ABSTRACT: Over the last several years, the City of Sacramento (City) has completed a handful of slipline installations to rehabilitate various types of pipelines, from transmission water lines to non-pressure storm drains. Projects, including the 6th Street water transmission main and the Executive Terminal culvert rehab, highlight successes and lessons learned with the City’s sliplining experience.

The City rehabilitated approximately 2,500 LF of a century old steel water transmission main in downtown Sacramento with a combination of traditional dig and replace and sliplining. On the non-pressure side, the City has realized the benefits of slipline installation with the rehabilitation of six culverts at the executive airport terminal, saving the expense and hassle of surface restoration costs. Other slipline applications have been equally successful with various defined project scopes, lengths of installation and product piping being used.

This paper briefly details the design and installation of three sliplining projects and the way the challenges of these projects were met. It summarizes lessons learned and the place that trenchless slipline rehabilitation holds within the City of Sacramento Utilities Department. These ‘lessons learned’ may be useful to other utilities and engineering groups that are looking to broaden the scope of replacement and rehabilitation options available to them, regardless of pipe application.

1. INTRODUCTION

The City of Sacramento Department of Utilities (DOU) serves more than 475,000 customers. It maintains more than 2,000 miles of water, drainage, and sewer pipes. The Department also operates two water treatment plants, two combined sewage primary wastewater treatment plants, 27 wells, over 200 pumping stations, and 11 reservoirs. Sacramento is one of only two cities in California with a combined sewer system.

The challenges that Sacramento DOU faces are much like any other utility in the country including aging infrastructure, growth management, and fiscal/political constraints. Portions of Sacramento’s infrastructure, including some of the larger water mains, are near the end of their useful lives and rehab/replacement issues must be addressed. The aging infrastructure includes both pressure and non-pressure piping systems. These systems are becoming more difficult to maintain as the infrastructure ages. A DOU master planning goal is to provide a healthful and reliable utility system that will meet the needs of a growing community, satisfy State and Federal regulations, and be as efficient as possible to operate and maintain.

2. SLIPLINING AS A REHABILITATION ALTERNATIVE

When dealing with aging infrastructure in its system, Sacramento DOU has experimented with different ways to tackle the potential renewal of pipelines instead of complete replacement. Prior to 2004, DOU used a few pipeline rehabilitation technologies including cured-in-place-pipe (CIPP), painted epoxy coating liners, and hand trowelled cement mortar lining replacement. 2004 was the year Sacramento DOU first installed a slipline repair.
Sliplining is the practice of inserting a new, smaller whole pipe into an existing pipe that is in need of rehabilitation or replacement. The benefits of sliplining include the use of an existing easement and utility location, the provision of a new whole pipe instead of a rehabilitated one, and potential improved corrosion resistance and flow dynamics of the new sliplined pipe over the existing pipeline. The degree of improved flow characteristics is dependent upon what new pipeline material is used. The one major downside to sliplining is the fact that, due to the nature of the installation, a smaller pipe must be used to replace the existing line. This will reduce the pipe’s flow area, making it difficult to increase pipe design flow if using the sliplining technique. If, however, the issue of design flow can be overcome, there is no simpler form of trenchless technology available today in terms of concept and execution in the field.

There are several pipe materials that lend themselves to sliplining application, due to the nature of the material and the joining methodology used to assemble the pipe. Butt fused HDPE pipe, with good corrosion resistance, is a candidate pipe material for sliplining. PVC pipe, with a high strength-to-weight ratio and thinner wall along with good corrosion resistance, is also a popular sliplining material. The use of PVC pipe is commonly used when thermal butt-fusion jointing is employed, such as with Fusible PVC™ pipe (FPVCP). For both HDPE and FPVCP, thermal butt-fusion joining provides a full strength continuous section, with no increase in the outer diameter, such as would be the case with a coupled or belled pipe joint. It also eliminates candidate entry points for root intrusion and infiltration associated with bell and spigot joints.

Since 2004, Sacramento DOU has considered sliplining as an installation method whenever conditions support it. The decision of whether or not to use sliplining for system rehabilitation is primarily based on calculations of the reduced flow area after the pipe has been sliplined. This is checked against current and future demands required of the pipeline. Relative costs also must be considered, particularly for short projects. This paper presents several sliplining case studies that Sacramento DOU has undertaken in the recent past to explore the ways that they have found sliplining to be a successful and simple rehabilitation method when the conditions supported its use.

### 3. SLIPLINING FOR PRESSURE PIPE RENEWAL

In 1998, the Sacramento DOU established a citywide riveted steel transmission main replacement program. This program was the result of a broken riveted steel pipe transmission main on Q Street which caused $185,000 in damages. At the time, Sacramento DOU had about 12 miles of riveted steel pipe that had been installed between 1870 and 1950 (see Figure 1). On average, Sacramento DOU has replaced about 1 to 2 miles of this pipe per year in the potable water system. As part of this replacement program, in 2009, a half mile section of 107 year old transmission main was slated for replacement on 6th Street, between I Street and Q Street (see Figure 2) (Williams, 2010).

![Figure 1. Riveted steel pipe removed from 6th Street as part of that rehabilitation project.](image-url)
Pipe replacement methods on the 6th Street Project included a combination of traditional open cut with ductile iron, welded steel, and PVC pipe materials, and the use of sliplining rehabilitation only for one 1,400 foot long segment. Sacramento DOU considered ductile iron, FPVC, and HDPE as pipe material options for the slipline section. The slipline material ultimately selected was 18” DR18 FPVC for its ability to deliver a 235 psi pressure rating while providing the thinnest pipe wall and the largest flow area per outside diameter of the evaluated pipe options. The project was awarded to Martin General Engineering in late 2009 and installation started in the spring of 2010.

The FPVC pipe was fused by Underground Solutions, Inc. The exterior fused joint bead was partially removed from the outside of the pipe. The interior bead was not removed. This provided a sufficiently smooth outer wall for the slipline process. The pipe was installed using a truck mounted winch assembly. The winch was tied off to a pull head attached to the sliplining pipe end after it was fished through the section to be sliplined (see Figure 3). The condition of the original pipe was good enough that skids or spacers were not required as part of this process. Only minor surficial scratching was observed on the FPVC after the pipeline had been installed using the slipline process.
Figure 3. Sliplined FPVCP being pulled through the existing riveted steel pipe into the receiving pit. Note the pull head used to connect to the pipe and the pulling mechanism.

For each branch connection along the sliplined alignment, i.e., for distribution lines and fire hydrant leads, a new ductile iron tee was installed. This involved placing five 18" thru dimension tees in the 1,400 foot length between the slipline entry and exit pits. Tee insertion was done by first exposing and removing a section of the existing deactivated riveted steel main where each tee was to be placed. The length removed was slightly longer than the actual tee length in order to provide access for inserting the tee and for tightening the joint bolts. The entire 1,400 length of slipline pipe was then pulled in from the entry pit to the exit pit. Working in sequential order backwards from the exit pit, the new sliplined pipe was then cut at the location where that tee was to be installed. An excavator back at the entry pit used a sling to push the remaining “sliding” pipe away from the “fixed” segment so that tee could be placed. Once that tee was installed onto the fixed segment, the excavator then used the sling to pull the sliding piece back home into the tee to complete the joint. All the joint bolts of that tee were then tightened and that tee was fixed. The operation was then repeated sequentially for each of the remaining tees. (See Figure 4.)

Once all the tee fittings and necessary valves were installed, the sliplined main was disinfected and pressure tested. Following satisfactory bacteria testing, the pipe was dechlorinated and the annular space between the new slipline and the old host riveted steel main was grouted with a light weight cement grout.

The project was completed on schedule. A total of 2,500 LF of riveted steel transmission main was replaced and is currently in service. More than half of the replaced pipe was FPVCP that was installed via sliplining. In addition, seven unnecessary connections to the transmission main were removed; abandoned crosses and tees were eliminated; and three new inspection manholes were added. Throughout the project, there were only three customer complaints and less than 1% was spent on change orders.

There were lessons learned along the way on this project. On non-metallic waterline installations, Sacramento DOU typically installs a continuous copper locating wire. Inserting locating wire did not work in the slipline section of this project. The wire kept getting pinched in the annulus and breaking. In the sliplined section, the riveted steel pipe was cut to insert the new tees so the riveted steel was no longer continuous. Thus it was planned to insert a new continuous tracing wire to facilitate locating the buried FPVCP. Also, it was difficult to get a water tight seal on old valves - pressure caps were definitely needed. A ‘trenchless’ application doesn’t necessarily mean there are no trenches involved. Insertion pits and locations for tee and valve connections needed to be excavated. The lightweight flowable foam grout worked very well as an annulus treatment between the sliplined pipe and the existing steel line. Due to its easily pumped nature, this grout could lend itself to other applications, such as subfloor.
leveling and/or abandonment of pipes to be left in the ground. Lastly, taking more photos of the construction site and progress is suggested. In preparing this paper, for example, it seems there were interesting installation events or occurrences, but there wasn’t a big choice of file photos available for illustration. In general, it just seems you can never have too much documentation.

4. SLIPLINING FOR NON-PRESSURE PIPE RENEWAL – STORM DRAINAGE

The Sacramento Executive Airport exit road crosses over six parallel culverts in a DOU maintained drainage swale. Each culvert was a 36-inch diameter, 118.5 lf long, corrugated metal pipe (CMP) that over 50+ years had corroded and partially collapsed in several areas. The roadway over the culverts was not showing any damage, but sinkholes over the culverts were evident in the adjacent landscaped areas. It was apparent that the situation would only get worse as the culverts got older. (See Figures 5, 6, & 7.)

Based on a hydraulic analysis, using new smooth interior pipe in lieu of the existing corrugated metal, Sacramento DOU staff determined this was a candidate site for sliplining rehabilitation. Even though sliplining would reduce the culvert cross-sectional area, sufficient freeboard was available to increase the inlet headwater depth and still pass the design flow. A total of 720 feet of new culvert lining, comprised of six lengths of 120 feet each, was required. Although in-house staff opted to perform the rehab field work themselves, procurement regulations required...
competitive bids for the construction materials. The following three sliplining material options were selected for bidding, based on size availability and suitable material properties:

1. Fusible C-905® PVC pipe, SDR 41 (O.D. of 32.00 inches and nominal I.D. of 30.35 inches).
2. Snap-Tite® gasketed HDPE pipe, SDR 32.5 (O.D. of 32.00 inches and nominal I.D. of 30.00 inches).
3. Fused joint HDPE, SDR 32.5 (O.D. of 32.00 inches and nominal I.D. of 29.91 inches).

After bids were opened, FPVCP, with the vendor performing all required joint fusing, was selected as the lowest cost lining material. Sacramento DOU crews performed the sliplining installation, but subcontracted out the annular space grouting between the new sliplined FPVCP and the host CMP culverts.

Figure 5. Culvert condition prior to rehabilitation. Note gaps between the CMP pipe and concrete headwall.

Figure 6. Sinkholes were developing over the culverts prior to rehabilitation.
Figure 7. Photo of CMP Culvert section removed to facilitate slipline installation.

Three of the six sliplines were pushed thru the CMP host pipes without major incident. Although all six CMP culverts had serious corrosion with some resultant oval shape development, the sliplined pipe was sufficiently strong to push thru many of the oval restrictions. A fourth culvert slipline rehab did require a small open cut trench in order to reconnect a lateral connection. The remaining two culverts proved much more challenging to rehab.

Two adjacent culverts (the 2nd and 3rd from the right in Figure 4) required about two ten foot long sections to be open cut and portions of the existing CMP to be removed. In these two locations, the CMP sidewalls had collapsed so much, that the end of the sliplined pipe became entangled in the remaining metal. No amount of pushing was going to get the sliplined pipe past these choke points. Fortunately, these were located on each side roadway in the adjacent landscaped areas, so traffic did not have to be rerouted in order to open up these sections.

The plan all along was to retain a specialty firm to provide, mix, and pump grout into the annular space between the host CMP and the new liners. Procurement requirements mandated that this grout work also be competitively advertised and bid. Based on pre-bid discussions with grouting firms, more or less standard light weight, low heat-of-hydration cementicious grout consisting of cement, fly ash, water, and a foaming agent was specified and bid. The target cured compressive strength was 200 psi.

DOU staff used quick-set mortar to construct bulkheads that would keep the fresh grout in the annular space while it cured. Inexpensive solvent welded shut off ball valves with 2" PVC pipe were used to construct temporary grout injection and air release ports. The air release ports were installed on opposite ends of the culverts from where the grout was injected. For the culverts with open cut removed sections, more than one grout injection port was installed, again on the opposite end from where air was allowed to escape.

The use of plasticizer in the grout mix was recommended by the selected grouting firm. This was a post-bid field modification. Use of plasticizer was recommended to improve grout flow past the necked down sections of the annular space where the sliplined pipe was pushed past collapsed sections of the host pipe. Plasticizer, added per the
recommendation of the grouting contractor, added about $5 per yard (2%) to the bid price of installed grout. Figure 8 shows the installed and grouted culverts.

Figure 8. The sliplined, grouted, and nearly complete Executive Airport culverts. Small circles above the sliplined pipe are air vent or grout injection port remnants yet to be sealed.

There were several lessons learned on this installation. For one, Sacramento DOU will strongly consider fully power washing then pulling a test mandrel completely thru before proceeding to slipline any more CMP culverts. Although the ends of these six culverts measured 36-inches, they were not a uniform diameter throughout. Mud that was not removed from the inverts until after the sliplined pipe material was purchased was obscuring some very seriously rusted out inverts. Some of the culverts, which may have been lengthened over time, had sections of old uncurved riveted structural corrugated plate. In the worst of the rusted sections, plates had slipped past one another, reducing the internal diameter. Other than the unexpected additional time spent having to open up sections to remove collapsed host pipe, however, the installation work was all within DOU staff capabilities and could be budgeted reasonably well. It was not a significant additional cost to add the plasticizer via change order, but next time it will likely be included in the bid specifications for grouting lengths in excess of 100 feet. Very close bids were received for both the pipe materials and the grouting work. Of the three liner material options, no bids were received for the fused joint HDPE. Having to open up and remove sections of collapsed CMP left some oversized holes. DOU wanted to encase the entire length of sliplined culvert in grout, so filling the oversized holes used about 10% more grout than was originally bid.

5. SLIPLINING FOR EMERGENCY PIPE REPAIR – GRAVITY SEWER

Sliplining is also applicable for emergency repairs that are sometimes unavoidable when operating a utility system. As part of an emergency repair, Sacramento DOU hired grouting and pipe repair contractors to stabilize a sinking manhole on a gravity sewer system. DOU engineers and maintenance staff worked closely with and alongside both contractors. Sliplining was utilized as an integral part of the repair.

In the spring of 2006, a gravity wastewater manhole in a fairly major neighborhood collector roadway was sinking and taking the roadway with it. It’s believed the manhole was initially installed on soft ground in the late 80’s. The manhole then settled and sheared off the outlet 12-inch diameter vitrified clay pipe (VCP). When the emergency
repair was started, there was a nominal 18-inch deep, 20-foot diameter dip in the roadway roughly centered on the problem manhole. (See Figure 9.)

The outlet pipe from the manhole was almost 20 feet below grade. Groundwater in this area was approximately 10 feet below grade and when the outlet pipe sheared off, groundwater began flowing into the wastewater line. The groundwater was pulling sand and supporting soils below the manhole into the failed outlet pipe. This loss of soil accelerated sinking of the manhole and further shearing of the outlet pipe. In order to start the repair, chemical grout was injected into the ground surrounding and below the manhole in order to stabilize it. A proprietary chemical grout with a nominal 8-second accelerator was used, which also effectively stopped groundwater from flowing into the manhole via the sheared off pipe.

In order to keep open an outlet from the settled manhole, it was proposed by staff to insert a 6-inch pipe thru the sheared off VCP outlet. It was proposed to pull the repair pipe into and thru the sheared section from the downstream manhole. Although it’s some 400+ feet between the downstream and settled manholes, only a 60-foot length of slipline repair thru the broken 12-inch clay line was planned. The remainder of the downstream VCP was in satisfactory condition.

Sliplining with a relatively short section of repair pipe was considered a viable option at this site since the flow area required for a repair pipe between the manholes did not need to have the capacity of a 12-inch line. HDPE was chosen for the sliplined pipe material due to its flexibility for insertion into the downstream manhole. The downstream manhole was located on private property. Therefore, a limited construction footprint was required.

Figure 9. A large amount of subsidence was evident at the surface. The problem manhole is in the center of this photograph below the man-lift tripod.

A rodding machine was used to push through the sheared section of 12-inch clay pipe and feed a winch cable through, which was then used to pull the slipliner back through the downstream manhole and clay pipe. A temporary ductile iron elbow fitting was installed in the downstream manhole thru which the HDPE was inserted in order to prevent damage from the winch cable, and to help force the HDPE to make the required 90-degree bend inside the 4-foot diameter manhole shaft. (See Figure 10.)
Figure 10. Insertion of the 6-inch HDPE sliplined pipe into the 12-inch broken VCP through the downstream manhole. The flange is on a temporary elbow fitting used to force the pipe to bend.

The new sliplined pipe was sealed just at the upstream manhole outlet. The majority of the 60-foot long section is free floating in the downstream 12-inch diameter VCP host pipe, i.e., the annulus was not grouted. After the issues below ground were solved, the area that sustained damage due to the subsidence of the road was rehabilitated. (See Figure 11.) A riser cone section was added to the manhole and the roadway surface was restored to its design grade.

Figure 11. After all below grade issues with the manhole were rectified, the damaged portion of the road was excavated, stabilized and resurfaced.
Lessons learned in this repair included the need for close partnership with staff and contractors hired on an emergency basis. Much of the repair strategy was the collusion and melding of ideas from many of the participants. Subsequent to this repair, Sacramento DOU has maintained open ended competitively bid service contracts with specialty firms to supplement in-house maintenance and repair capabilities. Procurement regulations for competitively bid services are not appropriate and take too much time to implement when emergencies arise. Similarly, the proprietary grout used to initially stabilize and seal the settling manhole was a very interesting and unique product.

6. REFLECTIONS FROM THE PROGRAM

Sacramento DOU has been pleased with the use of sliplining as a means to rehabilitate aging and critical infrastructure. It has proven to be successful in both pressure and non-pressure applications. It has also proven to work very well in a wide range of infrastructure projects from basic projects with unique circumstances to complicated emergency work with more typical circumstances. As long as the potential loss in flow volume from the smaller required flow area of the new pipe is considered and deemed acceptable, sliplining provides a relatively low cost and low disruption means to handle the inevitable rehabilitation work that all utilizes face.

7. REFERENCES