Slip lining to Rehabilitate an Existing Water Transmission Main Underneath Developed Property

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1. ABSTRACT

The City of Elyria, Ohio maintains as part of their system a 30-inch spiral wound steel water transmission main that passes under paved streets and a modular home community named Pikewood Manor. At the time of installation in the late 1930’s, the area of the alignment had a small waterway and drainage ditch running through it, as well as the Lake Shore Electric Railroad. Today, the 30-inch steel water main lies beneath the Pikewood Manor community and continues to be a primary transmission main for the Elyria Water Treatment Plant. In recent years the main has experienced multiple pin-hole leaks. Servicing and accessing the main has been very difficult due to the development that is now located on top of it.

The City decided to rehabilitate the pipeline and looked to trenchless technologies to minimize impacts to the residents of Pikewood Manor. In the end, slip lining a new water transmission pipeline inside the existing line was chosen as the most effective solution. In all, 2,000 LF of pipe was installed in this manner and allowed the construction effort to be relegated to the ends of the project site and away from the development.

This case study reviews the methodology selection process and how the design was developed. It will also review the construction outcomes and provide lessons learned from the project.

2. INTRODUCTION

The City of Elyria (City) was founded in 1817 by Herman Ely, originally of Massachusetts. He traveled to the Northwest Territory and built himself a log cabin along the Black River. As others began to arrive, a settlement developed. In order to better provide for themselves, the new residents built a saw mill powered by a nearby waterfall and used the wood they produced to build more houses. At the time of Mr. Ely’s death in 1852, the town had grown to be a prosperous one, boasting a population of more than 1,500 people as well as five churches, three flour mills, three grocery stores, and a town newspaper.

By the turn of the 20th century, the town’s population had grown to 8,000 people. In 1908, the Elyria Memorial Hospital was built, which continues to this day to be of great value to the people of Elyria and the surrounding towns and cities. The practice of commerce began to build within the city. Two additional lumber mills had been built, as well as two grist mills for the production of grain. The Garford Manufacturing Company was founded in 1892 by hometown industrialist Arthur L. Garford. Garford had developed the first padded bicycle seat known as the “Garford Saddle.” As he began to realize the coming importance of horseless carriages, Mr. Garford also founded the Automobile and Cycle Parts Company in 1893 to compete with Henry Ford. Both of these companies had
factories within the city limits, providing numerous jobs to the residents of the town, as well as an increased level of commerce.

As time passed, however, the city began to experience a downturn. In 1965, the Midway Mall opened within the city. The introduction of department stores forced many of the small businesses that made up the center of the city to close, as most of those who were unable to move into a store within the mall were unable to compete with the new businesses. In the 1970s, three of the automobile factories in the area were closed leaving hundreds without jobs. The closures gave rise to a new nickname for the area—the Rustbelt, so named for the decomposing car bodies and machinery left in the factories and surrounding areas. This depreciation continued through the late 70s and 80s before new businesses and residents were drawn into the city by new housing developments and roads. Instead of the former industrially fashioned city, a “bedroom community” was born, providing suburban living for nearby Cleveland.

As of the 2010 census, the population of Elyria was about 54,500 residents. Each of these residences requires access to the water distributed by the City of Elyria’s Water Distribution Department, which is supplied by the water treatment plant located along the coast of Lake Erie. Elyria is believed to be the first inland city in the United States to begin pumping water from the Great Lakes for distribution purposes.

In the mid-1800s, the city bought property along the coast of Lake Erie. There, they built their first water treatment plant in 1871 after fears that the Black River was becoming too polluted to be used for potable water. Distribution of the treated water began in 1904. In 1903, a 20-inch pipe had been installed as the city’s main distribution line. That line is still in use today, as are additional 42-inch and 30-inch distribution lines that were added later.

By 1922, the original plant had reached its full capacity. A new one was built which had the ability to treat 8 million gallons per day. Five water towers were built throughout the city with the first being erected in 1879. Large improvements were made to the plant in the 1950s and 60s which increased its capacity to 22 million gallons per day. This increased capacity allows the plant to not only provide water to the residents of Elyria, but also to the citizens of the surrounding Townships—North Ridgeville and Amherst, as well as the Northern Ohio Rural Water. Additionally, during the summer months, capacity is high enough that restrictions are not needed despite the increased demand for water.

The City of Elyria’s water distribution department is responsible for providing the city with a fully functional water system. Here is a listing of what the department operates and maintains:

- 300 miles of distribution mains
- 18 miles of transmission mains
  - PCCP (C301)
    - 4 miles of 48-inch
    - 4 miles of 36-inch
  - Steel Pipe
    - 10 miles of 30-inch

3. **REHAB PROJECT**

One of the 30-inch transmission lines was originally manufactured in 1937 by the Rolling Mills Company in Middletown, Ohio. It was a 7/16-inch thick spiral welded steel line with a bituminous cement coating on both the interior and exterior (as shown in Figure 1). Installed in the late 1930s, the transmission line connected to the existing 20-inch pipe that came from the original plant. When first installed, the area of its alignment had a small waterway, a drainage ditch, and the Lake Shore Electric Railroad running through it. Now, there is a modular home community on top of the pipe which makes it very difficult to assess the condition of the pipe.
The city began to have considerable difficulties with this steel pipe in the past few years. Pin hole leaks were becoming more frequent and joint failures started occurring so often that the city began to have custom fabricated plates on hand to make repairs. However, the problem of accessing the pipe to make these repairs was the greatest challenge.

Forty-five modular homes now sit directly on top of the area where the repairs would need to take place. When the complex, Pikewood Manor, was designed in the 1950s, there were very few records of easements in the city. This left no indication that the placement of such homes in the area would cause any difficulty. In modern day, however, Pikewood Manor posed a far greater problem. The City had been lucky that repairs up to that time had not required the movement of one of the modular homes. But that luck would certainly not last, given the propensity for leaks in the pipeline, and the number structures that the pipeline crossed under. The future potential that any necessary repairs to the pipeline would occur in very close proximity to or under the home pads, which in turn had the potential to cause structural damage or instability in the foundation, was high.

As it became more apparent to the city’s Water Distribution Department that the problems with the pipe were likely to begin increasing in frequency, it was decided that a full repair of the pipe was necessary. The task of designing the rehabilitation plan was assigned to the engineering firm Burgess & Niple, Inc.

4. DESIGN

Possibly the largest hurdle of the repair process was going to be how to access the pipe. Since the housing on top of the work site is all modular, the option of simply relocating the houses and tenants was investigated. Depending on the repair method used, there was the potential that all 45 homes located over the pipe would be impacted by the construction process. Moving the homes would involve fully emptying each and hiring extensive amounts of trucking and machinery for both the initial move and the return trip. The cost and inconvenience that this would have caused all involved eliminated it from further consideration.

Rerouting the pipe by abandoning the existing, failing pipe and installing a new standalone pipe was also considered. Instead of travelling under the modular homes, the pipe would instead run to the roadway and continue under the road until the end of the modular homes. By having a brand new lay-out, the city would be able to control precisely where the pipe would go, ensuring that they would have easy access for any future events, maintenance, or construction. This was eliminated as an option because the length of the pipe would have more than doubled the length required and should any expansion of the housing occur in a northwards direction, the city would be back in the same sort of limited access conundrum.
During the design process, the goals were to minimize the amount of time for the pipe to be out of service, to minimize the disruption to the residents living above the work that was to take place, and to minimize the destruction of pavement within the community. The deflections the pipe would have to make, the disruption of pavement through road crossings, and the fact that the pipe was located alongside a detention basin were also taken into account. The Burgess & Niple, Inc. team wanted a method that would be quick and simple with a product that was without joints, known to the owners, and had a good resistance to corrosion. With all of this taken into account, it was determined that trenchless installation would be the best option for the pipe rehab portion of the project. In an undeveloped area, where an additional section of pipe was installed to prepare for eventual development, open cut was chosen, as there was plenty of open space in which a trench could be dug.

Of the available trenchless technologies, pipe bursting, close-fit lining, cured-in-place-pipe (CIPP) lining, and slip lining were researched. Pipe bursting, which allows a pipe of similar or larger size to replace an existing pipe, was eliminated due to the expansion required; the welded steel needed to be properly cut and pushed a great enough distance away from the new pipe which could potentially heave the ground under the home pads. The remaining three choices were all methods that left the existing pipe intact and thus limited potential issues with the homes’ position on top of the pipeline. These methods would decrease the inner diameter and thus the flow area of the pipe, but the overall capacity of the pipeline was not a primary concern; some downsizing in this section could be accommodated. The use of a CIPP liner was eliminated due to its high costs and the fact that there are few available providers of pressure CIPP in sizes as large as 30-inches to be used for potable water. Additionally, such a liner would require mechanical end seals that were viewed as problematic. Close-fit lining requires an HDPE pipe to be processed through a reducing die, which temporarily diametrically reduces the outer diameter of the pipe during insertion into the existing pipe and then expands after placement to make a tight-fit. This method was not selected because the reduction process limits the pressure rating and wall thickness options for the tight-fit liner and is also dependent on the host pipe remaining in place for the long term which in cases of deteriorating pipe can be a problem.

Figure 2. Layout of pipe through Pikewood Manor. The red line represents the slipline portion of the project, the dark blue line represents the open cut portion of the project, and the light blue line represents the existing pipeline.
Sliplining was selected for the trenchless method because of its minimally destructive and hands-off nature (see Figure 2 for the decided upon layout of the rehabilitation). As an independent pipe, it would be less reliant on the host pipe which would provide a layer of protection against water leaks or pressure driven events. The pipe could be laid out and installed in a single operation which would minimize the inconvenience for the home owners. The use of the existing pipe for the installation also meant that there would be little threat of any negative interference from the small water basin along one portion of the alignment.

The next question was what material to use for the slipline. By choosing an insertion method that would use a fully restrained pipe, engineers were able to choose a final pipe product that was a factory produced, rather than field installed conduit. As such, two pipe choices were available, rather than being forced to use a particular type or limited by size and thicknesses. Both high density polyethylene (HDPE) and fusible polyvinylchloride (FPVCP) were considered for use, but it was decided to install 24-inch DR 21 DIPS FPVCP. This choice was based on the favorable inner diameter and pressure class rating combination of FPVCP versus HDPE (see Figure 3). The slipline installation method presents a constrained installation space, thus limiting the overall size, or outer diameter available for a pipeline to be inserted. Given the wall thickness differences between the two thermoplastics, FPVCP provides a visibly larger flow area for this application – almost four inches. Finally, FPVCP may reconnect to other piping systems with mechanical joints and ductile iron fittings, while HDPE requires the use of fused on flange or mechanical joint adapters inserts in order to couple with standard ductile iron fittings. While the specialized labor needed to install these fittings may not have been an issue during the construction, the City worried about their ability to service a system including these types of fittings in the future should something happen to the pipe. The decision was made to sole source the FPVCP for the sliplining portion of the project. As a PVC option which also used standard ductile iron fittings, the city felt comfortable in their use for reconnections to existing water lines and to the new line which was to be installed via open cut to the north. For the open cut portion, traditional bell and spigot PVC was chosen for installation.

![Figure 3. Illustration of the flow area difference between the same pressure class sections of 24-inch DIPS DR 21 FPVCP and 24-inch DIPS HDPE DR9, both within a 30-inch steel pipe section.](image)

## 5. CONSTRUCTION

Through a bidding process, the City of Elyria received bids from four separate construction companies. The City awarded the contract for the 2,100 foot slipline installation as well as the 850 foot open cut portion to Speer Brothers, Inc. (Speer Bros) after the bid tabulation determined that they were the lowest responsive bidder.

The first stage of the project involved a video assessment of the original pipe to ensure that there were no major blockages or failures within the pipe that might cause damage to the new sliplined pipe or difficulty for installation. During the initial inspection, there was a concern that a deflection within the pipe that had been shown in plans as it
crossed under a drainage area that no longer existed would be a problem. If the deflection was too severe, the slipline would not be successful. The video inspection was able to eliminate this concern before the installation began.

Once the existing pipe was shown to have no obvious inner defects, a “test-pull” of a FPVCP section was done to confirm that a pull-in could be completed using the pipe. For the test, a 40-foot length of FPVCP was attached to the pull head to be used in the project and pulled the full length of the existing pipe. This ensured that there were no smaller pieces of debris or broken sections of pipe that may have caused damage to the full length of pipe during installation. It also assured that the pipe was large enough at all points for the new pipe to pass through.

An entrance pit was dug to the North of Pikewood Manor, in an undeveloped area located next to the open cut section. The exit pit was to the South of the complex near the existing 30-inch water main and next to the water basin. Speer Bros used a 24-inch pull head for the project, which is the suggested size for the pipe to be installed. In an effort to avoid winding the pipe string between the trees located to the North and West of the entrance pit which could potentially cause the pipe to be severely bent, the full length of the pipe was not fused for the initial pull. Instead, the fusion technician, using a T-900 fusion machine, created one 400 foot section of pipe to attach to the pull head and begin installation. Insertion began on May 21st, 2015 and as the pipe insertion continued into the host pipe, each additional 40 foot length of pipe was fused onto the existing length and then inserted into the existing steel line. The fusion technician was able to continue to fuse pipe at a rate of approximately seven pipe lengths – about 480 feet – a day throughout the fusion process. In total, 48 thermal butt-fusion joints were needed for the entire pipe string. The pull was completed on May 29th and the new pipe passed hydrostatic testing on June 23rd.

To facilitate the pulling process, a 60,000 pound horizontal directional drilling rig was used. The drill rig injected bentonite drilling fluid into the existing transmission main as the pulling process was performed to ensure that the interior of the host pipe was well lubricated for the slipline operation (see Figure 4). By limiting the amount of friction between the pipes, Speer Bros significantly reduced the potential of damage caused to the outside of the new transmission line. After the FPVCP pipe passed pressure testing, cellular grout was used to fill the annular space between the new and existing pipes.
A small reamer was attached in front of the pull-head and the new pipe to be inserted to distribute the drilling slurry as lubricant.

A prior construction project that had taken place in the 1950’s replaced a section of pipe under a nearby overpass with a pre-stressed concrete cylinder pipe (PCCP) which included one of the two taps providing water to the modular homes. At no point did any of the housing lose their water access. The pipe being repaired was removed from service for eight weeks between the initial inspection and the completion of pressure testing of the new transmission line. This was done for convenience purposes; a contingency plan existed in the event that the failing pipe needed to be brought back online before the installation occurred. Once the new pipe was fully installed, the PCCP manufacturer came onto the site to supervise the reconnection to the existing pipe.

One of the valve vaults existing next to a modular home was abandoned during this installation process. In order to ensure that the foundation of the home remained stable, the support structure of the valve vault remained in place, though the space itself and the entrance to the manhole were filled with concrete. A connection to an existing 6-inch ductile iron water main was made at Wren Circle. Since the tap already existed in the old pipe, the task of drilling a new tap into the Fusible PVC was simple. In total, only two excavation pits were required in paved areas for the installation of the new pipe which significantly decreased interference with the lives of the residents in the area.
Once the annular space grouting was completed, the FPVCP was connected to the bell and spigot PVC piping that was used for the open-cut portion using standard mechanical joint fittings. Connection of the FPVCP sliplined pipe to the remaining steel pipeline on the other side of the project was also completed.

7. CONCLUSIONS

The slipline project for the City of Elyria went as smoothly as it possibly could. The City was able to remove nearly all disruption of daily life from the area residents by maintaining the water supply without a bypass line, removing the possibility of temporary relocation, and providing an installation option that would further limit disruption. There was limited destruction of pavement in the area, so few additional repairs were necessary by the city. The new pipe was able to be immediately connected to the existing line upon the installation’s completion, so full service was returned to the area right away.

At this time, the City of Elyria does not have a plan for rehabilitating the rest of their existing pipe infrastructure as there are similarly aged steel and cast iron pipes all over the city, however, the need for their replacement in the future can be expected. This particular pipe, which is located below a number of residences, near a body of water, and an overpass, remained in fairly good working condition, which may be a good indication that similar pipes may
be in equally as good condition. Due to the size of the pipe, residents were not losing any water pressure in their homes even with the pin hole leaks and joint failures, but sliplining the pipe has improved the City’s situation by making it safer, as they have removed the increasing possibility of a catastrophic event. The City is now looking at sliplining as a viable option in their tool box to secure the most effective and productive infrastructure for their city in the remaining pipe.

This project has demonstrated how effective sliplining can be in lowering overall costs and inconvenience to the public and contractors while providing high quality results. Rehabbing an aged pipe before a major failure occurs can be beneficial for both the owner and those living in the area around the pipe; since there was no catastrophic event, the residents whose water was provided were minimally impacted by the process of replacing the pipe. The impact to the surrounding area was also mitigated by the shortness of the fusing and insertion process. There was very little time during which any negative outcomes could have taken place; from start to finish, the integration of the new line only took eight days. By establishing a solid plan and ensuring that qualified, competent persons were involved in the development and execution of the project, the City of Elyria provided its citizens top quality service with a new material and technique without negatively impacting quality of life.