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# Fair Oaks 40 Pipeline Rehabilitation – It's What's on the Inside that Matters

Shawn Jobes, PE

Murraysmith, Roseville, CA

**ABSTRACT**: In May of 2019, the San Juan Water District (District) completed construction of the Fair Oaks 40" Pipeline (FO-40) Relining Project (Project). The Project consisted of relining a mortar and coal tar enamel (CTE) lined steel pipe originally constructed in 1956. The 40-inch diameter potable water pipeline is approximately 11,000 feet long and located in the City of Folsom and the County of Sacramento. In 2012, the District hired a contractor to repair joints and portions of the pipeline lining, but the extent of the failed lining made it cost-prohibitive to repair all of it with that project. In 2017, the District contracted with Murraysmith to develop contract documents for the removal of all the existing lining, preparation of the interior surface, and relining of the pipeline with cement mortar.

Challenges included:

- Much of the pipeline alignment is in residential backyards and difficult to access
- Removal and disposal of CTE lining, a non-RCRA hazardous material
- Frequent vertical and horizontal deflections
- Out of round pipe
- Meeting the District's limited construction budget of $2.18 M

The limited number of contractors engaged in this specialized work. With collaboration between the District, Murraysmith, ICM Group, and the Contractor, the Project was completed by using manual lining removal and surface preparation, and on schedule with minimal change orders.

## 1. INTRODUCTION

The San Juan Water District's (District) Fair Oaks 40-inch Pipeline (FO-40) was originally constructed in 1956. The pipeline consists of an approximately 3/16-inch straight seamed steel cylinder with swedge

joints. The coating is a coal tar system commonly used during that time. The lining system consisted of a layer of coal tar enamel (CTE) to provide corrosion resistance for the steel cylinder, topped with two layers of mortar (totaling between 0.37 and 0.42 inches in thickness) intended to protect the CTE.

In 2011, the District replaced a 65-foot segment of the pipeline, referred to as the Fair Oaks 40 American River Canyon Crossing. In 2012, the District entered into an agreement with a contractor, Trinet, to perform interior repairs, which included seal welding 380 swedged joints, plating over abandoned laterals, patching small leaks, and repairing small areas of damaged mortar lining with epoxy lining as well as hand-applied mortar lining (totaling approximately 490 square feet of mortar lining repair). An assessment of the pipeline interior was performed by ICM Group, Inc. (ICM) near the completion of the repair project, and the results were published in the 2013 Fair Oaks 40" Pipeline Assessment Report. The report identified the following:

- Approximately 27% of the pipeline lining was considered to be in good condition.
- Approximately 27% of the pipeline lining was considered to have bonding issues with the mortar lining.
- The remaining 46% of the pipeline had significant losses of mortar lining in the pipeline segments.

In addition, ICM's inspection revealed that the pipeline had significant out-of-roundness deflection of as much as 5%. Generally, allowable design deflection for this pipe is limited to 3% to maintain the integrity of the mortar lining and flexible coating system. Additionally, it was determined that the pipe had convex dents along the invert at the north ends of most pipe sticks, approximately three feet from the ends of each stick of pipe. It is presumed that the dents are the result of the pipes being set on a hard surface like the pipe stulls during installation. By doing so, a point load was created at those locations.

The out-of-roundness created by the dents near the joints, along with the types of joints used, contributed to the documented joint leakage, making it likely that the bedding and backfill were compromised. It is possible that the mortar lining began delaminating during initial installation, and it is also possible that it had continued to delaminate over the years of service. However, it is impossible to make this assumption with complete certainty.

The extent of the lining needing repair far exceeded the scope of the contract with Trinet. As a result, the scoped repairs were made and completed in 2013, but it was determined that it would be most cost-effective to rebid the project at a later date to a relining contractor to remove and reline the entire length of the FO-40 pipeline.

In June 2014, ICM inspected the liner again and reported the condition of the lining as follows:

- In the areas lined with either epoxy or cement mortar, the lining repairs are preventing rust.
- In the areas that remain unlined, there was tubercle growth, but there had been no reduction in the steel cylinder thickness.

## 2. PROJECT SCOPE AND GOALS

In 2017, the District awarded a contract with Murraysmith (formerly Quincy Engineering). The scope of the Project included:

- Removing 11,000 linear feet of existing lining from the FO-40 pipeline and relining it with cement mortar lining, exclusive of the 65-foot section previously replaced at the American River Canyon (ARC) crossing.
- Patching any leaks in the steel cylinder that were discovered after the removal of the CTE lining
- Estimating construction costs

- Determining whether the District's budget was sufficient to provide for the rehabilitation of all 11,000 linear feet of pipe or only a portion of it

- If the District's budget was insufficient, make recommendations to limit the rehabilitation to portions in lieu of the entire 11,000 LF of pipeline

The District's primary goals for the Project were:

1. Remove and reline the pipeline within budget
2. Minimize the impact on customers
3. Complete the construction project in the winter of 2017/18

## 3. CHALLENGES

The major project challenges included the following:

- COAL TAR ENAMEL (CTE)
    - Limited techniques available to remove it
    - Classified as a Non-RCRA Hazardous material in California
- EXISTING PIPE IRREGULARITIES:
    - Dents: Convex dents approximately three feet from the north ends of most pipe sticks
    - Out of roundness: the pipe was almost consistently larger in the horizontal direction than the vertical direction by approximately two inches
    - Previous Repair Plates: the pipe was previously repaired by Trinet with the use of ½" steel plates to seal pinhole leaks and abandoned laterals
- ACCESSIBILITY:
    - A large portion of the alignment resides in residential backyards.
    - It is also located in city and county roadways, residential streets, commercial parking lots, and the open space and parking areas of an apartment complex.
    - The District wanted to minimize the need to access private parcels and allow staging on private parcels if and only if the District could obtain a written agreement from the owner.
- HORIZONTAL AND VERTICAL PROFILE:
    - Mitered fittings and changes in both horizontal and vertical direction
    - Slopes of 10% to 15%
- OUTLETS, FITTINGS, AND VALVES:
    - 2-inch to 6-inch diameter outlets for laterals and air valves.
    - Several mainline valves smaller in diameter than the rest of the 40-inch transmission main
    - Several reducers that accompany the valves
- BUDGET:

- The District had $2.5M for the Project in the Fiscal Year 2018-2019 Budget, which included $253,000 for engineering and construction management.

- The District's preference was to remove and reline the entire 11,000 feet of the FO-40, but it was faced with having to eliminate some of it from the scope of work to stay within budget.

## 4. PRELIMINARY DESIGN

The primary goal of the preliminary design phase of the Project was to determine if it could be constructed within the District's existing construction budget of approximately $2.18 M. This could only be determined with a more detailed understanding of the Project. As a result, the preliminary design included the development of a preliminary design report (PDR) and feasibility analysis. The PDR and Feasibility Analysis included evaluating alternative lining materials and techniques and further defining the Project by determining the following:

1. The contractors qualified to clean and reline the pipe
2. The most cost-effective and acceptable cleaning and relining techniques
3. The number, size, and location of the entry and exit pits

Alternative Linings

Existing conditions of the pipeline, such as out of roundness, frequent bends and changes in slope, and its location within residential properties made slip lining the pipeline with either high density polyethylene (HDPE) or polyvinyl chloride (PVC) pipe infeasible. Cured in Place Pipe (CIPP) for pressure pipe was far more expensive than removing and relining the pipeline. Replacing the existing CTE/CML lining with a new CML lining was the preferred and most cost-effective method of relining the FO 40 pipeline for the following reasons:

- It provides adequate corrosion resistance to the existing steel pipe

- Cleaning for CML is less intense than for epoxy linings. After cleaning/removal of the existing lining, epoxy linings require additional surface preparation such as air conditioning or dry blasting. However, after the removal of the existing linings (cleaning), there are no other surface preparation requirements of the steel cylinder for CML.

- CML is less expensive than the other alternatives, i.e., epoxy or glass fiber reinforced polymer.

Qualified Contractors

There were only a few contractors currently engaged in relining a 40-inch pipeline with cement mortar including, Spiniello, Mainlining, and J. Fletcher Creamer & Sons (Creamer). We contacted other contractors, including Kiewit, LH Woods, SP Rados, and MMC, none of whom were either capable or interested in the Project. Additionally, Spiniello had recently purchased Mainlining, and Creamer closed its operations in California in 2013. We identified two cleaning companies, Aqua Drill and Genesis, which were interested and capable of removing the coal tar enamel (CTE) and cement mortar lining (CML). Both use high-pressure water jetting. Creamer often teams with Genesis, and Spiniello and Aqua Drill have an exclusive agreement.

Removal of Existing Lining (Cleaning)

Complete removal of the existing linings, both CTE and CML, is essential to properly clean the pipeline and remove all rust from the existing steel cylinder. Removal of the CTE, CML, and rust is necessary to reveal existing pinhole leaks for repair and ultimately stop further oxidation at these locations. Without

removing the coal tar and rust, there is the potential for continued moisture intrusion and potential for oxidation beneath the new lining, which could be problematic in the future.

The success of the new lining operation is dependent on the success of the cleaning operation that precedes it. Both cleaning and lining must be performed correctly to ensure the success of the final product. In addition, there are shared work elements such as the excavation of the entry and exit pits. Therefore, the cleaning and relining contractors must work in concert and rely upon one another to achieve the desired warrantied outcome. The cleaning contractors identified were Genesis and Aqua Drill. Both contractors use a water jetting process for removing the existing lining. In regards to this process, our research identified that with both cleaning contractors:

- A robotic apparatus is used to remove the lining with high-pressure water
- The access points and requirements for cleaning are more than adequate for lining
- The coal tar and cement mortar linings can be removed
- There is no dust from the lining removal because it is contained in the water
- There is no adverse effect on the steel pipe

However, there were differences between the cleaning contractors' water jetting methods related to:

- The pressure of the water used
- The quantity of water required
- The distance between the staging area and the pipe removal site
- The speed of the process
- Noise levels

The only other available means of removing the existing lining would be sandblasting or manual chipping of the lining. The disadvantages of these methods are:

- Sandblasting does not neatly remove CTE. The sandblasting produces heat, melts the tar, and mixes it with the sand. The mixture then slides down the pipe wall without removing it from the steel cylinder.
- Manual chipping requires manual labor in the pipe, does not provide a clean white metal finish of the existing steel cylinder, and could result in additional holes in the steel cylinder due to the use of hydraulic tools to remove the existing lining.

Pipe Entry and Exit Pit Locations

Because the District's budget was limited and there were only two lining and two cleaning contractors available and qualified to do the work, the design team consulted with the contractors to determine the minimum number of and most cost-effective locations for the entry and exit pits. Based upon the information obtained from the contractors regarding their operations and identifying locations that could be reasonably accessed with minimal disruption to residents, the following criteria were developed and used to identify preliminary pipe entry and exit pit locations and additional construction space requirements at each location:

- The size of the pipeline access pits would be approximately 12 ft x 15 ft
- Approximately 10 feet of pipe would have to be removed to get cleaning and lining equipment in.

- Entry and exit pits, i.e. pipe removal sites, shall be placed away from existing pipe joints
- Frequency of entry points varies from approximately 250 to 1,000 feet depending upon the vertical profile
- It is preferable to have entry points at low points in the profile
- It is preferable to have entry points where there is available access and in areas of low impact to residents and minimal impact to existing landscape features
- Access locations are required on both sides of existing in-line valves
- The operation can go two directions from any given excavation site
- Approximately 1,200 square foot area for water jetting equipment:
    - 350-700 HP Diesel Pumps
    - Mobile 20-foot Container
    - Mobile 20-foot Frac Tank
    - Containers and Frac Tanks can be located several hundred feet away from the entry location, such as on the street in front of a residential property with umbilical hoses to the entry location at the back of the property.

Preliminary plans were developed, identifying the proposed pit and equipment staging areas.

Construction Costs

In August 2017, after developing the preliminary plans that identified the most economically feasible entry and exit pit locations, we solicited construction costs from two lining contractors. Lining Contractor A's estimate was $1.6M ($0.8M for cleaning/$0.8M for relining), and Lining Contractor B's estimate was $5.5M ($1.0M for cleaning/$4.5M for relining). The estimates differed by nearly $4.0M. Since the two estimates for cleaning were similar, it was evident that the highest variability was not associated with cleaning, but rather with the lining contractors' costs.

The best way to confirm the difference in the construction costs offered by the two contractors was to identify and compare construction costs for similar projects. However, there are few similar projects of this size and type in California. The projects we had for comparison were:

- Project 1- Orange County Feeder Extension Relining Project- Reach 1: completed with water jetting and Lining Contractor B in Los Angeles for the Metropolitan Water District of Southern California (MWD) in July 2017
- Project 2- The San Juan Water District Water Treatment Plant - Raw Water Pipeline Rehabilitation Project: completed with manual cleaning by Lining Contractor A for the District in 2010.

Project 1- The Orange County Feeder Extension Relining Project- Reach 1:

- Was bid in July 2016 and completed in July 2017.
- Was a 36-inch CTE lined steel pipeline originally designed in the 1940s.
- Was constructed within a main arterial road, Bristol Street, in Santa Ana, California.
- Included some modifications to the pipeline, such as installing cathodic protection, new access manways, and welding plates over the pinhole leaks.

- After investigating and even performing test sections with different cleaning methods, MWD determined that the only feasible method of adequately removing the coal tar was water jetting
- Thirteen (13) contractors attended the pre-bid meeting on July 6, 2016.
- MWD received only one bid on bid day from Contractor B.
- MWD rebid the project and modified the specifications to allow a variety of cleaning methods.
- Contractor B was, again, the only contractor to bid the project.
- The final bid was $4.5M.

Project 2- The San Juan Water District Water Treatment Plant - Raw Water Pipeline Rehabilitation Project

- 1,372 LF of 54-inch, 766 LF of 72-inch, 876 LF of 66-inch, and 174 LF of 42-inch steel pipeline
- The 42-inch pipeline was originally constructed and lined with CTE in 1952
- Located on the District's WTP site
- Two lining contractors bid on the project: Lining Contractor A and Lining Contractor B.
- Lining Contractor A's bid was $685,965, and Lining Contractor B's bid was $1,249,985.
- Project completed in 2010.
- Change orders totalled $19,232 (2.8%)

Because the District had a limited construction budget for the FO-40 Project of approximately $2.18M, and because of the District's experience on the Raw Water Pipeline Rehabilitation Project where the bids varied so greatly between the two lining contractors, the District directed the design team to pause document development and provide additional verification of construction costs. The research included contacting all the contractors who had attended the MWD pre-bid meeting in 2016. The goal of the communication with those contractors was to determine if any other contractors could or would bid on the Fair Oaks 40 Project; and if so, what bid price could the District expect.

The results of the research determined that the only contractors interested and capable of bidding the Project were Lining Contractor A and Lining Contractor B. However because Lining Contractor A was located in New Jersey and no longer had operations in California, they would not commit to bidding the Project.

After submitting the PDR and Feasibility Analysis in September 2017, the District reviewed the analysis. On October 23, 2017, the District directed the design team to complete development of contract documents with:

- Options for manual and water jetting cleaning
- Provisions for a flexible five (5) month (150 calendar day) construction timeline. The purpose was to increase the potential for both contractors to bid on it by allowing them to construct it when it was most beneficial and had availability.
- Bid documents to be issued in 2018
- Substantial completion of construction, no later than May 15, 2019, to get the pipeline online for peak summer demands

## 5. DESIGN

For the design team, the significant effort associated with development of the construction documents for this Project was related to determining and specifying the level of cleaning required, specifying the requirements for disposal of the CTE, minimizing impacts and potential safety hazards to residents, identifying utilities, traffic control, and permitting requirements. For the District, the significant effort was associated with coordinating and developing agreements with the property owners whose properties would be impacted by the entry and exit pits.

Cleaning

One of the differences between the two similar projects identified during the preliminary design phase was the method of cleaning used. On the MWD project, with Lining Contractor B as the contractor, the cleaning was performed with robotic high-pressure water jetting equipment. On the SJWD project, with Contractor A was the contractor, the cleaning was performed by manual scraping. For the design team, the question was, "Can manual scraping of the CTE provide a surface to which the new cement mortar can properly bonding and provide a quality, long-lasting cement mortar lining?" Although Creamer had performed the work on the San Juan Water District Water Treatment Plant - Raw Water Pipeline Rehabilitation Project for the District in 2010, the pipe had not been inspected since project completion.

To determine whether to allow manual scraping as an alternative cleaning method, the District invited Murraysmith to inspect the 42-inch raw water pipeline while it was drained for maintenance. In April 2018, Murraysmith's Project Manager, Todd Kotey, accompanied one of the District's engineers, Andrew Pierson, into the pipeline. This inspection was 8 years after the removal of the CTE lining and installation of the new cement mortar lining. Results of the inspections were as follows:

The mortar surface was a heavy orange peel surface. There were no detectable cracks in the mortar. Further, it was determined by sounding (tapping on the mortar with a ¾-inch bolt) that the mortar adhered to the steel liner with no delamination identified.

As a result of the inspection, it was confirmed that manual cleaning was an acceptable method for removing the CTE and CML, and the specifications included manual cleaning with requirements to only remove any part of the lining that was loose.

Non-RCRA Hazardous Material Disposal

Coal tar contains high concentrations of polynuclear aromatic hydrocarbons (PAHs) within its make-up. In addition to the federal listed hazardous wastes, there are two other classifications of hazardous waste in California. They are Resource Conservation and Recovery Act (RCRA) hazardous or non-RCRA hazardous. "Non-RCRA hazardous," is a California legally defined term pertaining to material that is not classified as hazardous under the Federal identification (RCRA) but is classified as hazardous through the California waste determination process.

At a minimum, the coal tar and related waste on this Project, including coal tar containing wastewater, is considered non-RCRA hazardous (due to PAH), and it would need to be shipped to a landfill that would accept it. However, if it contains any of the RCRA metals in it, it could be toxic; and, therefore, be considered RCRA hazardous. Toxic waste presents a concern as it may be able to leach from waste and pollute groundwater. The toxicity of waste is determined by the Toxicity Characteristic Leaching Procedure (TCLP). TCLP rule identifies all the compounds to test for (8 metals and 11 organics) to determine if it falls into the RCRA hazardous category or not.

Based on previous materials testing on the existing CTE, it was unlikely that the CTE or the mortar contains any of the RCRA hazardous metals. Because each of the landfills has specific restrictions on what it does and does not accept, the contractor is required to do the testing during construction. As a result, the design team developed the contract documents assuming it would be classified as Non-RCRA, which it was.

Lining

As previously identified in Section 3, the inside diameter had internal irregularities; including but not limited to convex dents, out of roundness, ½-inch steel plates installed to seal pinhole leaks and abandoned laterals in the previous repair performed in 2013, and mitered fittings and changes in both horizontal and vertical direction.

A rotating machine troweled-mortar finish cannot provide a consistent mortar thickness given the irregularities in the inside diameter of the steel cylinder, nor can a rotating, machine-troweled finish be applied evenly to mitered fittings, an alternative finish was recommended. For a consistent mortar lining thickness, there are alternative trowel types, such as a drag trowel or an un-troweled centrifugally placed mortar lining, which will leave an "orange peel" finish. The "orange peel" finish has a small impact on the design coefficient (C value) of the pipe but very minimal. The orange peel finish is also less expensive than the troweled finish. As a result, we recommended an orange peel finish and recommended taking lining coupons at random intervals during construction to confirm application thickness, as well as monitoring machine speed, mortar flow rates, and volumetric measuring of mortar applied.

Proper curing of the cement mortar is essential to the quality of the lining. According to MWD, 35% humidity is the minimum desired level of humidity during the curing process. The following requirements for curing the cement mortar lining were included in the specifications:

- Complete hand finishing work within 24 hours after machine applied mortar lining has been completed
- The pipe shall be closed during lining and curing to control the velocity of air to maintain a moist atmosphere in each segment
- Cure by the water-spray method no later than 12 hours after application of the lining
- Tightly close off water-sprayed lining with bulkheads or entirely surround it with tight enclosures and keep the surfaces continuously moist.

Coordination with Residents

Coordination with the residents was provided by the District. The District met with residents whose properties would be impacted by an entry or exit pit. The design team included provisions in the specifications related to safety at the pits and work on the private parcels, including:

- The contractor, not the District, was responsible for providing security within the backyards and work sites as deemed necessary for the protection of its equipment, materials, or work and residents' property from vandalism or theft. The District would not be responsible for theft or damage to the contractor's equipment, materials, or work.
- Limiting the contractor to working on private parcels between 9:00 am and 5:00 pm on weekdays.
- Requirements for 6-foot high post driven locked temporary chain link fencing at each open excavation site in non-paved areas and trench plates at open excavation sites in paved areas to prevent the entry of the public into the pipeline and construction excavations. The fencing was to encompass all construction sites, the contractor's yard, storage area, and temporary structures and sheds.
- A list of the anticipated restoration required at the residential properties which were not visible from the street and photos of those parcels.

The District made final agreements with property owners during construction after the contractor finalized the entry and exit pit locations and the construction schedule.

Utilities, Traffic Control, and Permitting

To minimize conflicts and aid the progression of the construction, the design team performed the following work:

- Avoided utility conflicts when locating entry and exit pits, wherever possible
- Developed traffic control plans for each of the potential entry and exit pits locations, including the additional construction staging areas identified on the plans in public rights of way.
- Coordinated with the City of Folsom and County of Sacramento on encroachment permit requirements and approval of the traffic control plans before bidding the Project
- Developed a non-permitted Water Pollution Control Plan (WPCP) that complied with the District's National Pollutant Discharge Elimination System (NPDES) Low Threat Discharge Permit and with Sacramento County encroachment permit requirements.

## 6. BID PHASE

The project documents were issued for bid on May 6, 2018. Project bids were received on June 19, 2018, and are summarized as follows:

| | |
|---|---|
| Lining Contractor A | $2,598,842.00 |
| Lining Contractor B | $6,166,322.00 |

Lining Contractor A was the lowest responsive, responsible bidder. Their bid documents were reviewed and found to be complete and in order, including license, insurance, and bonds.

## 7. CONSTRUCTION COSTS

Notice to proceed was issued to the Lining Contractor A on October 29, 2018, and the pipeline was back in service on May 12, 2019 (3 days ahead of the required schedule). The change orders incurred were primarily the result of the additional patch repair required for the pinhole identified after removal of the lining.

Overall Project Costs

| | |
|---|---|
| Construction Bid | $2,598,842 |
| Construction Change Orders (5.8%) | $ 151,916 |
| Engineering | $ 219,219 |
| Construction Management | $ 230,680 |
| Total Project Cost | $ 3,200,057 |