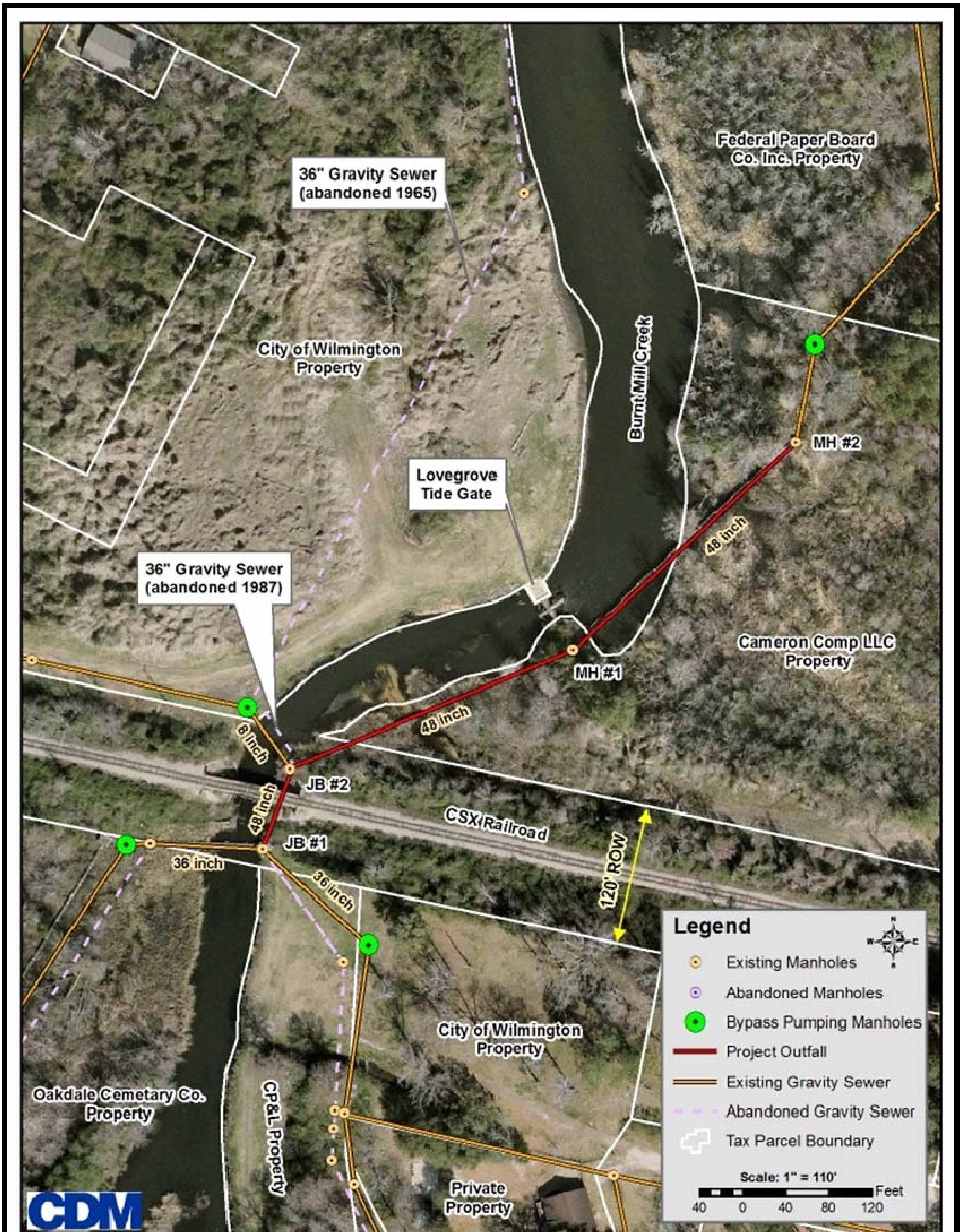
36" Gravity Sewer
(abandoned 1965)
Federal Paper Board
Co. Inc. Property
City of Wilmington
Property
Burnt Mill Creek
MH #2
Lovegrove
Tide Gate
48 inch
36" Gravity Sewer
(abandoned 1987)
Cameron Comp LLC
Property
MH #1
48 inch
8 inch
JB #2
48 inch
CSX Railroad
JB #1
36 inch
36 inch
120' ROW
City of Wilmington
Property
Oakdale Cemetary Co.
Property
CP&L Property
Private
Property
Legend
Existing Manholes
Abandoned Manholes
Bypass Pumping Manholes
Project Outfall
Existing Gravity Sewer
Abandoned Gravity Sewer
Tax Parcel Boundary
Scale: 1" = 110'
Feet
40 0 40 80 120
CDM

Figure 2. Map of Burnt Mill Creek Outfall Showing Location in a Tidal Marsh Area and Showing Relation to CSX Railroad Corridor

Figure 3 – View of Pipe and Retaining Straps Looking from Junction Box #2 to Manhole #1

Figure 4 – View of Pipe and Concrete Piers Looking Downstream (Low Tide)

Figure 5 – View of Pipe and Concrete Piers Looking Downstream (High Tide)

IMPROVEMENT ALTERNATIVES EVALUATION

CDM evaluated various rehabilitation alternatives for the pipe, junction boxes, and manholes for the purpose of identifying a cost-effective and long term solution. The alternatives considered included full pipeline replacement or cured-in-place (CIP) liner for the pipe and replacement or a drop-in fiberglass structure for the junction boxes and manholes. Other alternatives were considered, but eliminated due to various structural limitations. Based on discussions with City staff and a review of pump station operations downstream of the trunk sewer, it was concluded that the pipeline capacity was sufficient and did not need to be increased. The following is a brief description of each of the alternatives as well as a brief summary of the alternatives eliminated from further consideration.

Pipe Rehabilitation Alternatives

Two rehabilitation alternatives were considered viable options for the pipe: (1) a combination of replacement and CIP lining or (2) CIP lining only.

- Alternative 1: Full replacement and CIP lining would include using a CIP liner for the 70 feet of 48-inch diameter pipe under the CSX railroad between JB#1 and JB#2 and replacement of the 560 feet of 48-inch diameter pipe between JB#2 and MH#2. CIP liner is recommended for the 70-foot stretch due to the potential construction and permitting difficulties associated with open-cutting within the bridge abutment and railroad easement. Replacement of the 560-feet would include removal of the existing 48-inch diameter pipe and installation of a new 48-inch diameter pipe at the same slope and alignment.

- Alternative 2: CIP lining of the entire 630 feet would include installing a new CIP liner within the existing pipe capable of meeting the full structural requirements of a replacement pipe. A one-piece liner could be installed over the entire 630 feet. Based on discussions with City staff, the reduction in cross-sectional flow area due to the liner thickness (approximately two inches total) would not result in hydraulic deficiencies.
- Other Alternatives Considered: CDM considered two additional rehabilitation alternatives including installation of a parallel aboveground pipe and directional drilling for a new belowground pipe. The parallel pipe was removed from consideration based on discussions with City staff. Directionally drilling from JB#1 to MH#2 was eliminated due to slope limitations associated with lowering the pipe from an aerial to below ground vertical alignment. Directional drilling from JB#1 to MH#1 was eliminated due to the difficulties and associated cost implications of connecting and redirecting the contributing branches.

Junction Boxes and Manholes Rehabilitation Alternatives

Two rehabilitation alternatives were considered for the junction boxes and manholes: (1) full replacement or (2) drop-in fiberglass structures.

- Alternative 1: Full replacement of the junction boxes and manholes would include removal of the existing infrastructure, which would potentially include the existing concrete base slabs and timber piles. The existing junction boxes appear to be larger than required for the inlet and outlet pipes. Therefore, the replacement junction boxes may be smaller in length and width compared to the existing boxes. The manholes would be replaced with eight-foot diameter concrete manholes.
- Alternative 2: Fiberglass structures would be installed within the existing junction boxes and manholes. Installation of the fiberglass structure in the existing junction box would include forming a fiberglass box to mimic the dimensions of the existing concrete junction box, with an annular space between the two boxes to be filled with concrete for structural support. The thickness of the poured concrete would be determined based on the structural requirements for strength and serviceability. For this project the fiberglass box and surrounding concrete would be required to meet all structural requirements, with the assumption being the existing concrete box will completely deteriorate. The existing junction box covers may be placed back on the fiberglass boxes, depending on their condition determined in the field. The same approach would be used for the manholes, except the manhole cone would be removed for installation of the fiberglass manhole and a new cone constructed. The fiberglass structures would be connected to the existing concrete base slabs and associated timber piles to address buoyant forces and lateral loads due to the tidal influences. For this option to work, the existing concrete base slabs and timber piles would need sufficient structural integrity to withstand the added weight of the fiberglass box and additional concrete. A preliminary structural analysis of the piles indicates that if the piles currently in place were new, they would have adequate structural integrity to support the existing junction boxes/manholes as well as the added load from the fiberglass drop-in structures and associated concrete.
- Other Alternatives Considered: CDM considered two additional options for rehabilitating the junction boxes and manholes. A cementitious spray-on liner was considered, but was

determined to provide minimal necessary structural support and therefore was eliminated. A CIP liner was considered, but discussions with a local vendor indicate that the liner provides some, but not full structural support required for these junction boxes and manholes. Due to the condition of the junction boxes and manholes, it was assumed for this project that they would continue to degrade to the point that little to no structural support is provided. Both rehabilitation options were therefore eliminated.

Recommended Rehabilitation Design

Further evaluation of these alternatives was conducted based on cost and non-cost factors including constructability, environmental impacts, permitting issues, implementation schedule, and other long term considerations. There were concerns over the long-term structural viability of a cured-in-place liner in an aerial pipe application should the existing host pipe fail structurally. Other concerns included potential UV degradation of the CIP liner should the host pipe corrode sufficiently to expose the liner. The final selection favored the use of a cured-in-place liner due to the desire to make the repair quickly and the significant cost savings this approach provided. The CIP liner was assumed to be designed with sufficient rigidity for the aerial application, and it was believed that the host pipe would provide sufficient coverage to prevent any potential UV degradation of the liner.

Based on the results of these evaluations, CDM recommended that the Authority proceed with design and construction of the following:

- CIP line all 630 feet of 48-inch diameter gravity sanitary sewer.
- Replace Junction Boxes #1 and #2 and associated base slabs and piles using the same box dimensions as were previously in place.
- Replace Manholes #1 and #2 and associated base slabs and piles using 8-foot diameter concrete manholes.
- CIP lining of the entire 630 feet of 48-inch diameter gravity sanitary sewer was recommended based on the cost savings and reduced non-cost factors compared to replacement. The cost savings associated with the CIP liner versus replacement was estimated to be approximately $600,000 to $700,000. Two key non-cost factors are access to the site and the environmental impacts associated with wetland disturbances. Required access for the CIP lining could be generally limited to Junction Box #1 and Manhole #2, both of which were easily accessible. Reduced access requirements also reduce the impacts to the coastal wetlands bordering a majority of the project pipe to the east.

Replacement of the manholes and junction boxes were recommended instead of the drop-in fiberglass structures due to the uncertainty associated with the original design, current condition, and remaining design service life of the existing base slabs and timber piles. The added cost of replacing the junction boxes/manholes and their associated base slabs and piles versus installing the drop-in fiberglass structures and making no improvements to the base slabs or piles was estimated to be approximately $700,000 to $800,000. The base slabs and timber piles are potentially subjected to intermittent inundation of brackish waters due to daily tidal fluctuations in Burnt Mill Creek. Based on discussions with contractors in the Wilmington area, concerns were raised regarding a 50-year expected design service life, from the point of initial construction. Since the base slabs and timber piles are currently 43 years old, 21 years for a portion of Junction Box #2, the remaining service life is significantly less than the Authority's request that an expected design service life of 50 years be considered for this project. Expecting an additional 50 year design service life may not be prudent based on the harsh site conditions and limited base slab and timber pile condition assessment capabilities. The cost, constructability challenges, permitting, and environmental impacts are greater for replacement versus the drop-in fiberglass structures. However, the level of confidence associated with avoiding a structure failure and associated sewage overflow is greater for the replacement alternative.

PERMITTING REQUIREMENTS

The permitting process posed significant challenges given the need to address Section 404 Army Corps of Engineers wetland and North Carolina Section 401 Water Quality requirements, coastal area management rules, and encroachment restrictions from a nearby railroad corridor, which included a 1912 vintage truss bridge in close proximity to the project. Given the desire to address the situation immediately, close coordination with numerous permitting agencies was required.

The Army Corps of Engineers was contacted about using Nationwide Permit Number 3, which is for maintenance activities on an existing structure. While this permit does not typically require an application and reporting requirements, the Corps required both because of the high quality nature of the wetlands in the vicinity of the project. While this slowed project implementation, this coordination was worthwhile as it reduced the risk of delays later during project construction.

Because this project became high profile, the Corps representative made a rare site visit to check compliance during construction. This visit went well as all permitting requirements, monitoring, and reporting had been met during construction.

CONSTRUCTION OF IMPROVEMENTS

Bypass Pumping Operations

Because of the configuration of and the environmentally sensitive nature of the project site, bypass pumping was an important consideration of the project implementation.

Bypass pumping was complicated by a number of factors:

- Junction box #1 received flow from two directions with one sewer crossing under a significant creek. This required use of multiple pump locations and a manifolded bypass force main.
- The sewer downstream of junction box #1 passed under a truss-type railroad bridge with limited room to locate a bypass pipeline.
- The entire project area is subject to flooding during large rainfall events, especially if the event corresponded with high tides.
- Difficulty laying the bypass pipe through wetlands and tidal marsh areas.
- The Authority was very concerned with potential spills given the environmentally sensitive location of the project.

A system of cables and winches was used to lay the bypass piping through wetland areas to reduce any impacts. This significantly decreased the amount and type of equipment that had to enter these areas. To reduce the risk of spills, full redundancy was used for the pumps and 24-hour manned monitoring of the bypass pumping system was required. This was beneficial in that there were several occasions that pumps became clogged in the evening requiring maintenance. A key project success was that there were no bypass pumping failures on the project despite the difficult location and working conditions.

Pipeline Cleaning

Because of concerns of the integrity of the existing pipeline, removal of sediment prior to rehabilitation required care. The contract documents specified the use of low pressure cleaning and nozzles to reduce the potential for further damage to the existing pipe. Afterward, additional hand-cleaning was required using manned-entry. Because of safety concerns, manned entry was restricted to low tide periods, further complicating project scheduling. Many locations of the pipeline were found to have 24 inches of sediment or more.

Helical Anchor Failure and Emergency Replacement

It was anticipated that pipe buoyancy would increase upon removal of the sediment in the pipe. Therefore, the helical anchor design was reviewed during the design of the pipeline rehabilitation. New anchors had been installed only three years previously as part of a previous pier improvements project, and the design was consistent with current design needs. Despite this review, however, the anchors failed upon removal of the sediment. As a result, the pipeline began to float during high tide conditions. This was a result of the anchors not being fully embedded in a hard sediment layer, thus preventing the anchors from being installed to the required depth as designed (see design detail in Figure 6).

The anchor failure created the need for an emergency helical anchor design and construction project in a difficult-to-access project location. The pipe was kept filled with water to avoid it from floating during anchor repair.

In the new installation, the anchor shaft thickness was increased and the diameter of the helices was reduced to ease penetration into the hard sediment layer. In addition, the helical edges were sharpened to improve penetration into the hard layer (see Figure 7). This resulted in anchor installation to the required depth as designed.

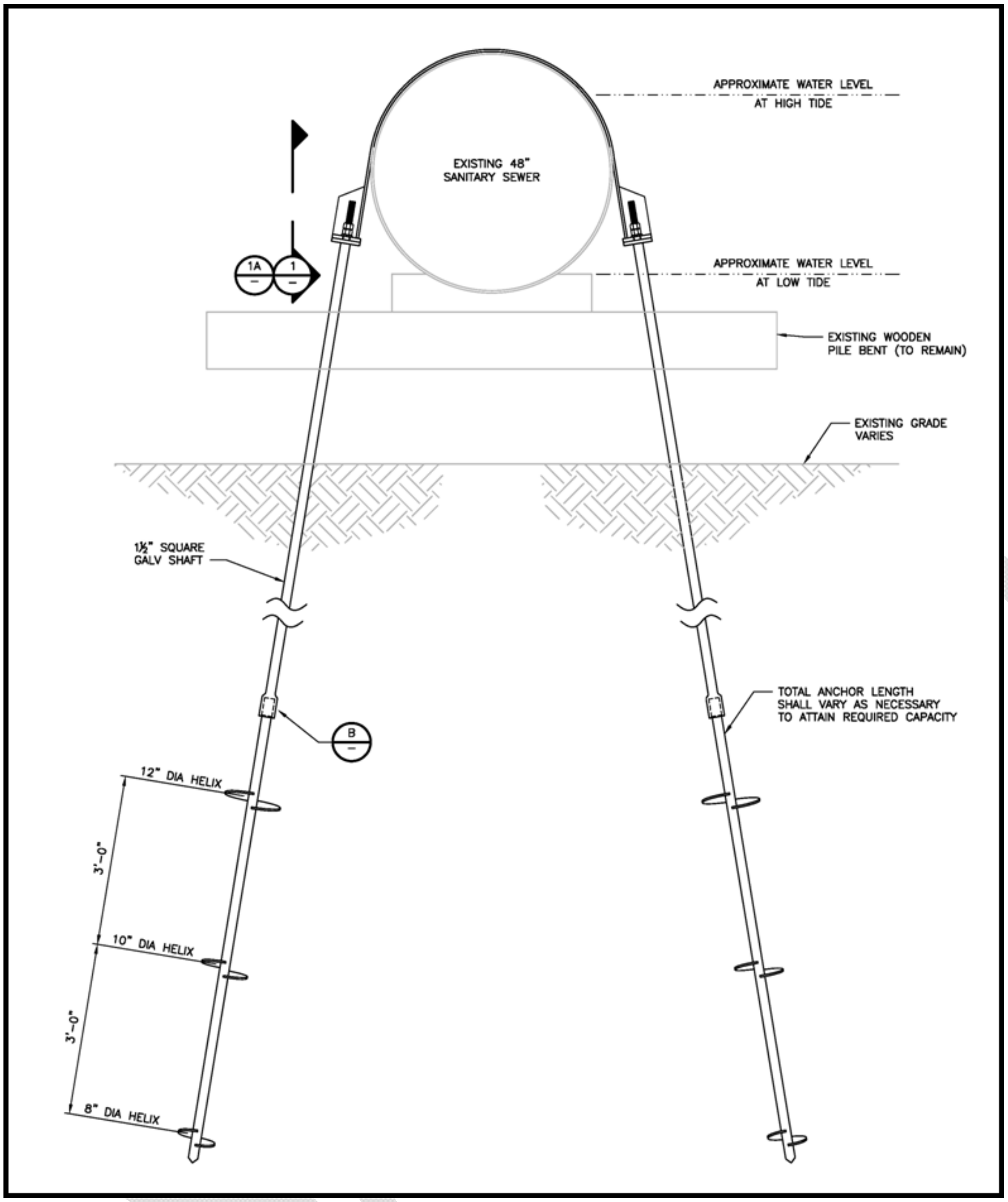

Figure 6 – Helical Anchors Installed Three Years Prior Failed Upon Removal of Sediment in the Pipe. New Anchors with a Thicker Shaft and Smaller, Sharpened Helices Achieved the Required Installation Depth.

Cured-in-Place Liner Design

The cured-in-place liner was designed based on the need to span the 20 foot distance between piers. The design assumed the liner would provide the full pipeline strength, including consideration of the potential for side loads during tidal flows and/or storm conditions.

There was some concern with possible future ultraviolet light degradation of the liner material should the host pipe continue to deteriorate to a degree that the liner would be exposed. To address this, the small holes that had been identified were patched and a visual monitoring program was put in place to identify any additional corrosion that could lead to liner exposure.

After initial installation of the liner, an existing manhole at the end of the liner section began to float during high tide. This was found to be a result of the manhole not being connected to the pile cap. This required removal of the last segment of liner and replacement of the liner with a new ductile iron pipe. A new manhole was also installed in addition to a new pile and pile cap.

Figure 7 – New Helical Anchors Were Installed on an Emergency Basis – Thicker Shaft Anchors and Increased Installation Torque Penetrated a Hard Sediment Layer to Install Anchors to the Required Depth

The new manhole was connected to the pile to prevent future floatation.

Pile driving in the vicinity of the railroad corridor was a concern. Specifications called for vibration monitoring on the railroad tracks and close monitoring of any track movement to identify and potential problems prior to the tracks being used.

Lastly, because of the severely corrosive environment, a cathodic protection system was installed to protect the new steel piles and the steel helical anchors.

SUMMARY AND CONCLUSIONS

The Burnt Mill Creek sewer rehabilitation project, which included the bypass pumping, sewer cleaning, liner installation, junction box replacement, and the manhole replacement was completed in eight weeks despite numerous unexpected delays. The total project cost was approximately $3.5 million.

In summary, the priority setting framework employed by the Authority identified a high-risk pipeline that was subject to potential failure in a sensitive environmental area. Despite the problems that surfaced during the rehabilitation project, considerable time and effort was saved by rehabilitating this pipeline proactively rather than during an emergency or responsive situation.

State and federal permitting issues were able to be addressed in a timely and organized way. In addition, CSX railroad was contacted and potential impacts to their corridor were considered and addressed.

The condition assessment approach identified existing corrosion issues and allowed a thoughtful rehabilitation evaluation process to be completed, which ultimately saved the Authority cost. This led to an overall successful project that eliminated a potential infrastructure failure in a proactive manner.

REFERENCES

Miles, S.W; Styers, F.C; Nesbit, C.M (2007) *A Case Study in Setting Pipeline Rehabilitation Priorities Using Condition and Criticality Criteria;* North American Society for Trenchless Technology (NASTT) *NO-DIG 2007*, San Diego, CA.