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City of Port Angeles Pulls Off Challenging Slipline to Divert CSOs

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1. ABSTRACT

The City of Port Angeles required three pipelines to deliver effluent sewer to a water treatment plant as part of a combined sewer overflow (CSO) diversion project. An abandoned existing partially buried 48-inch reinforced concrete waterline which runs the length of the Port Angeles waterfront was used to rout the required force main pipelines in order to reduce disturbance to sensitive areas including Native American burial grounds, protected coastal species habitat, and high-quality wetlands. A pipe bundle consisting of two 14-inch and a single 30-inch pipe were sliplined through the existing waterline using a horizontal directional drill rig. Complex transitions from grade to subsurface elevations in tidally influenced zones of protected shoreline complicated the design and installation at the slipline pull and insertion pits. The 4,500 lineal foot slipline design is detailed along with specific challenges that required unique solutions both in design and during the construction.

2. INTRODUCTION

In 2006 a force main ruptured in Port Angeles Harbor, releasing an estimated 6 to 8 million gallons (MG) of untreated sewage. The Department of Ecology then required replacement and relocation of the pipeline outside of the harbor to eliminate additional environmental risk. The City of Port Angeles originally constructed the failed interceptor trunk line in 1967-1968 to carry CSO flows from the west end of the city to the primary wastewater treatment plant on the east side of the city waterfront. Approximately 4,000 feet of the pressurized sewer pipeline was laid two to four feet deep in the harbor nearly fifty feet off shore. This paper details the replacement of the CSO by utilizing an abandoned waterline with an onshore alignment paralleling the deteriorated force main. An overview map of the project site is shown in Figure 1.



Figure 1. Project location and vicinity map.

In order to meet the Washington Department of Ecology deadline of December 31, 2015 a two-phased approach was developed to reduce the number and volume of overflows into the harbor. Phase I of the project consisted of replacing the existing main interceptor trunk line from pump station No. 4 to the wastewater treatment plant and installation of an open cut sewer main to control discharge from a CSO. Phase II will implement treatment plant upgrades, retrofit an existing 5 MG tank, and upgrade the existing pump station No. 4 and connect the Phase I pipelines to the pump station and wastewater treatment plant. It was determined early in the Phase I design that sliplining an existing abandoned 48-inch reinforced concrete Industrial Waterline (IWL) with 30-inch and two 14-inch HDPE pipes would be preferable to open cut construction of the three force main pipelines. The City desired the use of HDPE pipe over other potential slipline pipe materials. Figure 2 shows various CSO locations along the City waterfront and the location of the Phase I project. (Port Angeles, 2014)

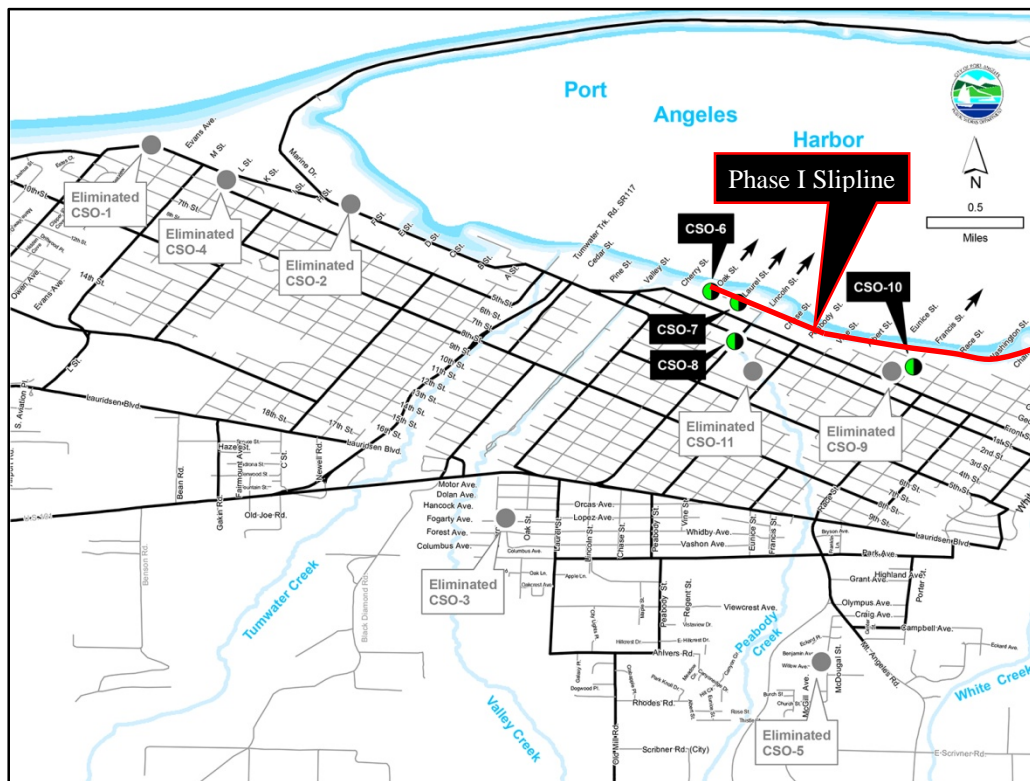


Figure 2. Port Angeles CSO map and Phase I slipline alignment.

3. PROJECT DESIGN

Trenchless construction, namely sliplining an existing reinforced concrete IWL pipeline, was recognized early in the design as a desirable alternative to open cut construction of the three pipelines along the highly sensitive waterfront. In order to increase the capacity of the pump station No. 4 to over three hundred percent, as determined through hydraulic modeling, three pipelines would be required to carry the flows to the wastewater treatment plant. Hydraulic analysis determined that a 30-inch and two 14-inch pipelines would meet the necessary flow requirements.

One of the most concerning issues that persisted throughout the design and later during construction was the historic and cultural risk of encountering Native American burial remains. In 2003, a Washington Department of Transportation project to construct a massive graving dock, a concrete lagoon dry dock, located on the Ediz Hook of the Port Angeles harbor was being built in order to construct replacement sections of the Hood Canal Bridge, which is a floating bridge supported by hollow pontoons. Less than two weeks into construction, human bones were unearthed and it was discovered that the site was located on the Tse-whit-zen Indian village and burial ground. After spending \$90 million, the state walked away from the unfinished project after discovering over 335 intact Indian skeletons resulting in what federal archeologists described as the largest prehistoric Indian village and burial ground found in the United States. The Phase I pipeline alignment is located less than two miles from the Indian village and burial ground site.

Very limited potholing was allowed under strict supervision of archeologists during the initial design of the slipline. Outdated as-built drawings of the 48-inch IWL pipe were heavily relied on for much of the location and elevation information. Suspect locations consisting of possible elevation shifts or potential debris and degradation were identified via CCTV inspection; however, due to groundwater inflow submerging the pipe, portions of the pipeline condition were unable to be assessed. Potential pull and reception pit locations were potholed in order to ascertain unsuitable grade deviations and potential fittings/repairs within the IWL which could lead to increased installation forces or inability to pull the pipe bundle. One portion of the IWL alignment was known to have multiple dramatic angle and elevation shifts as it traversed a shallow creek. Due to the increased risk posed to the slipline method, an open cut design was deemed the most viable alternative for this section of the alignment. Open cutting this portion also allowed for greater flexibility in making pipe connections without the necessity to acquire precise angle and alignment information.

The bundle consisting of one 30-inch and two 14-inch pipes was designed to carry the maximum flow volume possible, while maintaining sufficient clearance within the 48-inch IWL concrete pipe to slide through the anticipated grade and angle deviations. Multiple standard dimension ratio (SDR) and size options were considered in design to maximize flow and available annular space while providing adequate strength for the longest possible pull lengths. A horizontal directional drill (HDD) rig was required by specification to pull the slipline bundles into the 48-inch IWL. Requiring an HDD rig as opposed to other cable pulling methods afforded the ability, if needed, to adjust the bundle either by thrust or rotation to achieve the final lineup for in-pit connections. The design ensured that all connections of the 30-inch pipe would be butt fused. In order to provide the contractor with flexibility, the two 14-inch pipeline connections allowed the use of mechanical or electrofusion fittings in addition to butt fuse connections in the event that butt fusion was not possible. Electrofusion couplers slip over the outside of the product pipe and use an embedded metal heating element to fuse to the pipe. Disadvantages of electrofusion couplers in this case were the cost, much greater outside diameter required to make the connection, and additional care and skill required for installation. Work areas and pit lengths were determined largely by the installation curvature requirements of the product pipe, but also the fusibility of the joints after the bundles were pulled into place. Designing longer excavations allowed the pipes to be lifted and placed into the fusion equipment for butt fused connections, thus eliminating more costly or potentially weak points in the piping system.

Due to the unknown condition and imprecise location information of the alignment and grade deviations, the design required the contractor to pothole the pit locations prior to construction. In addition, the design required the contractor to pull a full diameter proof and cleaning pig through each segment to be sliplined. Once the pig was pulled successfully, the design required a 40-foot long test bundle identical to the configuration of the product pipe bundle be pulled through each slipline segment. Forces were monitored and recorded during the pigging and test bundle pulls to determine if there were problematic locations that would require additional excavations and removal of sections of

the 48-inch IWL host pipe prior to pullback of the product pipe bundle. Any additional pits required as a result of the preparatory work would be covered as an additional pay item in the contract.

The design required each pipeline of the pull bundle to have an independent pull head with an outside diameter that was equal to or less than the diameter of each pipe to prevent the pull head from hanging up on the host pipe. The independent pull heads would ensure that forces would be as evenly distributed as possible during pullback of the pipe bundle without causing a potential binding point. Once the pipelines were installed, it was deemed unnecessary to grout or fill the resulting annular space. However, the intermediate pit connection points between slipline segments were backfilled with controlled density fill (CDF) to ensure restraint from movement.

At the far west end of the project the pull pit size was limited by multiple utilities and site constraints. The pull pit would allow room for the pipes to enter the pit but not enough clearance for an in-pit fusion machine to cap the pipes. Specialized end caps were required to be fused inline for each pipe immediately behind the pull head prior to pullback. Once pullback was completed, the pull head could be cutoff with the caps remaining to allow post installation hydrostatic testing. By addressing these issues in design, the overall disruption at this particular location was limited in area and duration.



Figure 3. Slipline Segment Overview and Pull/Insertion Pit Locations

4. PROJECT CONSTRUCTION

Since the precise location of the 48-inch IWL pipeline was not known, the contractor used a battery powered sonde locate system, common in the HDD industry to walkover locate the entire length of each slipline segment. The depth and alignment was recorded and marked every fifteen feet for the length of the pipeline. This allowed the contractor a preliminary method of determining if grade or alignment deviations existed while stringing the drill pipe through the host pipe prior to pulling the cleaning pig. Figure 4 shows the side-load battery powered locating sonde used to track the 48-inch IWL host pipe and the setup of the HDD drill rig.



Figure 4. (Left) HDD battery powered locating sonde. (Right) HDD rig setup over existing host pipe.

After performing the initial potholing and preliminary work including pipe fusion and testing, the contractor began the slipline process by pulling the full diameter foam proof/cleaning pig through each segment of the existing 48-inch reinforced concrete IWL. Figure 5 (left) shows the foam pig being pulled from the first slipline segment that was approximately 1,200 feet long. After pulling the foam pig through the 48-inch IWL the contractor then pulled a 40-foot long test bundle built to mimic the actual slipline product pipe bundle. The test bundle shown in Figure 5 (right) provided an additional level of confirmation that the subsequent slipline installation would be successful for each segment. Pull forces were monitored during each pull in the event that a preemptive excavation and removal of the reinforced host pipe would be deemed necessary.



Figure 5. (Left) Proof and cleaning pig pulled prior to slipline. (Right) Test bundle pulled prior to slipline.

After pulling the pipe pig and test bundle, the contractor began sliplining the 48-inch IWL. The contractor used a specially designed pipe taming/bundling frame with rollers (Figure 6) to group the three pipes together before entering into the host pipe. This taming and bundling was necessary to group the pipes as they entered the host pipe to reduce friction and prevent the pipes from rolling during pullback.



Figure 6. Insertion of 30-inch and two 14-inch pipes using bundling/taming frame.

In order to reduce the friction load the contractor elected to lubricate the pipe bundle as it was pulled into the existing concrete host pipe. A standard HDD mixing system with pump was employed to mix and spray the liquid polymer lubricant as seen in Figure 7. Lubrication proved necessary as the installation forces increased for the longer slipline segments, which also contained large bends as opposed to the first pull segment, which was absent curvature.



Figure 7. (Left) Pullback from pit C to B with liquid polymer lubricant. (Right) Pullback from pit F to D (see Fig. 3)

During construction the contractor was able to show that it was likely possible to eliminate Pit E without overstress of the product pipe bundle. The engineer and owner worked with the contractor and allowed the two segments to be combined into a single pull as a no-cost change with the agreement that if pull forces reached the maximum allowable limit of the product pipe of 155,000 lbs, then the contractor would stop the pull and the intermediate pit would be constructed at the termination point. Ultimately the pullback of the combined segments was successful and an intermediate pit was not necessary. This field decision was advantageous for all parties. It saved the contractor excavation and restoration costs and helped to reduce the overall construction schedule.

The estimated maximum installation loads were calculated in the design for both a non-lubricated and lubricated condition for each slipline segment. This range of estimated pull forces is shown in Figure 8 as vertical dashed lines for each segment. The method used to calculate the slipline estimated maximum installation loads was based on the method presented in Chapter 12 of the *Plastics Pipe Institute Handbook of Polyethylene Pipe, Second Edition (2008)*. During construction, the actual installation loads were monitored and recorded by the contractor and Staheli Trenchless Consultants' on site inspection staff. Figure 8 shows the measured installation forces for each slipline segment compared to predicted values of a lubricated and non-lubricated condition.

Installation Force Vs. Length

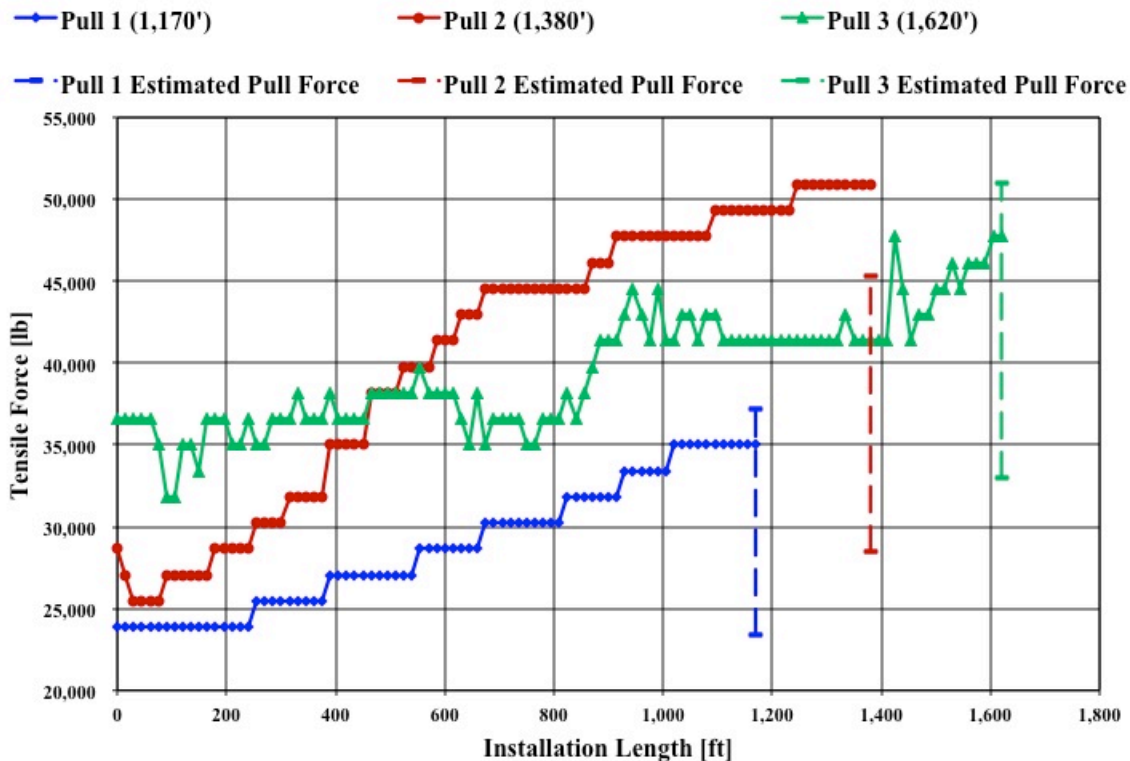


Figure 8. Installation Force Versus Segment Length and Estimated Pull Force Envelope (Lubricated to Non-lubricated Range)

Of note in Figure 8 is for the second pull segment (shown in red); the installation forces exceeded the predicted range. This was likely due to the curvature of both the existing pipeline as well as the more severe bending necessary to curve the pipe as it was laid along the ground surface to avoid park benches, concrete lampposts, and protected vegetation. The increased capstan forces inside the concrete IWL coupled with increased surface friction due to bends and pulling the pipe up a grade, likely contributed to the increased installation loading beyond the predicted values.

After completion of the slipline installation, the contractor utilized two in-pit fusion machines to butt fuse the 30-inch and two 14-inch pipes at the pull/insertion pits. The designed pit lengths proved sufficient for the contractor to fuse the pipes, thus eliminating more costly and technically challenging mechanical or electrofusion connections. Figure 9 (Left) shows two segments, which would later be cut and fused, being pulled together into a single slipline pit. Figure 9 (Right) shows the two in-pit fusion machines used to butt fuse the segments of pipe together.



Figure 9. (Left) Slipline pit with two pipe bundles. (Right) In-pit HDPE fusion machines used to make connections.

Figure 10 (Left) shows the fusion of the 14-inch pipeline after the 30-inch pipe had been fused. The butt fuse joints proved reliable with all of the fused joints passing the post installation hydrostatic testing. The contractor elected to use butt fused joints in part because of cost but also for reliability. Reliability was extremely important to the contractor because if a joint failed in one of the three 4,500 foot pipe strings then the majority of the pipe would require draining to perform the repair and then refilled and retested. Figure 10 (Right) shows the 30-inch pipe fused at the transition point from sliplined pipe to a 250 lineal foot intermediate section of open cut pipe. This section was designed as open cut due to large elevation and angle deviations. Also seen in Figure 10 (Right) is the 1950's era riprap and creosote pile retaining wall built to protect the waterfront along the length of the harbor.



Figure 10. (Left) In-pit fusion of the 14-inch pipe. (Right) Fusion of the 30-inch pipe at an angle/elevation change.

5. CONCLUSION

The slipline construction for the City of Port Angeles Phase I CSO Project proved extremely successful. Due to the project constraints, a very conservative design was crafted to guard against unknown conditions and potentially high impact issues. Historical and cultural impacts were identified early in the design process as potentially significant if artifacts were actually encountered in excavations, thus driving the approach to sliplining. Potential challenges for the slipline were addressed through limiting the maximum outside diameter of the three pipelines and requiring both a cleaning pipe pig and test bundle be pulled prior to each segment of the slipline. Although the belt and suspenders approach ultimately proved unnecessary, the additional requirements were not found overly burdensome and were regarded as appropriate by all including the contractor performing the work. A proactive design and construction management team worked in union with the contractor early in the submittal process which allowed flexibility as the work was executed. The contractor utilized a well-planned pipe support and bundling frame as well as lubrication during the slipline installation to reduce the overall pull stress. In tracking the pull forces for the first two segments,

the contractor was able to demonstrate that the good practices would allow the exclusion of an intermediate pull pit, thus saving overall schedule and costs.

Even though the project was extremely successful and incident free, preemptive steps taken in design along with subsequent specification requirements implemented during construction are necessary to ensure project success when considering a project with unknowns and elevated risk profile. Proper investigation by designers in conjunction with the aforementioned preparatory steps is of utmost importance to minimize potentially fatal project issues. Even if not required by specification, the author strongly recommends that Contractors take these and similar precautionary steps which may prove invaluable in similarly challenging circumstances where alignment deviations or pipe conditions are unknown or unreliable. These preemptive measures are negligible in terms of overall project costs, but may prove invaluable in preventing costly delays or untenable contingency plans.

6. REFERENCES

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