North American Society for Trenchless Technology (NASTT)
NASTT's 2013 No-Dig Show

Sacramento, California
March 3-7, 2013

TM1-T2-03

Cutting-Edge Trenchless Technology Proposed for Challenging CSO Project

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ABSTRACT: Under the Washington Administrative Code, King County in Seattle, WA is required to limit the number of Combined Sewer Overflows (CSOs) into Puget Sound to a long-term average of no more than one per year. In response, the South Magnolia CSO Control Project is currently under design with the construction of a 1.5-million-gallon buried storage tank near the base of the Magnolia bluff and a new conveyance pipeline to convey peak flows to the tank. The conveyance pipeline must have a minimum flow diameter of 24 inches, convey combined sewer approximately 3,000 feet, flow by gravity, traverse through landslide deposits on the side of the bluff, and be installed at depths of up to 165 feet.

During pre-design, King County considered trenchless alternatives and decided to design a horizontal directional drill (HDD) for the installation of the conveyance pipeline, which would result in one of the largest on-grade HDD installations ever constructed. After a value engineering session on the project, it was decided to include Direct Pipe® as an alternative to HDD construction due to recent advances with the Direct Pipe® technology. With either HDD or Direct Pipe®, the County will be designing a trenchless technology on the cutting edge. This paper presents the strategies that allowed the use of cutting-edge trenchless techniques.

1. INTRODUCTION

The South Magnolia Combined Sewer Overflow (CSO) Control Project seeks to meet the CSO control objective defined by King County and the State of Washington of limiting untreated CSOs into Puget Sound to a long-term average of no more than one per year. This objective will be accomplished by providing storage in the South Magnolia Basin, located in Seattle, Washington. An overview map of the project area is shown in Figure 1. Currently, the existing sewer system routes sanitary and storm flow within the basin to 32nd Avenue West (located on the western boundary of the project area and left edge of the figure), where a diversion structure directs low flow to the South Magnolia Trunk Sewer and overflows to Puget Sound.

In 2010, King County performed an alternatives analysis for controlling CSOs in the basin, and identified the preferred alternative as the construction of a new 1.5-million-gallon buried storage tank located in the Port of Seattle West Yard, east of 23rd Avenue West and just south of the Magnolia Bridge, and a new pipeline to convey wet-weather flows to the tank (Carollo, 2010). The report identified horizontal directional drilling (HDD) as the most appropriate methodology for installation of the new trunk line.

In 2011 King County hired the design team of Tetra Tech, Staheli Trenchless, and Shannon & Wilson to design the project. One of the initial tasks of the conveyance pipeline Design Team was to verify HDD, the trenchless method recommended in the pre-design study, as the most appropriate installation methodology in light of geotechnical conditions, project risks and project design parameters.

Figure 1. Project Location

2. INITIAL TRENCHLESS FEASIBILITY ASSESSMENT

During the pre design phase, a trenchless methods feasibility and risk study was performed to determine the optimum trenchless method for constructing the pipe. The goals of the conveyance pipeline design were to convey flow from the existing diversion structure to the new storage tank, develop an alignment with the minimum number of private easements, and choose an alignment with the best soil conditions for a given technology, minimizing the risk of the trenchless construction. In the analysis, four primary methods were considered: microtunneling, open shield pipe jacking, the Direct Pipe® method, and HDD. These methods were evaluated for a number of criteria, including public impact, cost, environmental, permitting, suitability for the anticipated geotechnical conditions, and the ability to draw competitive bids.

During the evaluation, it was necessary to establish alignments that could be constructed with the different trenchless methods. HDD was deemed feasible from the new storage tank to the existing diversion structure based on the bore geometry; however, the need to maintain gravity flow and a maximum allowable slope of 1% led to concerns regarding the method history for the installation of large-diameter (36 inches and greater) on-grade pipelines. In order to minimize the potential for adverse grades due to HDD installation tolerance, the Design Team proposed a new alignment that consisted of constructing a new diversion structure to the north of the existing structure to increase elevation at the upstream end of the conveyance pipeline, thereby increasing the allowable slope to 1.8%. Figure 2 shows the alignments that were developed and considered in the technology assessment.

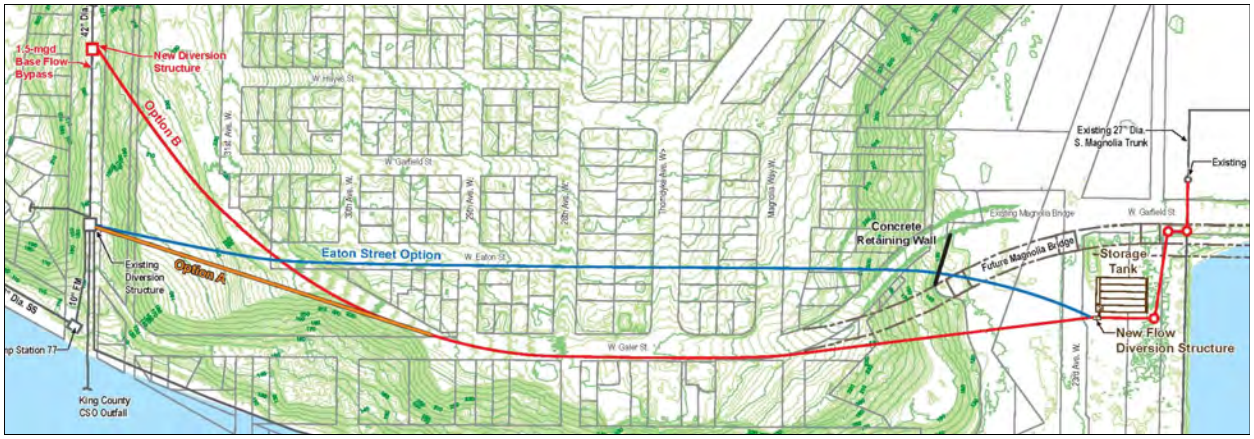

Figure 2. Project Area Showing HDD Alignments Considered

One of the technologies evaluated, Direct Pipe® was relatively new to the United States with only three installed pipelines in the U.S. at the time of the evaluation and therefore deserves some discussion. The Direct Pipe® method is relatively new technique that essentially combines HDD and microtunneling (Herrenknecht, 2012). A slurry microtunneling boring machine (MTBM) is propelled forward by a pipe thruster that pushes the machine and a steel pipeline along a predetermined alignment, which can include both vertical and horizontal curves, limited by the bend radius of the steel pipeline. A primary difference between microtunneling and Direct Pipe® is the guidance system that allows the MTBM to steer along horizontal and vertical curves in the same manner as HDD. Another key difference is that the pipe thruster is typically located at the ground surface, similar to HDD, and as such can push long sections of steel pipe rather than the single pipe segments that are typically cartridge loaded in a jacking frame within a shaft (Figure 3). As a result of this ability, Direct Pipe® is limited to the installation of steel pipe only, as opposed to the range of pipe materials which can be installed via microtunneling. However, unlike microtunneling, the MTBM can be pulled back with the pipe thrusters should an obstruction be encountered.


Figure 3. Installation of a 42-inch steel pipe in New York, August 2011. On the left, the pipe thruster is pushing the MTBM forward while the trailing steel pipeline can be seen supported by cranes. On the right is a close-up view of the pipe thruster in action. Photos provided by Herrenknecht AG.

The primary advantage of Direct Pipe® for the installation of the conveyance pipeline is the ability to meet grade tolerances of plus or minus 1 inch over thousands of feet without the need for intermediate shafts. The primary disadvantage is the lack of direct experience with Direct Pipe® and project history within the United States and specifically with the Contractors who may be bidding this project.

As discussed above, Direct Pipe® was included in the original method comparison. However, at the time the feasibility study was completed, installed lengths were limited to approximately 1000 feet for pipes in the 24 to 36-inch diameter range. The method was initially eliminated, therefore, due to both the perceived need for intermediate shafts (removing one of the clear advantages of the method), as well as the concern that only one U.S. Contractor owned the equipment required to perform the installation.

3. SELECTION OF THE TRENCHLESS METHOD

Based on the analysis, HDD was selected as the most practical option for installation of the conveyance pipeline due to several factors including installable length without the need for intermediate shafts. The primary advantages of HDD for the installation of the conveyance pipeline are competitive cost, reasonable time to complete the work, and the proven status of the method for installation of similar lengths and diameters in the anticipated soil conditions. The primary disadvantage is grade control exceeding the tolerance of what is typically required for gravity pipelines. The use of HDD for installation of a gravity pipeline is fairly rare, especially in diameters larger than 12 inches. Bores with a grade of 1 to 2 percent have been successfully installed using conventional magnetic steering tools, but most have had depths of cover less than 30 feet. Since the HDD process uses multiple reaming passes to enlarge the bores, the invert of the bore has a tendency to decrease in elevation, or to “wallow out,” potentially leading to undesirable pipeline sags or reverse grades.

Grade risk issues for the conveyance pipeline are primarily due to the diameter of the pipeline and the depth of the installation. The pipeline will cross beneath Magnolia bluff at significant depths—up to 160 feet. This will make it more difficult to maintain the desired grade, because locating accuracy decreases with depth. Additionally, the pipeline diameter is large enough to require multiple reaming passes to achieve the final bore diameter. With each reamer pass, the grade of the pipeline has the potential to drop below the installation grade set with the pilot bore. If the HDD option is constructed, it will be critical to ensure that the bore is accurately tracked during the pilot bore and reaming passes, and during any re-drilling to correct adverse grades if necessary in order to ensure the necessary flow requirements of the pipeline are met.

4. GEOTECHNICAL EVALUATION FOR DESIGN

Once the initial feasibility study was completed, the pipeline alignments were refined to establish the appropriate plan and profile and a geotechnical investigation was planned to support the design of the pipeline. The topography of Magnolia bluff is extremely variable, resulting in inconsistent depths of cover over the proposed pipeline. Depths of cover range from 10 to 20 feet at 32nd Avenue West and beneath Smith Cove Park at the west and east ends of the proposed pipeline, to up to 160 feet beneath West Galer Street in the middle of the proposed pipeline. The steep hillsides above 32nd Avenue West and Smith Cove Park have experienced past slope instability, and historical landslide scarps are found throughout the project area, as well as remedial measures such as horizontal drains and retaining walls.

Over 11 borings were initially advanced to confirm the HDD design alternative, as shown on Figure 4. The borings have been advanced as part of a phased geotechnical investigation associated with the conveyance pipeline. The soils in the project area have been determined to be primarily glacial in origin, and generally consist of glacial till underlain by glacial outwash and glacial clay. Regardless of methodology, the conveyance pipeline alignment will pass through both glacial outwash, consisting of very dense, silty sand with trace gravel, and glacial clay, consisting of very stiff to hard sandy silt, clayey silt, and silty clay (Shannon & Wilson, 2009).

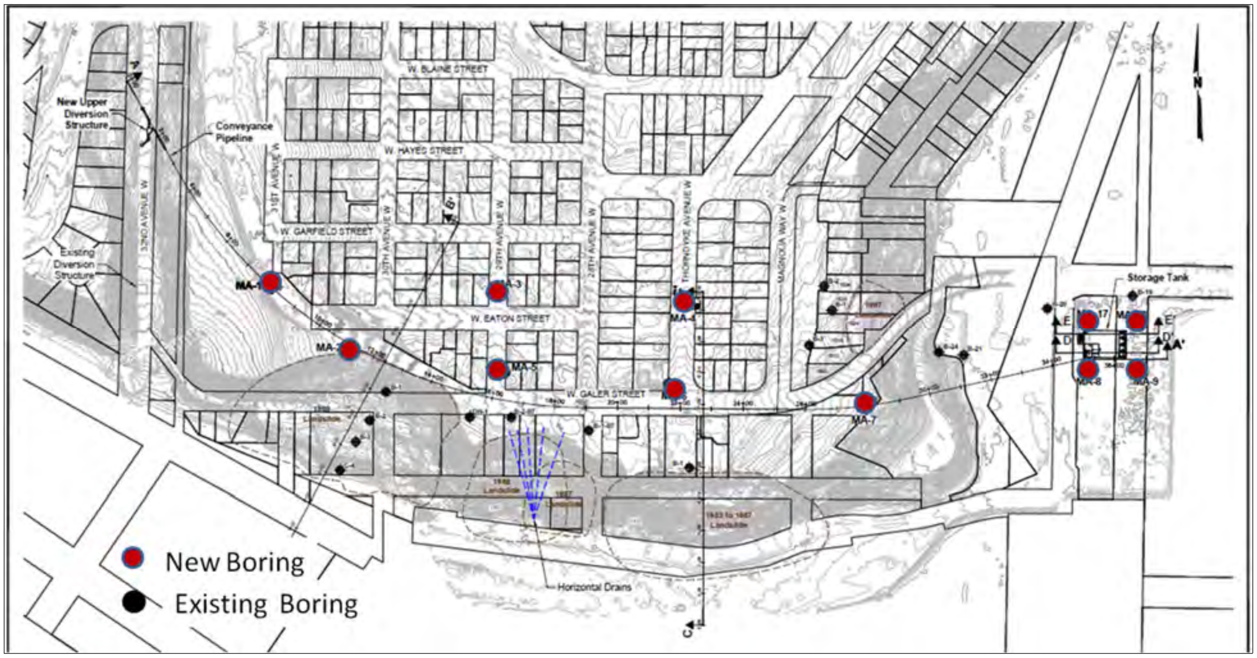

Figure 4. Geotechnical Investigations Along Alignment to Confirm HDD

5. PROGRESSION OF THE DESIGN

Once the trenchless method had been selected and the geotechnical conditions verified for constructability, a Basis of Design Report (BODR) was prepared detailing all of the project decisions, including the alignment, the tank location and configuration, the hydraulics, and the diversion structure modifications to allow HDD. King County then held a Value Engineering (VE) session to allow peer-review of the pre-design and to investigate creative ideas that might save project costs.

The VE team provided many suggestions for the project, validated the use of HDD for the conveyance pipeline, and suggested that the Design Team re-evaluate the use of Direct Pipe® for the installation of the conveyance pipeline. The primary project advantage was allowing construction of the pipeline to the existing diversion structure, rather than having to construct a new diversion structure, a significant construction cost savings. Use of the existing diversion structure is made possible by the capability of the Direct Pipe® method to install the pipeline at a 1% grade.

6. RE-EVALUATION OF A DIRECT PIPE® ALTERNATIVE

During the re-evaluation of Direct Pipe®, several of the original design assumptions were modified to allow its use. First, the pipeline had to be upsized to a minimum of a 48-inch diameter to allow the technology to install the necessary 2,600 feet of pipeline. The increased diameter is necessary to house booster pumps and a hydraulic motor and reservoir within the heading of the MTBM. It was also necessary to evaluate the global use of the technology. Direct Pipe® is a rapidly developing and expanding technology, and since the time of the initial feasibility study, had been used to install a 48-inch diameter casing approximately 4,600 feet in the Netherlands and a 56-inch casing approximately 2,800 feet in Great Britain. Additionally, Direct Pipe® equipment had been purchased by additional Contractors within the U.S. and was recently made available to rent directly from the manufacturer. These changes led the project team to include the use of Direct Pipe® for the installation of the conveyance pipeline. However, because of the relative newness of the method to the trenchless technology contracting community, it was difficult to estimate how many contractors would be qualified and available to bid the project.

Because of these concerns, it was decided to provide two alternatives for the bid. The two pipeline design options required separate designs for each of the two methodologies, primarily because of the different starting and end points. The HDD option will require the construction of a new diversion structure in 32nd Avenue West that will direct wet-weather flows through the new conveyance pipe to the proposed storage tank. The new diversion structure is necessary to provide 1.8% continuous grade over the 3,000-foot pipeline. Once the system is in operation, low flows up to about 1.5 million gallons per day (mgd) will pass through the upper diversion structure and be routed through the existing diversion structure to the South Magnolia Trunk Sewer. High flows will be directed to the new storage tank by way of the conveyance pipeline.

The Direct Pipe® option did not require a new diversion structure but could be built with only slight modifications to the existing diversion structure to send high flows down to the tank, with low flows still being directed through the South Magnolia Trunk Sewer.

7. TWO SEPARATE DESIGNS

The alignments corresponding to each of the two methods are shown in Figure 5. The two designs converge in Smith Cove Park (eastern side of the project area and right side of the figure), which is anticipated to be the entry location for both options. From this point, both options follow the same open-cut alignment across the park and beneath 23rd Avenue West to intersect the new storage tank located in the Port of Seattle West Yard. The storage tank itself will be constructed under separate contract.

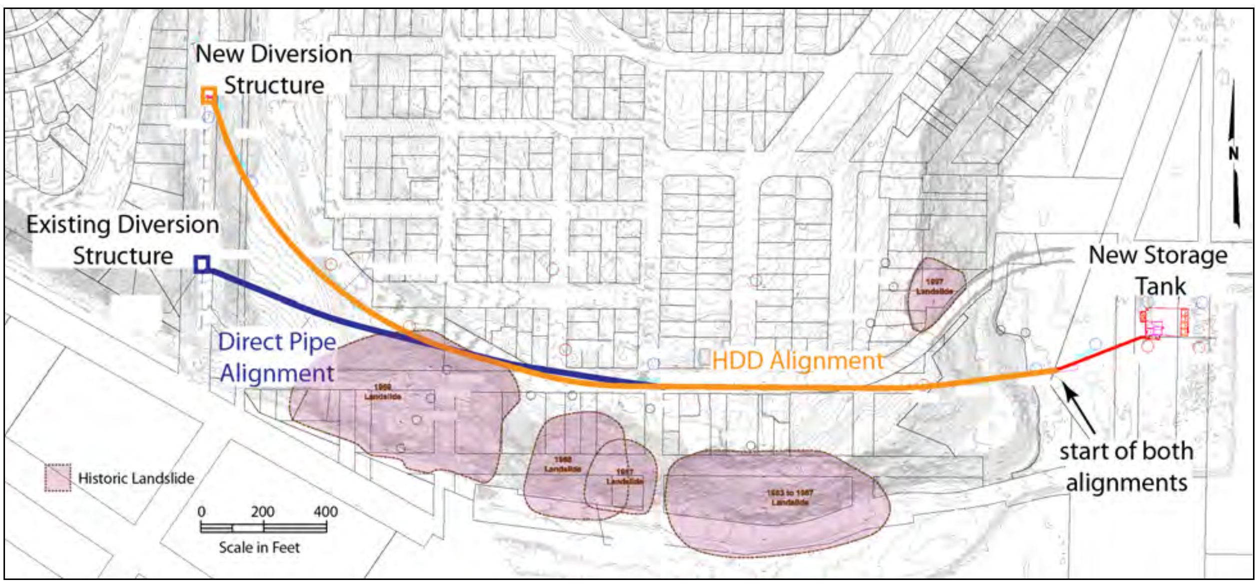

Figure 5. Direct Pipe ® and HDD Alignments

Details of each design are provided in Table 1.

Table 1. Design Details of the two installation options

	HDD	DIRECT PIPE®
Length	3,000 feet, as it travels all the way up to the elevation of the new diversion structure in order to obtain the maximum grade of 1.8%	2,750 feet, as it travels in a more direct fashion to the existing diversion structure
Grade	1.80%	0.90%
Bend Radius	Must curve on a 1,150-foot bend radius in order to stay out of private easements and allow pipe pullback on 32nd Ave W	Must curve on a minimum 4,800-foot bend radius to keep estimated jacking forces below reasonable levels
Diameter	The minimum flow diameter of 27.5 inches requires a 36-inch outside diameter pipe	A minimum 48-inch pipe is required due to both the length of the tunnel and the need for booster pumps and a hydraulic motor and reservoir within the heading of the MTBM.
Pipe Type	HDPE, due to the required bend radius	Steel, due to the installation method
Wall Thickness	DR 8.5 is required to withstand long-term loading resulting from 160 feet of cover	Minimum 1 inch due to estimated jacking forces

Because of the new alignment alternative, additional geotechnical investigation was performed and resulted in the cross section shown in Figure 6.

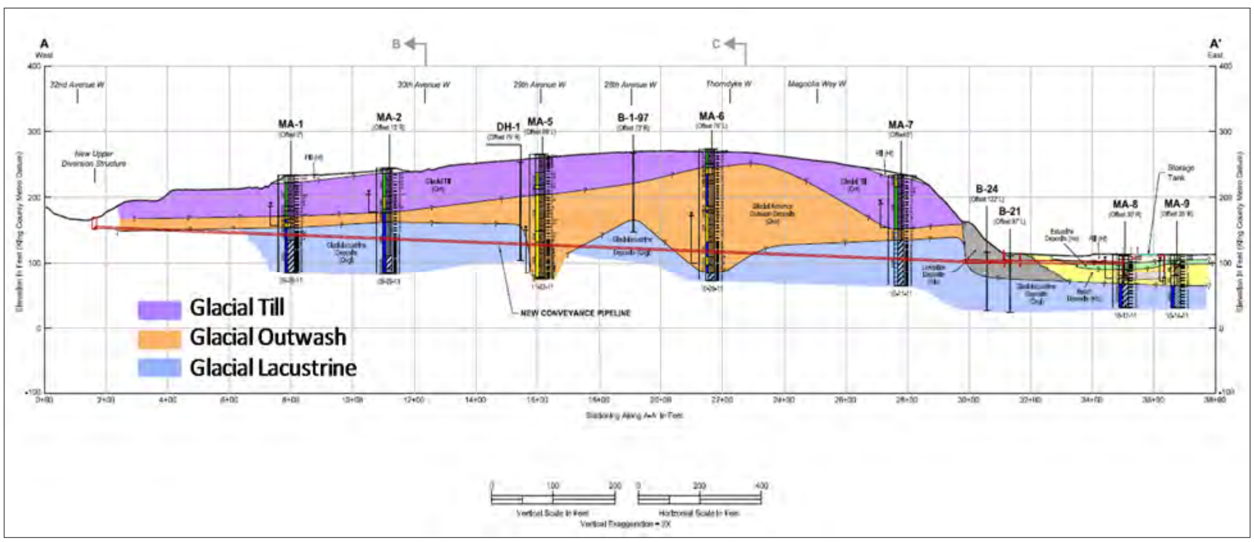

Figure 6. Cross Section showing Primary Soil Types

8. PROCUREMENT

Two bid options will be included in the contract, and will correspond to two complete sets of contract documents, including two full sets of plans and specifications. Contractor's qualifications will be based on the method for which they are proposing. For the HDD, this includes experience requirements on bores of similar length and diameter for the Contractor and key personnel. Qualifications for the Direct Pipe® method will focus on the Direct Pipe® experience of the key personnel.

The conveyance contract will be advertised in either the 3rd or 4th quarter of 2013. Regardless of method, all work on the project must be complete prior to the start of 2016.

9. REFERENCES

Carollo Engineers (2010) – South Magnolia CSO Facility Engineering Report.

Herrenknecht AG (2012) – Herrenknecht Direct Pipe®: One-Pass Trenchless Installation of Pipelines in All Geologies.

Shannon & Wilson, Inc. (2009) – Preliminary Geologic/Geotechnical Evaluation of Magnolia Combined Sewer Overflow (CSO) Alternatives, Seattle, Washington.

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