PACIFIC NORTHWEST CHAPTER NASTT

Pacific Northwest Trenchless Review

2015

Meeting Challenges, Achieving Success

Inside:

- Reinforced Concrete Jacking Pipe Lessons
- CSO Separation Project in a Landslide Area
- Details on the PNW Trenchless Symposium

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Pacific Northwest Trenchless Review

WINTER 2015

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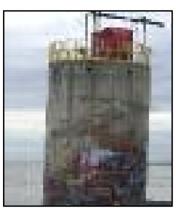

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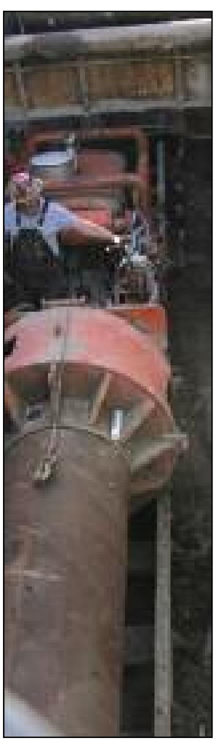

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Come to SeaTac for Our Symposium

Christopher Price - *Chair, NASTT PNW Chapter*

This has been an incredible year for trenchless technology. Challenging rehabilitation projects this year in the Pacific Northwest include large-upsize pipe bursting, unique pipe ram engulfment, and thousands of feet of CIPP installation. New installations have been world class, with horizontal directional drills ranging from an on-grade installation of 2,700 feet of 30-inch fusible PVC pipe to a 36-inch steel raw water pipeline bored 3,800 feet beneath the Willamette River in basalt rock with compressive strengths as high as 50,000 psi.

A local utility saw the successful implementation of a pilot project in Seattle to install over 20,000 feet of four-inch electrical conduit using both HDD and pilot tube installation methods; both were previously untried technologies for the utility owner.

In April, the 2014 No-Dig Show was a resounding success. Innovations in trenchless equipment, methods, and projects were highlighted with Orlando serving as an exciting backdrop. Our own Past Chair, Laura Wetter, received NASTT's Trent Ralston Young Trenchless Achievement Award. Laura was recognized at No-Dig for her valuable contributions to the trenchless technology industry. Her accomplishments are a direct result of steadfast dedication to excellence and service to our industry. My personal thanks yet again to Laura for her continued efforts as editor-in-chief of the Pacific Northwest Trenchless Review. Her commitment continues to make this publication an annual success.

As my tenure as Chair of the Pacific Northwest Chapter comes to a close, I take this opportunity to thank you all. I can honestly admit that serving the Chapter over the last five years has at times been very challenging but equally rewarding. My sincere thanks to colleagues that have supported my efforts and to the mentors that have helped guide me along the way. I know that with continued effort we will continue to grow the Pacific Northwest Chapter and promote education and innovation in trenchless technology. I look forward to continuing to work with the Chapter to promote the use of trenchless technology to meet challenging project requirements.

Without a doubt 2015 will prove to be another banner year for the Pacific Northwest Chapter. We are excited to welcome everyone to join us for our biennial Trenchless Symposium, February 4-5 in SeaTac. To register or for more information and to stay informed of current and upcoming events, please visit our website at www.pnwnastt.org. I look forward to seeing you at the 2015 Trenchless Symposium in SeaTac and also in Denver for the 2015 NoDig Show. Please feel free to contact me for more information at chris@stahelitrenchless.com or (425) 205-4930.

Regards,
Christopher Price
Chair, NASTT PNW Chapter

Big Plans for 2015 – See You in Denver!

Derek Potvin - *NASTT Chair*

It has been a great year for NASTT, and our record-breaking 2014 No-Dig Show held in Orlando, Florida, was definitely a major highlight. We had over 1,800 attendees, an excellent technical program and an exceptionally successful Educational Fund Auction, all thanks to our dedicated volunteer members including members of your Pacific Northwest chapter.

This year's 13th Annual Educational Fund Auction and Reception was a Pirates of the Caribbean-themed night of fun and fundraising. The auctions have to date raised over $750,000 for educational initiatives such as sponsoring students' attendance at NASTT's No-Dig Shows, awarding scholarships, publishing trenchless resources and providing targeted training courses to the membership at-large.

Plans for NASTT's 2015 No-Dig Show in Denver, March 15-19, are well under way. The technical program will have many valuable and informative presentations, and the exhibit hall will be full of new products and services to support the trenchless industry. We will also host our Good Practices training program, which includes seven different specialized full- and half-day courses.

The Pacific Northwest Chapter is home to several trenchless advocates who serve on our 2015 Program Committee including Dan Buonadonna, Jack Burnam, Steven Donovan, Kimberlie Staheli and Laura Wetter. The majority of these volunteers will also serve as 2015 session leaders. They are sure to bring you an excellent technical program.

Also, be sure to join us in Denver during No-Dig for NASTT's 14th Annual Educational Fund Auction and the 1980s ski-themed auction reception, 'Totally Rad Slopes'! The Auction Committee is working hard to offer you a fantastic event that is sure to raise thousands of dollars for a great cause. We're looking forward to showcasing our dedicated volunteer members when we convene in the Rocky Mountains!

We are also excited that your own Pacific Northwest member, Kimberlie Staheli, who currently serves as NASTT's Board of Directors Vice Chair, will be taking the helm in January as Chair. I am sure she will do a great job in this position as she continues to be a voice for the trenchless industry.

Again, I cannot thank our Pacific Northwest Chapter volunteers and members enough for your dedication and support. You are truly Trenchless Champions, and I look forward to seeing you in Denver next year.

Sincerely,
Derek Potvin
NASTT Chair & International Representative

The Biennial

Pacific Northwest Trenchless Symposium

Wednesday-Thursday, February 4-5, 2015

Cedarbrook Lodge, SeaTac, Washington

Presented by the

PACIFIC NORTHWEST CHAPTER NASTT

Registration options include an informative technical program, product/service exhibit area, and NASTT Rehabilitation Short Course.

All the benefits of a national conference with a convenient local setting!

The PNW Trenchless Symposium and Trenchless Rehabilitation Short Course

NASTT Rehabilitation Trenchless Technology Short Course - Wednesday February 4, 2015

The Introduction to Trenchless Rehabilitation Technologies Short Course addresses trenchless methods commonly used to rehabilitate existing pipelines. The course covers initial assesment, project planning, and rehbilitation methods for watermains and sewer. These methods include: (1) lining technologies (cement mortar, polymer, CIPP, etc.); (2) sliplining; (3) pipe bursting; (4) pipe reaming; and (5) lateral and manhole repairs and lining. The course will consist of a 4-hour morning breadth session with an in depth session after lunch. Examples and case studies will be presented to assist attendees in determining which method is preferable to use under various project conditions and requirements.

Course Includes:

- The limitations and advantages of each method discussed
- Assesment techniques for existing pipelines
- Inspection of water and sewer pieplines including manholes and laterals
- Cement Mortar Lining, Polymer Lining, CIPP Lining, Internal Joint Seals, Fiber Reinforced Polymers
- Sliplining, Pipe Bursting and Pipe Reaming
- Continuing Education Units (CEUs) for all participants

PNW Trenchless Symposium - Thursday February 5, 2015

A full day of presentations detailing local trenchless highlights in construction, design, and academic research. An exhibit hall will showcase current trenchless industry innovations in equipment and materials.

Planned topics include:

- Pipe Bursting case history
- Microtunneling case history
- HDD construction case history
- and case histories on other trenchless methods

Prices:

Short Course only	$300
Symposium only	$200
Short Course + Symposium	$500
Exhibitors*	$500

*includes 8'x10' space with table and power supply, registration for the symposium for one person and company recognition in the program

Register Online At:

www.regonline.com/2015pnwnasttsymposium

For all questions please contact Chris Sivesind at csivesind@akkerman.com (507.440.6473) or Christopher Price at chris@stahelitrenchless.com (425.205.4930)

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Coming Events

February 4-5, 2015

PNW Trenchless Symposium and NASTT's Trenchless Technology Short Course - Rehabilitation
Cedarbrook Lodge
SeaTac, Washington
Information:
www.pnwnastt.org

February 12, 2015

NASTT's Laterals Good Practices Course
Surrey, British Columbia
Information:
mhill@nastt.org

March 15, 2015

NASTT's Trenchless Technology Short Course – New Installation
Colorado Convention Center
Denver, Colorado
Information:
www.nastt.org

March 15, 2015

NASTT's Trenchless Technology Short Course – Rehabilitation
Colorado Convention Center
Denver, Colorado
Information:
www.nastt.org

March 15-19, 2015

NASTT's 2015 No-Dig Show
Colorado Convention Center
Denver, Colorado
Information: www.nodigshow.com

March 18 & 19, 2015

NASTT's Pipe Bursting Good Practices Course
Colorado Convention Center
Denver, Colorado
Information:
www.nastt.org

March 18 & 19, 2015

NASTT's New Installation Methods Good Practices
Colorado Convention Center
Denver, Colorado
Information:
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March 18 & 19, 2015

NASTT's HDD Good Practices Guidelines Course
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Denver, Colorado
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www.nastt.org

March 18 & 19, 2015

NASTT's Cured-In-Place Pipe Good Practices Course
Colorado Convention Center
Denver, Colorado
Information: www.nastt.org

March 18 & 19, 2015

NASTT's Laterals Good Practices Course
Colorado Convention Center
Denver, Colorado
Information:
www.nastt.org

Reinforced Concrete Jacking Pipe: Lessons Learned

Mark W. Hutchinson, P.E.
Bureau of Environmental Services, Portland

Over the past 20 years the City of Portland, Oregon, has experienced a few challenges with concrete jacking pipe. This has led us to implement fairly stringent specifications, rules of thumb for design, contractor submittal, and in-plant and on-site inspection of our pipe.

In the beginning we left the details of the pipe specifications and design mostly to ASTM C-76 and the local pipe supplier. This resulted in pipe that was the minimum that the pipe plant could build for the price they bid and the machinery they had on site. Details regarding pipe manufacturing were not ironed out until after a review of the submittals was received and during plant inspections. We found that the pipe that showed up at the construction site was not always the pipe we needed. We also found that when pipe was damaged during installation it was hard to determine whether the damage was due to pipe design, contractor practices, project design or unforeseen ground conditions. This led us to look at the risk and where we needed to require minimum standards for reinforced concrete jacking pipe, plant inspections and protocols during construction.

DESIGN CONSIDERATIONS

Good pipe performance follows design decisions based on risks associated with installation. The City cannot afford the strongest pipe all the time, but we have learned the hard way to look at risks and the costs associated with those risks upfront for the least overall project cost. Pipe failures on our projects have resulted in rejection of as much as 20 percent of the pipe made, excavations and repairs ranging from $40,000 to $100,000, or months in project delay awaiting resolution.

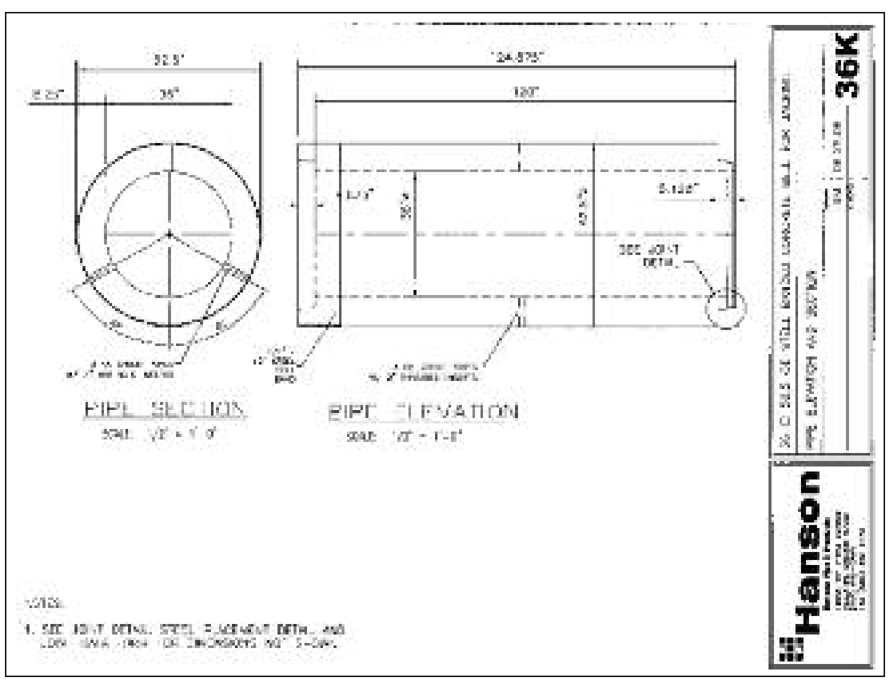


Figure 1. Concrete Jacking Pipe Components

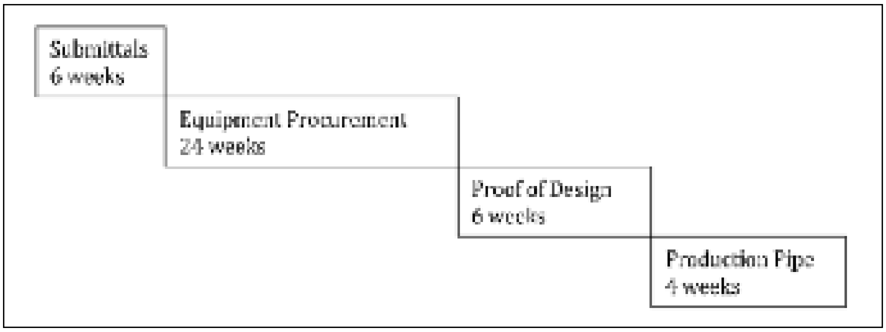


Figure 2. Pipe Production Schedule

On City of Portland contracts, the contractor is responsible for the design of the pipe; however, the latitude for that design is based on risks of the project. Projects with larger risks require more detailed specification requirements and pipe plant inspection. The risks are weighed against the corresponding ramifications of pipe failure, the cost, and likelihood of the incident.

Following the risk analysis and discussion, a pipe design memoranda is developed that discusses:

- Pipe requirements – diameter, ground pressure, internal pressures, external water pressures, jacking loads, soil loads, corrosion from flow inside (H2S attack), or contaminated soils on the exterior.
- A comparison of pipe materials considered – strength, joint type, expected pipe life, cost, risk of failure, and manufacturing schedule.
- A recommendation for the project that can be revisited later if substitutions are proposed by the contractor.

We have found it is also wise to discuss the schedule with the local pipe manufacturer which could include purchasing new pipe or making equipment and changes to their facility to make the pipe. Making the phone calls ahead has allowed the design team to understand the challenges with project schedule, cost and pipe availability. Overall project schedule can be affected by pipe design, procurement of forms, testing and production as discussed later. Figure 2 depicts a schedule for production of 2,000 feet of jacking pipe for a microtunnel project.

We have learned that it is wise to specify minimums in the contract documents for pipe diameter, bell and spigot design, reinforcing, submittal requirements, and testing and quality control standards.

Pipe diameter is largely a matter of hydraulics and flow-carrying capability, and economics or money. Hydraulics is pretty straightforward, but the economics of pipe involves two things worth mentioning. First, at times larger pipe diameter is chosen to match larger pipe jacking equipment with more power, ability to process larger rock, or the need for face access. We find that discussions with a good trenchless engineering firm and pipe jacking contractors at the earlier stages of design will help in understanding the capabilities of equipment available. The second situation comes to play when multiple pipe jacks are needed of different diameters due to hydraulics. At times it has been cheaper and quicker to choose one size of pipe. For instance if hydraulics dictates a need for 4,000 feet of 84-inch-diameter pipe, and 400-feet of 72-inch-diameter pipe on the same proj-

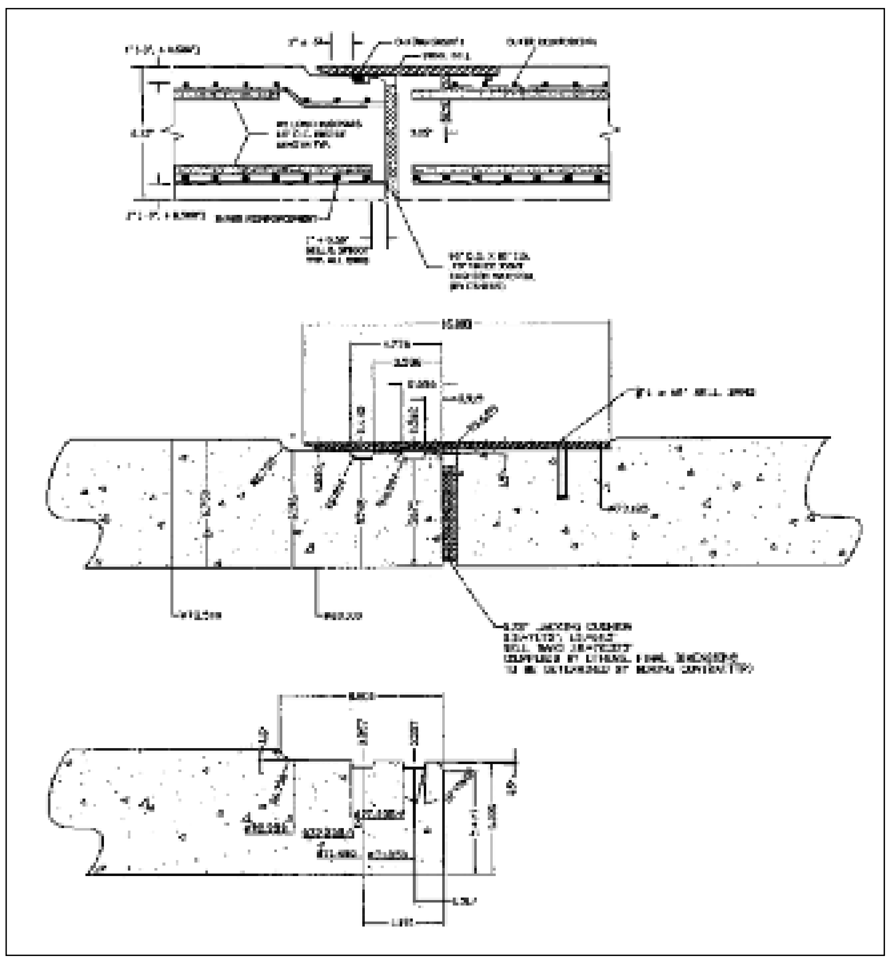


Figure 3. (Top) Steel bell, concrete spigot confied "O" ring joint. (Bottom) Steel bell, concrete spigot double gasket joint.

Figure 4. Looking inside an 84-inch pipe jack

ect, it might work out to settle on only 84-inch jacking pipe. This decision is best made after receiving cost and schedule estimates from the pipe manufacturer.

The joint design is a key component of the pipe's ability to transfer jacking loads and seal water in or out of the pipe. We have used four types of joint designs, and prefer the steel bell single and double gasket and concrete spigot pipe (Figure 3). We prefer the steel belled pipe because we experience fewer problems with bell and spigot failures during jacking. As you can see from the pictures, the steel bell joint configuration allows for better transfer of load from the spigot of one pipe to the pipe wall of the next. This is important when excessive loads are placed on the pipe due to deviation from alignment, which create eccentric loads, or when large loads are required when grinding through large rock, or excessive jacking loads due to pipe-soil friction issues.

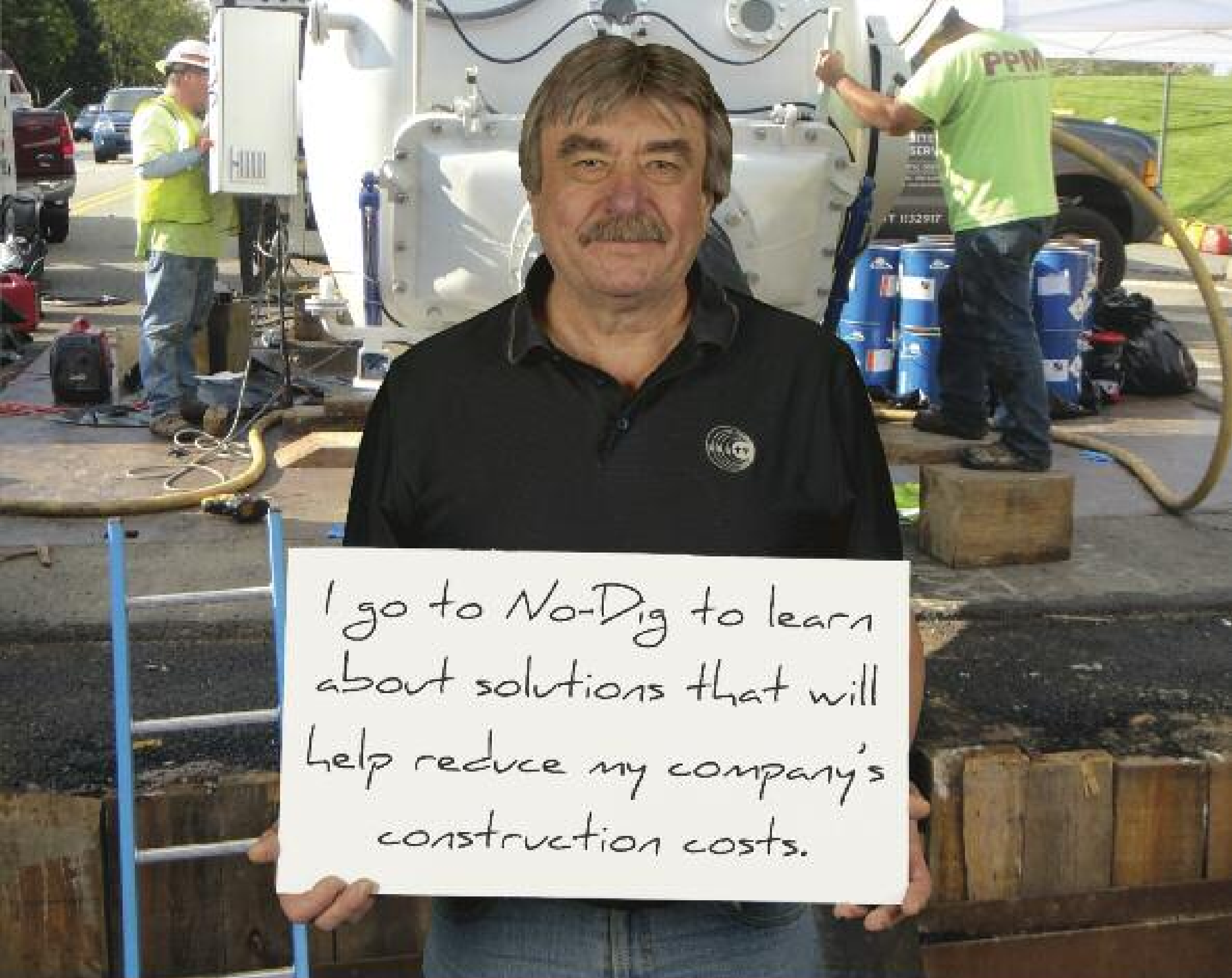
Pipe-reinforcing design and pipe-loading calculations are not part of this article. The reader should refer to ASCE Standard of Practice 27 and ASTM C-76. The City of Portland does require minimum reinforcing into the bells and spigots of the pipe to prevent damage, minimum longitudinal steel to reduce circumferential cracking, minimum cover, and steel placement tolerances. These requirements are referenced in the City of Portland Manufacturing Standards for Precast Concrete Products.

The City of Portland has found that good design and submittals have to be accompanied by full-time inspectors at the pipe plant to verify submittal requirements and detect defects early in the process. We have found that active inspection saves time as well as guarantee a quality pipe.

CONSTRUCTION CONSIDERATIONS

During construction, the pipe production is a critical path item and needs early attention. We have found on most large projects it's a race between building the shafts, getting the pipe, and getting the microtunnel boring machine or jacking equipment. Too often the attention is spent on shaft submittals or jacking machinery submittals and the schedule is dictated by pipe production with no float in the schedule for problems in the pipe production. This can result in pressure to accept lower quality pipe.

In theory, proof of design testing is completed and pipe production begins after the tests pass. Unfortunately that is not normally what we see. Typically the first pipe manufactured has issues with reinforcing steel layout, clearances, conflicts between grout ports and steel bands. The first pipe cast will often have rock pockets or damage during casting and form removal before the technique is perfected.



NASTT's 2015 No-Dig Show

March 15-19

Colorado Convention Center - Denver, Colorado

- Technical Papers
- Industry Exhibits
- Innovations
- Networking Events

NASTT's No-Dig Show offers a first-rate educational program that rivals no other! Ask George Ragula, No-Dig is his go-to show for a comprehensive technical program, knowledgeable people always willing to share trenchless experiences and exposure to cutting edge technologies that all help provide him with technical solutions to reduce his company's construction costs. Attend the educational sessions at NASTT's 2015 No-Dig Show and find cost-saving solutions for your company!

Pictured above: George Ragula, Distribution Technology Manager, Public Service Electric & Gas (PSE&G), Newark, NJ

Mark your calendar and make your plans to attend NASTT's 2015 No-Dig Show in Denver, Colorado.

nodigshow.com

On one project where we used dry cast pipe, a change from fly ash to slag created havoc with pipe form stripping and many rejected pipe. On another project the production was sped up and a substantial amount of the pipe had to be ground to meet squareness tolerances, delaying pipe jacking. On another dry cast project, spigots would separate from the pipe barrel when stripped too soon. Having an in-plant inspection allowed these issues to be resolved and remedied during pipe production.

The City of Portland has an inspector at the pipe plant when the pipe is in production. Each pipe is given a unique identification number and has a data sheet on which the dimensions are recorded. Developing a tracking sheet for each pipe will help keep reject pipe from inadvertently entering the pipe jacking string.

Once pipe has cleared quality control at the pipe plant, the inspector at the site and contractor receive a list of pipe that is approved for installation. When pipe arrives on site and is still on the truck, it is checked against the list before off-loading onto the site. Prior to pipe jacking in the shaft the pipe gasket area is inspected one more time before jacking. The contractor or on-site inspector also updates the lay diagram with the pipe identification numbers as pipe is jacked into place when they number the inside of the pipe. This comes in handy later when issues arise with the pipe, to help sort out the source of the issue. For instance, if a pipe spigot was patched at the factory and later that joint was leaking, changes could be made to the repair procedure.

Inspection of the pipe during jacking is important but not easily done. Access to the pipe jacking operation is controlled by the contractor. Inside the pipe are augers, other pipes, hoses, and confined space safety issues to be dealt with before entering the pipe string during jacking. That said, the contractor has down time when the pipe can be inspected. Adding language to the specifications to provide contractor support for pipe checks at an interval where production is not impeded allows for inspection and corrections to be made before the entire pipe line is complete. If abnormally high jacking loads or grade deviations are witnessed, this is also a good time to observe how the pipe is handling this stress.

The focus of inspection of the pipe during pipe jacking is to find cracks and leaks. If the leaking or cracked pipe is found before the pipe jack is complete the damaged pipe can be jacked out the receiving shaft.

Once the pipe is in place it is checked for leakage and air tested, then the annual space outside the pipe is grouted, the intermediate jacking stations are patched. Joints that fail air testing and pipe that is leaking that weren't jacked out are then repaired.

LEGAL ASPECTS OF JACKING PIPE

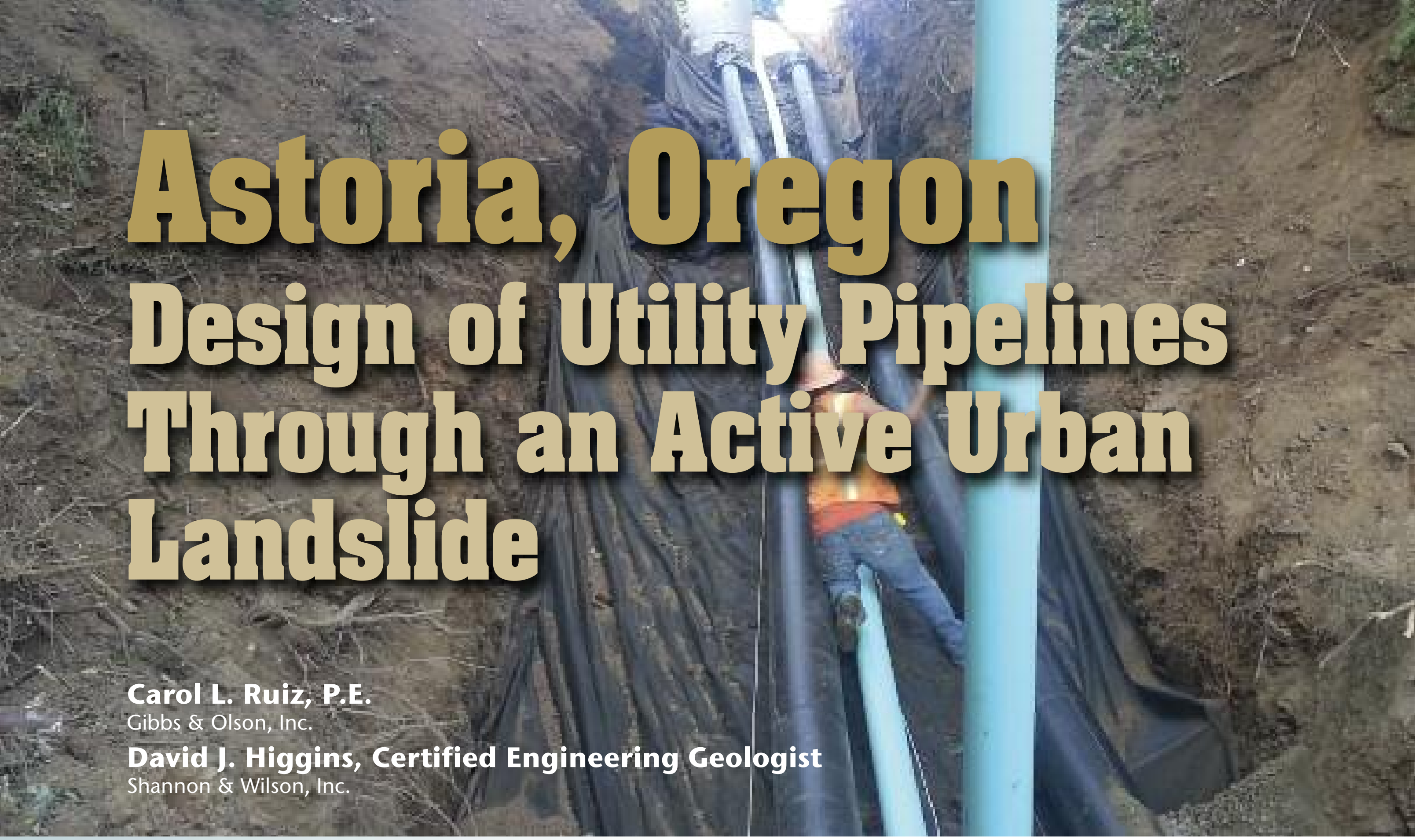
There are many things you cannot control when pipe jacking, the soils you jack through, the Contractors you hire will come with the workman, equipment and skill they have, but through up front planning and inspection during manufacturing you can rule out the pipe as a significant variable. Inevitably the day will come when as an owner you will be walking or crawling inside a newly jacked concrete pipe measuring cracks with your trusty 0.01 inch feeler gauge with the design engineer, pipe manufacturer, and Contractor measuring cracks, and looking at leaking joints. Later in a meeting the pipe manufacturer and Contractor will say to you that the pipe is cracked because they ran into ground or obstructions outside the pipe that no one can see. In a separate meeting that you probably weren't invited to, the Contractor will be telling the pipe manufacturer that the pipe was not built square enough, or strong enough. At this same meeting the manufacture will be telling the Contractor that they did not use the pipe as it was intended, or that the cuts they made in the quality so that they could make the pipe for the price agreed to, resulted in the issues on your project. You could find yourself in another meeting where the design engineer tells you that the design was fine but that the broken pipe is because the pipe manufacture did not follow the requirements of the specifications, which you have no idea of whether they did or they did not without good design criteria and inspection.

These are all examples of the challenge of too little consideration of jacking pipe. If attention is paid in the design phase to the risks the pipe faces then proper specifications and contract documents can be developed. If the pipe is inspected and documented during production at the pipe plant, the question of manufacture error can be known and eliminated. If the pipe is tracked, jacking loads are documented and the pipe is periodically checked the Contractor's means and methods can be verified against the ground you own and the design you bought. This will not eliminate challenges or claims but will make resolution of those issues easier.

REFERENCES

ASCE, (2000)-ASCE 27-00 Standard Practice for Direct Design of Precast Concrete Pipe for Jacking In Trenchless Construction

City of Portland, Bureau of Environmental Services, Engineering Group, Construction Services, Material Testing Lab,(January 2006) Manufacturing Standards for Precast Concrete Products



Astoria, Oregon

Design of Utility Pipelines Through an Active Urban Landslide

Carol L. Ruiz, P.E.
Gibbs & Olson, Inc.
David J. Higgins, Certified Engineering Geologist
Shannon & Wilson, Inc.

The City of Astoria's $6-million 11th Street Combined Sewer Overflow (CSO) Separation Project is the latest in a series of projects intended to reduce the number of untreated combined storm and sanitary sewer system overflows into the Columbia River. This project replaced the previous combined sewer collection and conveyance system consisting primarily of 12- to 30-inch terracotta pipe with areas of corrugated metal and PVC pipe. Many sections of pipe were sheared or crushed due to landslide movement, causing cavities to form adjacent to the pipelines and below sections of roadway. The pipe breaks and cavities allowed surface water inflow and groundwater infiltration into the collection system, contributing to more frequent overflow events. Some of the cast iron waterlines were also known to repeatedly experience localized failures.

The new stormwater conveyance system bypasses the sanitary interceptor and discharges non-commingled stormwater directly to the Columbia River through five separate outfalls. The project included 12,600 feet of storm sewer, 1,500 feet of sanitary sewer, and 4,900 feet of water pipelines. A previously abandoned outfall at the end of Ninth Street was rehabilitated using trenchless pipebursting construction and is now active as one of these five outfalls. The bursting portion of the project replaced 370 feet of 24-inch clay pipe with 28-inch HDPE in a single run.

Although entirely within an urban residential area, the project site posed unique challenges, including routing buried pipelines through two large, active landslides; extreme slopes of up to 28 percent;

Clay pipe was replaced with HDPE pipe.

shallow groundwater; and groundwater springs surfacing through pavement cracks. Comprehensive risk assessment and management of these challenges was achieved during the planning and design phase of the project. Detailed geologic evaluations and special pipeline design elements, including careful selection of pipeline materials, were part of the assessment.

The City's stated objective was not to fix landslides, but to accommodate earth movements and increase stability to the degree practical while taking care not to exacerbate the landslides. The replacement pipeline and roadway design was based on sound geotechnical modeling, followed by the selection of deformation-tolerant pipe and flexible connection fittings that were strategically placed to address the identified challenges where tension and compression zones exist.

The design was intended to enhance groundwater collection and drainage to reduce the rate of creeping ground movements, to the degree practical, and decrease the volume of inflow and infiltration (I&I) into area pipelines. The city was provided with a high-performing system that achieved these goals, while also accommodating for ground movement over a long service life, and reducing untreated storm and sanitary system overflows into the Columbia River. Additionally, inflow to the city's wastewater treatment plant was significantly reduced.

History and Background

Astoria is located in the northwest corner of Oregon near the mouth of the Columbia River. The city's annual rainfall is about 67 inches per year. The largest single day's rainfall on record is 7.2 inches, which happened on October 31, 1942. The city has also seen monthly rainfalls of 51.4 inches in December 1933 and 38.6 inches in January 2006.

Residential neighborhoods are constructed on a steep, north-facing hillside overlooking the Columbia River and the downtown commercial district that sits on the flat southern riverbank. Much of the residential hillside is encompassed by a massive ancient landslide complex that includes dozens of individual landslide blocks. Landslide hazards are a well-known issue for the city, and extensive studies and mapping have been conducted over the last couple decades to identify specific hazard areas. Creeping earth movements have occurred throughout Astoria's history; residents and city managers have learned to live with these movements, tolerating occasional utility breaks and cracking pavements, walls, and foundations, and making repairs and replacements when needed.

The activity within individual landslide blocks differs, ranging from inactive to several inches of creeping movement a year. Occasional catastrophic failures occur within portions of individual landslide blocks, causing severe damage to residences, city streets, and utilities. Most landslide blocks experience creeping movements of varying rates and directions, with differential movements occurring at the interface between individual slide masses.

Creeping earth movements crack pavements and other infrastructure in Astoria.

Pipeline Design

Data from the geotechnical exploration and instrumentation program was used to provide understanding of anticipated future landslide movements, as well as their orientation, groundwater characterization and location of springs, was used to develop an approach to the pipeline design and the locations of flexible fittings, cutoff walls, trench drains, and interceptor drains, including the final selection of three different pipeline materials and the placement of equipment.

The new sanitary sewer and stormwater drain pipelines use high-density polyethylene (HDPE) within active landslide limits, including areas of slight, moderate, and severe ground deformation. In all other areas of the project, new sewer and storm pipelines use PVC pipe. New water pipelines in areas of severe ground deformation are also HDPE. Water pipes in all other areas use ductile iron pipe with restrained joints, which is more resistant to ground movement than the previous cast iron water pipelines. The HDPE pipe used in the most active landslide areas is flexible and provides a continuous low-friction surface area with smooth fused joints, which reduces strain and accommodates creeping ground movements.

At locations with severe ground deformation, expansion/contraction fittings and EBAA Iron FLEX-TEND sleeves were incorporated into the new water, storm sewer, and sanitary sewer pipelines, allowing for up to eight inches of movement at each location. Although these fittings are expensive — an increase in the project's capital cost by approximately three percent — they were determined to be cost-effective because they increase pipeline longevity and will reduce maintenance costs over the next 20 to 30 years.

The flexible joints were installed on both the storm sewer and sanitary sewer pipes at three locations on Eighth Street. The locations of the flexible joints are shown in Figure 1. The first area, north of Harrison Avenue, is at the edge of the severe deformation zone and is in both tension and compression. The second area, mid-block between Franklin and Grand avenues, is an intermediate location where ground stress transitions from tension to compression. The third location, along Eighth Street, is mid-block between Franklin and Exchange avenues and is the lower end of the compression zone at the base of the hillside.

The area of the severe ground deformation zone encompasses only the very edge of Ninth Street, between Franklin and Grand avenues. However, Ninth Street does not connect Franklin and Grand avenues due to extreme slopes. Because this area was to remain as a steeply sloped earth section, a flexible joint was installed on both the storm sewer and sanitary sewer pipes mid-block between Franklin and Grand.

The area on 10th Street between Franklin and Grand was identified as a severe ground deformation zone because it interfaces two converging landslides with different directions and movement rates. Flexible joints were installed on the storm sewer pipe uphill from Grand Avenue, which is on the edge of the severe zone; and midway between Franklin Avenue and Exchange Street, at the up-slope limits of the converging landslide masses. Both of the areas are likely to experience continued earth movement over time from tension, compressive, and translational forces; the flexible joints can accommodate movements associated with all these forces.

The final area of severe ground deformation is on 12th Street, from mid-block north to mid-block south of Harrison Avenue. The area between Harrison and Grand is atop a steep embankment at the toe of a landslide that is primarily in tension, and flexible joints were installed on both the storm sewer and sanitary sewer pipes to accommodate the earth movement. The area between Harrison and Irving avenues is identified as on the edge of the severe deformation zone; it is the interface between slower and faster moving land movements.

In addition to fusion-welded HDPE pipe, Kor-N-Seal flexible rubber boot connections were used at storm and sanitary sewer manhole structure connections to provide additional system flexibility. Where manholes where installed in the moderate to severe land deformation areas, the pipe was extended into the manhole six inches in both the upstream and downstream location, allowing for additional pipe movement in and out of the manhole structure and preventing the pipe and manhole connections from separating or compressing.

Groundwater Drainage

High groundwater in the project area decreases landslide stability, exacerbates earth movements, and increases the risk of

Figure 1. Pipeline Infrastructure Map

Construction of cutoff wall and perforated pipe laterals for interceptor drain

groundwater infiltration into the sanitary sewer pipelines. Thus, a permanent groundwater collection system was an important project component to ensure the newly installed pipelines are not affected by the intrusion of water into the trench section. The system also reduces premature deterioration of the roadway sections and lowers groundwater levels.

Groundwater has a tendency to collect and travel downstream along the crushed rock trench backfill and pipe zone bedding, essentially causing the pipe trench to act as an under-drain. This collection and movement of groundwater in the pipe bedding and backfill can compromise the integrity of buried facilities and potentially cause roadway failure and sinkholes.

In areas where seepage or springs were identified, two methods were incorporated into the design to collect groundwater: trench cutoff walls with slotted under-drains, and strategic placement of interceptor drains at spring locations, both of which convey detained water to the drainage system.

Perpendicular trench cutoff walls were constructed on the downstream end of the trenches with control density fill (CDF) poured 12 inches thick and six inches wider and deeper than the overall trench dimensions. Groundwater infiltrating into the trench backfill is blocked by the CDF cutoff walls, collected in slotted under-drains, positioned just upstream of the trench cutoff wall, and conveyed into the next downstream storm drainage structure. This required the new storm drain system to be constructed below the depth of the under-drain/interceptor pipe. Linear trench under-drains run parallel to the storm drainage pipelines at locations where shallow groundwater was encountered in explorations and where I&I was observed in the pipeline documentation videos.

Conclusion

The 11th Street CSO Separation Project was designed to meet — and in some cases surpass — the City of Astoria's goals in a challenging project area of landslide movement. The project physically separated the stormwater from the sanitary sewer system in the project area and as a result, by discharging stormwater directly into the Columbia River and reducing groundwater inflow to the sanitary sewer, significantly reduced flow to the wastewater treatment facility. Permanent drainage helps control groundwater in the project area and reduces seepage, which will improve landslide stability. The selected pipeline materials and flexible fittings and boot connections increase pipeline durability and accommodate continued creeping ground movement. These measures provide the City with a longer useful pipeline service life.

Ocean Wastewater Outfall Infrastructures Need Love, Too:

Strategies to Perform a Successful Assessment Program

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Ocean outfalls are essentially large, buried pipelines or tunnels that transport treated wastewater to a submarine discharge point from several hundred feet to as much as several miles offshore. Submarine outfalls are common throughout the world. This paper discusses three outfall inspection programs (summarized in Table 1) that are uniquely different but share common challenges.

Anchorage Outfall

A. Background and General Project Description:

The purpose of this project was to provide an accurate condition assessment of the ocean outfall system for the Anchorage Water & Wastewater Utility (AWWU) and provide recommendations for future management of this very critical asset that extends approximately 900 feet into the waters of the Kinik Arm of Cook Inlet. The shortness of this outfall is due to very high tidally influenced velocities and mixing zones close to the shoreline in the receiving waters. The inspection work was completed using a combination of rugged robotic transporters, closed-circuit television (CCTV) and sonar technologies designed for large pipelines.

B. Inspection and Results:

The outfall asset is divided into three components. The first is the land portion that extends from the Asplund WWTF to the Beach Tower, passing through a sampling/dechlorination station. The second is the ocean portion that extends from the Beach Tower to the diffuser structure. The third is a bypass outfall from the WWTF to the Beach Tower (this bypass was the original on-land outfall extending to the Beach Tower which was put into secondary service once the new on-land outfall was completed). Access to the Beach Tower required rebuilding the existing access road that is severely damaged each year by shifting ice during the spring breakup.

All work was timed around low-low tide that occurs in early June (35-feet tidal fluctuation between high and low) to allow as much of the outfall to dewater as possible. It is the second largest tide change in the world, thus creating an enormous challenge to access the outfall through the Beach Tower, inspect, and exit the site before the incoming tide surrounded the tower again. Flow

Outfall Location	Diameter	Total Length	Pipe Material	General Comments
Anchorage	84"–120"	900'	RCP	25%/75% land/ocean
Honolulu	84"	19,700'	RCP	46%/54% land/ocean
Port Townsend	18"-20"	840'	HDPE/CIP	Only offshore outfall inspected

Table 1. Summary of Outfall Infrastructures

from the WWTF was temporarily redirected to two empty clarifiers in order to conduct the inspection work. A fork lift was used to lift the CCTV equipment to the top of the 35-foot Beach Tower as the tide receded, and crews were lowered into the structure on the downstream side of this weir structure in order to deploy the transport platform and execute the inspection. All inspection work needed to be completed within a strict 1.5-hour window to prevent an overflow at the WWTP.

Inspections were video recorded as the CCTV platform traveled down the pipe segment. An interesting note is that because there was only one access to the outfall both launch and retrieval had to occur at the Beach Tower. Great care was required to prevent the extended cable from fouling around the CCTV as pull back was occurring.

C. Recording and Quantifying the Inspection Data:

The observations were recorded into an electronic database using the required CUES GraniteXP© NASSCO PACP defect codes. The results of the inspections were presented and analyzed conceptually by displaying the type and category of defects observed. Irregular textures and mottling were observed along the pipe alignment, but no actual pipe wall loss or serious corrosion was observed

Settled sediments along the pipe floor of the bypass outfall from the WWTF to the Beach Tower impeded the forward movement of the CCTV camera during the upstream reversal inspection and the inspection had to be abandoned.

D. Outcome and Recommendations:

- The small cracks and surface texturing visible in parts of the system did not appear to indicate a larger structural issue or deficiency of the pipes.
- Maintenance-related defects such as debris and obstacles were also minor and appeared to be isolated instances.
- Sediment levels observed were within reason and did not appear to impact hydraulic performance.
- According to the American Society of Civil Engineers and the United States Environmental Protection Agency, the average inspection frequency for sewers is every 15 years. (1) In comparison, the Water Environment Federation recommends inspection every 5-8 years. (2) It is recommended that a median value from these resources be selected, and that the AWWU outfall system be placed on a 10-year inspection cycle to monitor the performance and structural condition of each of the pipeline sections.

A beach tower was the staging area for CCTV inspection of an ocean outfall for the AWWU.

Honolulu Outfall

A. Background and General Project Plan Description:

The City and County of Honolulu (CCH) operates and maintains an ocean outfall at their Honouliuli WWTP. Because of its age and function, a condition assessment of the entire outfall infrastructure is required as part of an asset management program.

The outfall is an 84-inch pipeline that consists of: the “land portion” (approximately 9,100 feet) that extends from the WWTP downstream to a buried structure at the beach; and the “ocean portion” (10,600 feet) that extends from the beach into the ocean, terminating at a diffuser structure and access gate at a discharge depth of approximately 200 feet below water surface.

There are a number of access or manhole structures located along the entire alignment of the outfall (in both the land and ocean portions).

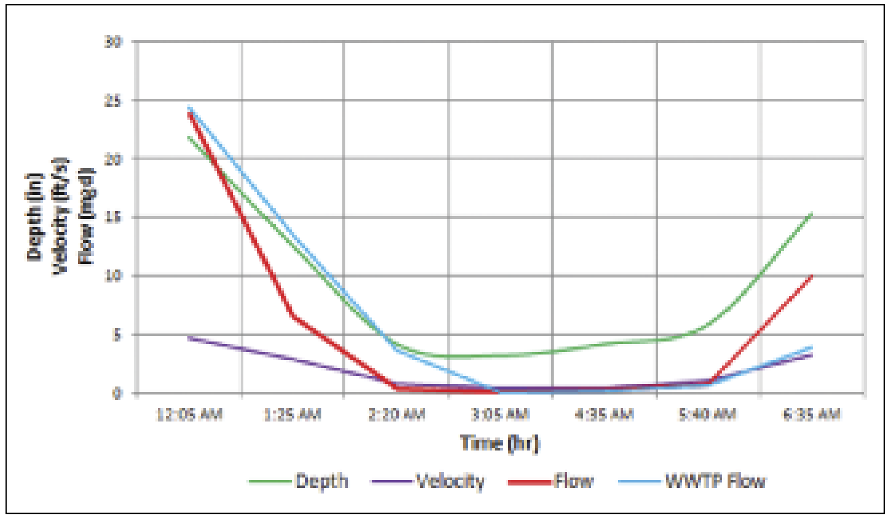
B. Pre-Inspection and Results:

The first action in the process of implementing this assessment was the decision to conduct a dry run as an important preparation step prior to the full inspection and assessment. The purpose of the dry run was to reduce the uncertainties regarding coordination, improve efficiencies during the actual inspection phase, and provide the inspection team with a reliable estimate for flow shutdown time.

The planning stage for the dry run included the following activities:

- Locate, expose, and evaluate selected manhole structure tops to determine accessibility issues.
- Complete temporary access coordination with property owners.
- Evaluate and implement safety protocols required for the full inspection.
- Coordination meetings with all project stakeholders.

Flow data from the dry run during WWTP shutdown and flow diversion show how both depths and velocities drop dramatically, allowing for a potential four-hour window to conduct the actual inspection work.



Results of Flow Conditions Following Honouliuli WWTP Shutdown

The pre-inspection work included using a pole-mounted CCTV unit that allowed the inspection team to observe conditions within the outfall. This allowed evaluation of the actual condition of the pipe and how this might impact the full inspection phase.

The data gathered during the pre-inspection dry run and the analysis clearly indicated that a complete inspection of both the land and ocean portion of the outfall can be conducted.

C. The Proposed Inspection Plan:

Equipment recommended for the follow-up detailed inspection of the land

MudMaster Internal Pipeline Inspection

portion will be the CUES Mudmaster® transporter system and carrying a scissor-lift, pan-and-tilt CCTV and sonar equipment designed specifically for large-diameter pipelines. The unit must be steerable as it will need to navigate long deployments between access manholes, navigating potential obstructions and obstacles routinely found in outfall structures.

All inspections will be digitally recorded and will include screen displays showing the upstream and downstream manhole identifications, approximate location, surface conditions, direction of movement, measured pipe diameter, stationing, observations, codes, and voice-over by the operator during the inspection process. All deficiencies such as wall deterioration, surface delamination, ribbing (extended corrosion between interior reinforcing hoops that is the last stage before reinforcement is exposed), exposed reinforcement, corrosion, ovality, pipe protrusions, negative grades, exposed aggregate, and pipe joint defects will be documented using the pan-and-tilt features of the camera.

Because the ocean portion is permanently submerged and internally flooded, the options for inspection are limited compared to the land portion. There are two inspection efforts involved: external and internal.

External inspection of the ocean portion of the outfall (zero to 200 feet depth) will be conducted using a remotely operated vehicle (ROV). The protective armor stone backfill will be inspected to visually observe the condition of these stones and locate any obvious leaks through the backfill. The concrete surface is likely to not be visible because the outer surface of the pipe is typically covered in marine growth. Consequently, only significant structural deterioration or damage can be observed. Leaks at joints or through fractures in the pipe would also be detectable. The ROV will also be fitted with acoustical tracking gear linked to a surface GPS. This addition will help to determine coordinates of underwater features, such as access locations, missing armor stone, exposed pipe, or any other anomalies.

The internal inspection of the ocean outfall is complicated by a few factors:

- Near-zero visibility;
- Duration of flow stoppage;
- Access points;
- Sea conditions.

Grease and scum coatings on the pipe ID and sediment in the invert are stirred into suspension by the ROV thrusters. When these conditions are combined with background suspended particulates in the wastewater stream, visibility inside the pipe quickly drops to near-zero conditions. This requires an ROV that is capable of "seeing in the dark." Use of ROVs for internal pipe inspections is a proven technology. The assessment in poor visibility conditions can be performed with equipment such as a SeaEye Falcon® ROV equipped with 2-D imaging and profiling sonar.

The ROV will be fitted with 2-D imaging and profiling sensors that will function as "acoustic cameras." The imaging sonar will run continuously as the ROV moves forward down the pipeline. This system will provide near-video-like images of the pipe inside diameter (ID), joints, and any debris.

At chosen locations, the ROV will be parked and the profiling sonar used to record an acoustical cross-section of the pipe ID. This will show thickness of sediment in the pipe invert and any major structural defects. The ability to detect minor structural defects on the pipe ID may be limited by marine or biological growth on the pipe wall. The ROV will be inserted into the pipeline at the junction box on the beach and "flown" to the flap gate structure upstream of the diffuser structure. Because this work involves divers working from a vessel, it will be performed during a period of favorable sea conditions.

Port Townsend Outfall

A. Background and General Project Description:

The City of Port Townsend, Washington, commissioned an inspection of its existing WWTP outfall, a relatively old structure that was constructed in two phases. In the 1940s the original outfall pipeline was constructed. The original outfall section extended 413 feet from a shoreline manhole to a terminal single port discharge approximately 17 feet below Mean Lower Low Water

(MLLW). This shallow single-port outfall functioned for approximately 20 years until the City extended and improved the outfall in 1966. In 1966, the outfall pipeline was extended approximately 500 feet farther offshore from the existing terminus.

B. Inspection and Results:

An internal inspection was conducted of the offshore portion of the WWTP outfall pipe using a video camera with lights mounted on a track crawler that was inserted into the outfall at the beach manhole. The video camera and lights were capable of pivoting to allow a 360-degree view around the interior pipe wall. The internal inspection video was performed in two stages. For the first stage of inspection, a CCTV unit was used with the camera and lights oriented to view forward and slightly downward to record the pipe invert and side-walls. For the second stage, the camera and lights were oriented to view upward and slightly forward.

CCTV inspection data of the internal condition of the outfall were reviewed and a summary of the findings was developed to define problem areas and potential significant issues with current outfall operation and future use. The internal inspection did not include the outfall diffuser section because the track crawler encountered a large accumulation of rocks that blocked passage approximately 40 feet from the outfall terminus.

An exterior inspection was conducted of the offshore portion of the WWTP outfall pipe using divers. A tracer dye (Rhodamine WT) was injected into the effluent flow entering the outfall pipe at the Port Townsend WWTP. The dye injection rate (~20ml/min) and concentration were sufficient to provide a visual reference for divers looking for potential outfall pipeline leaks.

The following list summarizes the key aspects of the internal condition of the outfall:

* The outfall invert contains substantial amount of gravel and rocks (small to large) that reduces the pipe volume by 5-15 percent;
* The outfall invert contains some regions with accumulations of large rocks (4-6 inches) that reduce pipe volume by 10-20 percent;
* Outfall joint offsets and discontinuities were noted at numerous joints in the older section of the outfall, but no clear joint failures were observed;
* The outfall invert contains substantial growths (possible bacteria mats) on top of gravel and rocks that further reduce the pipe's hydraulic capacity;
* Biological growth on the invert was populated with large numbers of white/gray worms of unknown type.

Diver Observing Leak Detected by Dye Tracer

The gravel and rock blockage presents a hydraulic constraint to high effluent flows. The large rocks could potentially be transported into the diffuser section, where they could eventually plug diffuser ports and restrict effluent discharge.

D. Outcome and Recommendations:

This assessment recommended that alternatives be considered to replace the existing outfall. Although it was functional at the time of the inspection, it is clear that the outfall system is nearing its useful life expectancy. The three key factors supporting this recommendation are:

- There is historic and on-going leakage of the older, near-shore section, which should reasonably be expected to continue and get worse over time.
- There is substantial corrosion of the exposed cast iron outfall diffuser due to its 40-plus years of exposure to seawater. While it remains intact and functional, it is in marginal condition at best.
- There is significant gravel and rock debris in the outfall pipeline at the downstream end. This debris reduces the capacity of the outfall, which may not be an issue now but could be an issue as Port Townsend expands. Gravel removal would likely further damage the existing outfall.

GENERAL RECOMMENDATIONS AND CONSIDERATIONS

Although each of the outfall inspections represented conditions that varied widely, there are common challenges and subsequent considerations that should be evaluated for any outfall assessment program.

1. Hydraulic conditions and characteristics should be determined before an actual inspection is performed.
2. A pre-inspection field assessment or "dry run" is strongly recommended as this will likely identify field conditions that will determine the appropriate technologies needed to perform the entire outfall inspection.
3. The transition from land-to-ocean (beach or seawall) is not necessarily the optimal location to deploy CCTV and ROV equipment. This commonly occurs several hundred feet upstream of this point due to elevated hydraulic gradient, even under no-flow conditions and several hours after WWTP shutdown.
4. Modifications to conventional crawler-style CCTV transporters will be required if zebra mussels are encountered inside the outfall structure.
5. Pre-collaboration and careful coordination with treatment plant operators is crucial in order to plan and execute the inspection work under optimal (slack or low-flow) hydraulic conditions. This will require a series of pre-inspection meetings with personnel responsible for storage and hold-back of wastewater flow at the treatment plant as well as upstream lift stations and interceptor control structures.
6. Generally, ROVs can navigate within the submerged outfall up to 2-3 feet-per-second of flow.
7. Hydro-cleaning during the inspection process is generally not required unless there are breaks or exposed/open joints in the submerged portion of the outfall.

NOTES:

1. *Collection Systems O&M Fact Sheet: Sewer Cleaning and Inspection. USEPA, ASCE. 1999*
2. *Wastewater Collection Systems Management: WEF Manual of Practice No. 7, 5th ed. Task Force on Wastewater Collection Systems Management. 1999*

Cutting-Edge Trenchless Technology Proposed for Challenging CSO Project

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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. Currently, the existing sewer system routes sanitary and storm

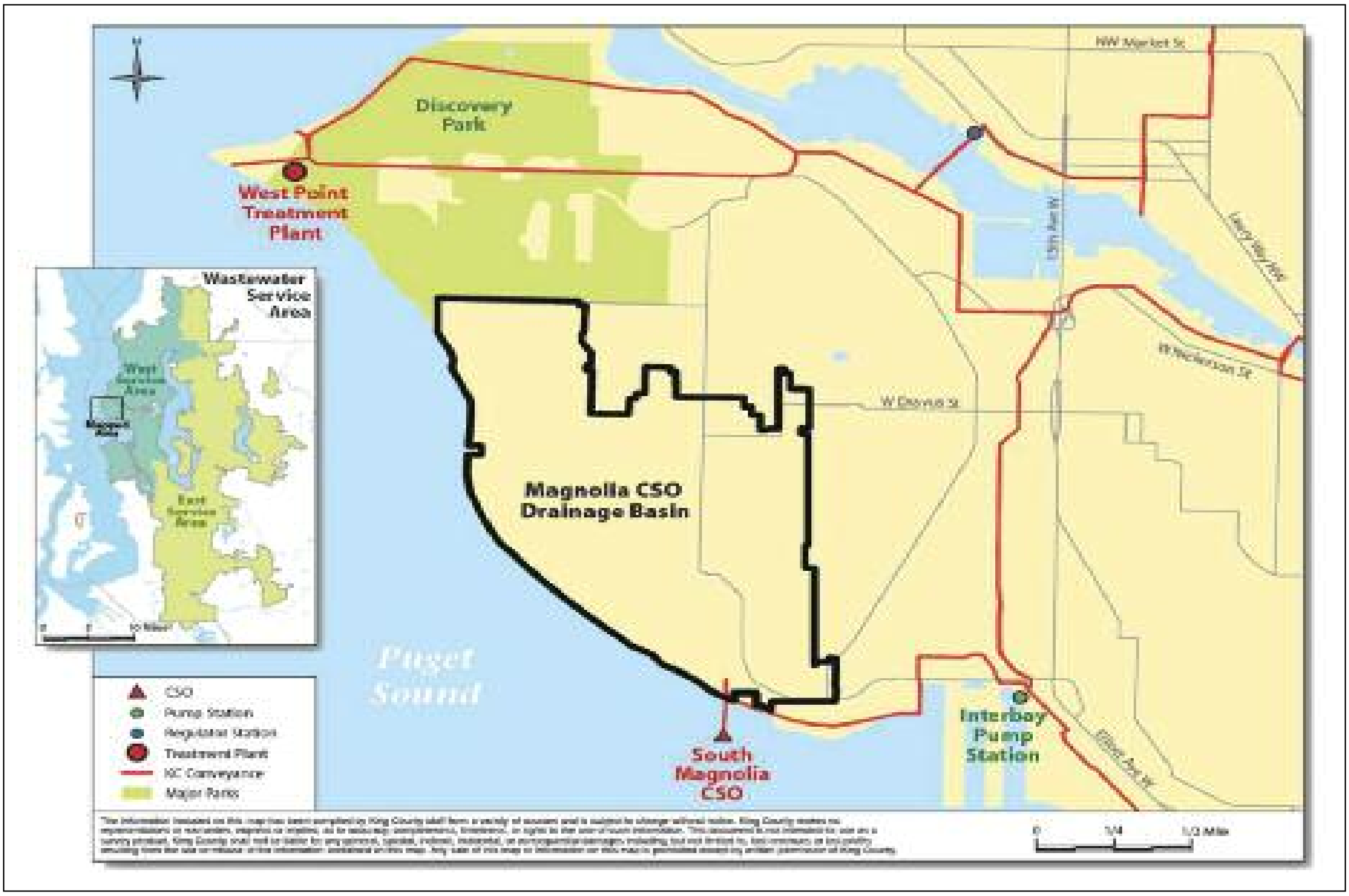

Figure 1. Magnolia CSO Project Area

Figure 2. Installation of a 42-inch steel pipe in New York, August 2011. Photo provided by Herrenknecht AG.

flow within the basin to 32nd Avenue West, where a diversion structure directs low flow to the South Magnolia Trunk Sewer and overflows to Puget Sound (Figure 1).

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 constructed via horizontal directional drilling (HDD) to convey wet-weather flows through the Magnolia Bluff to the tank.

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

INITIAL 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 conveyance pipeline needed to 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 160 feet. 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.

At the time of the evaluation, Direct Pipe was relatively new to the United States with only three installed pipelines in the U.S. The Direct Pipe method 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

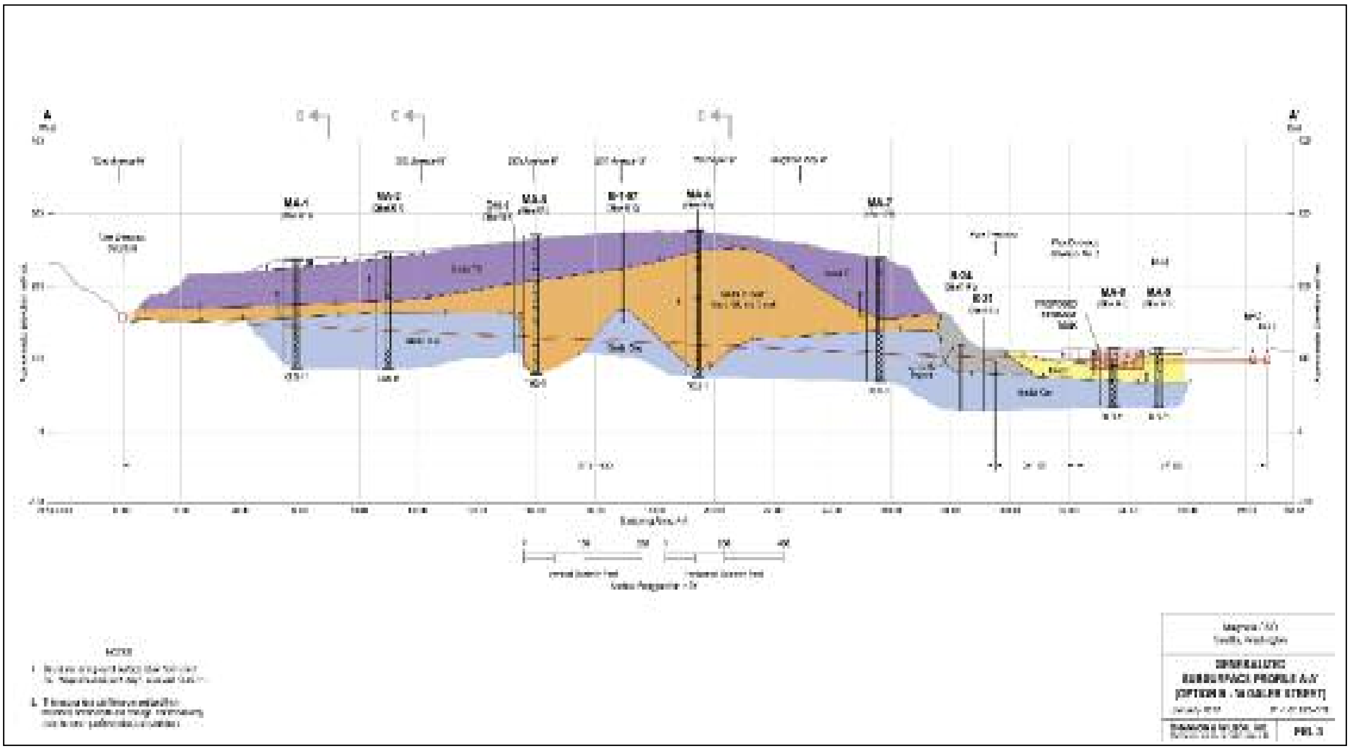

Figure 3. Geotechnical profile for an early version of the HDD alignment

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 2). 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.

The primary advantage of Direct Pipe for the installation of the conveyance pipeline was the ability to meet grade tolerances of plus or minus one inch over thousands of feet without the need for intermediate shafts. The primary disadvantage was the lack of direct experience with Direct Pipe and project history within the United States and specifically with the contractors who may be bidding on 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 1,000 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.

SELECTION OF 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 were 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 of very dense/stiff silt, clay, and sand (Figure 3). The primary disadvantage was grade control exceeding the tolerance of what is typically required for gravity pipelines.

However, later in the design process, King County 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 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 on 32nd Avenue West, rather than having to construct a new diversion structure, a significant construction cost savings. Use of the existing diversion structure was made possible by the capability of the Direct

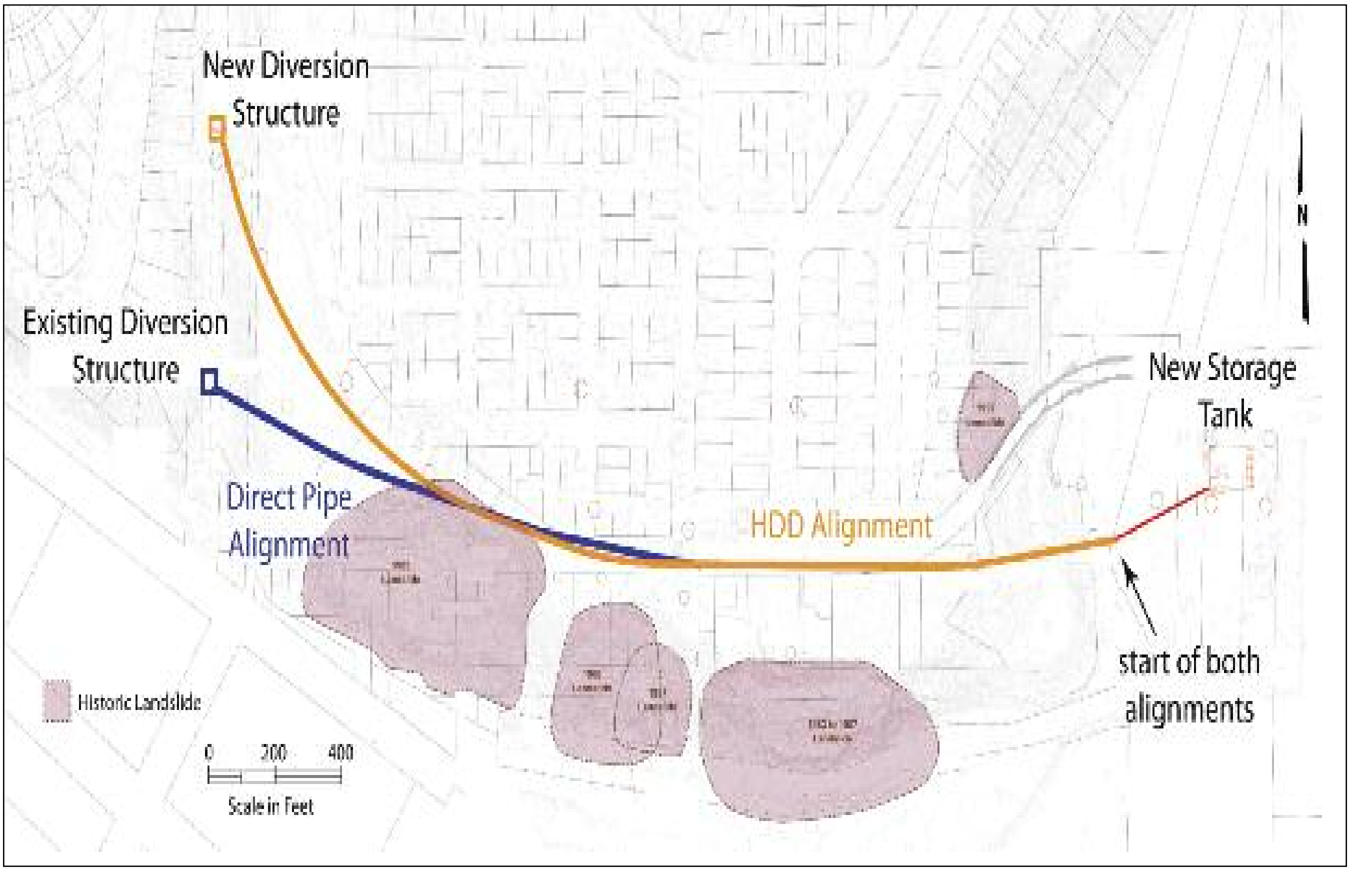

Figure 4. Direct Pipe® and HDD Alignments

Pipe method to install the pipeline at a 1% grade.

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 48-inch diameter to allow the technology to install the necessary 2,600 feet of pipeline. The increased diameter was 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 required the construction of a new diversion structure in 32nd Avenue West to direct wet-weather flows through the new conveyance pipe to the proposed storage tank. The new diversion structure was 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.

TWO SEPARATE DESIGNS

The alignments corresponding to each

	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

Table 1. Design Details of the two installation options

of the two methods are shown in Figure 4. The two designs converge in Smith Cove Park, which was 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. Details of each design are provided in Table 1.

PROCUREMENT

Two bid options were included in the contract, corresponding to two complete sets of contract documents, including two full sets of plans and specifications. Contractor qualifications were based on the method for which they proposed. For the HDD, this included experience requirements on bores of similar length and diameter for the contractor and key personnel. Qualifications for the Direct Pipe method focused on the Direct Pipe experience of the key personnel.

The conveyance contract was bid and awarded in early 2014, with HDD coming in as the lowest bid method. Construction of this cutting-edge project began in late 2014, and will result in one of the largest, longest on-grade HDD installations ever constructed.

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.

City of Port Angeles Pulls Off Challenging Slipline to Divert CSOs

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Staheli Trenchless Consultants

The City of Port Angeles, Washington, recently completed the Francis Street Combined Sewer Overflow (CSO) Diversion Project to reduce the number of overflows to the Pacific Ocean. In 2006, an estimated 6 to 8 million gallons (MG) of untreated sewage was released into Puget Sound when an existing force main ruptured. The pipeline was deemed at risk by the Department of Ecology and required replacement and relocation outside of the harbor to eliminate the environmental risk posed by the pipeline.

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 City's wastewater treatment plant and installation of a new sewer main to control discharge from future CSOs. Phase II will implement treatment plant upgrades, retrofit an existing 5 MG tank, upgrade the existing Pump Station No. 4, and connect the Phase I pipelines to the pump station and wastewater treatment plant.

The project had many challenges that made open-cut construction of new pipelines prohibitive, including wetlands, coastal species, and Native American burial grounds. As such, it was necessary to find ways to install the new pipelines with as little disruption as possible.

PROJECT DESIGN AND CONSTRUCTION

Trenchless construction, namely sliplining an existing reinforced concrete Industrial Waterline (IWL), was recognized early in the design as a desirable alternative to open-cut construction of three pipelines along the highly sensitive waterfront. In order to increase the capacity of the pump station No. 4 by over 300 percent as required by the hydraulic modeling, three pipelines were required to carry the flows to the wastewater treatment plant. Hydraulic analysis determined that one 30-inch and two 14-inch pipelines would carry the maximum flow volume possible, while maintaining sufficient clearance within the 48-inch IWL concrete pipe to snake 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, providing the ability, if needed, to adjust the bundle either by thrust or rotation to achieve the final lineup for pit connections.

Since the known location of the 48-inch IWL pipeline was not exact, the contractor used a walkover 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 15 feet for the length of the pipeline. This allowed the contractor a preliminary method for determining if grade alignment deviations existed while stringing the drill pipe through the host pipe prior to pulling the cleaning pipe pig. Figure 1 shows the side-load battery-powered locating sonde used to track the 48-inch IWL host pipe and the setup of the HDD rig.

Figure 1. (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 a full-diameter foam proof/cleaning pig through each segment of the existing 48-inch reinforced concrete IWL. Figure 2 shows the foam pig being pulled from the first slipline segment, which 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. Pull forces were monitored during each pull in the event that a pre-emptive excavation and removal of the reinforced host pipe would be determined necessary.

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 3) 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.

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. Lubrication proved necessary as the installation forces increased for the longer slipline segments, which also contained large bends as opposed to straight installations

During construction the contractor was able to show that it was likely possible to eliminate one pit 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 with the agreement that if pull forces reached the maximum allowable limit, then the contractor would stop the pull and the intermediate pit would be constructed at the termina-

Figure 2. Proof and cleaning pig pulled prior to slipline.

Figure 3. Insertion of 30-inch and two 14-inch pipes using bundling/taming frame.

Figure 4. Pullback with liquid polymer lubricant.

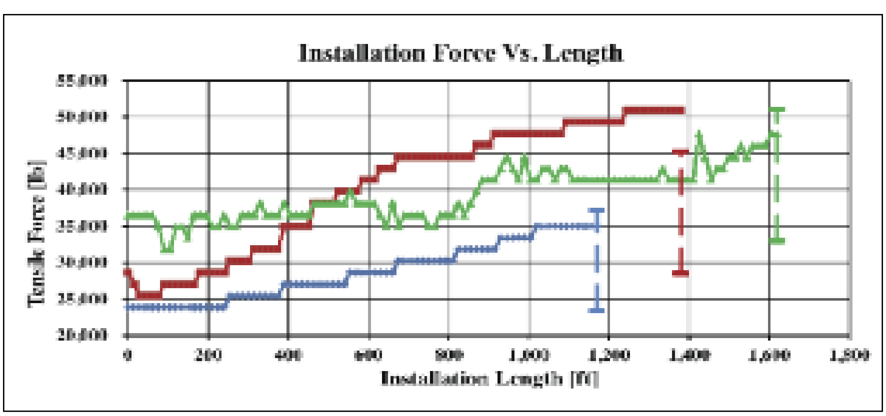


Figure 5. Installation Force Versus Segment Length and Estimated Pull Force Envelope (Lubricated to Non-lubricated Range)

tion 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 5 as vertical dashed lines for each segment. The method used to calculate the slipline estimated maximum installation loads was based on the method presented the Plastics Pipe Institute Handbook of Polyethylene Pipe, Second Edition (2008). During construction, actual installation loads were monitored and recorded by the contractor and Staheli Trenchless Consultants' on site inspection staff. Figure 5 shows the actual installation forces for each slipline segment compared to predicted values of a lubricated and non-lubricated condition.

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 mechanical or electrofusion connections (Figure 6).

Figure 7 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 4,000-foot pipe strings then the majority of the pipe would require draining to perform the repair and would then need to be refilled and retested.

CONCLUSION

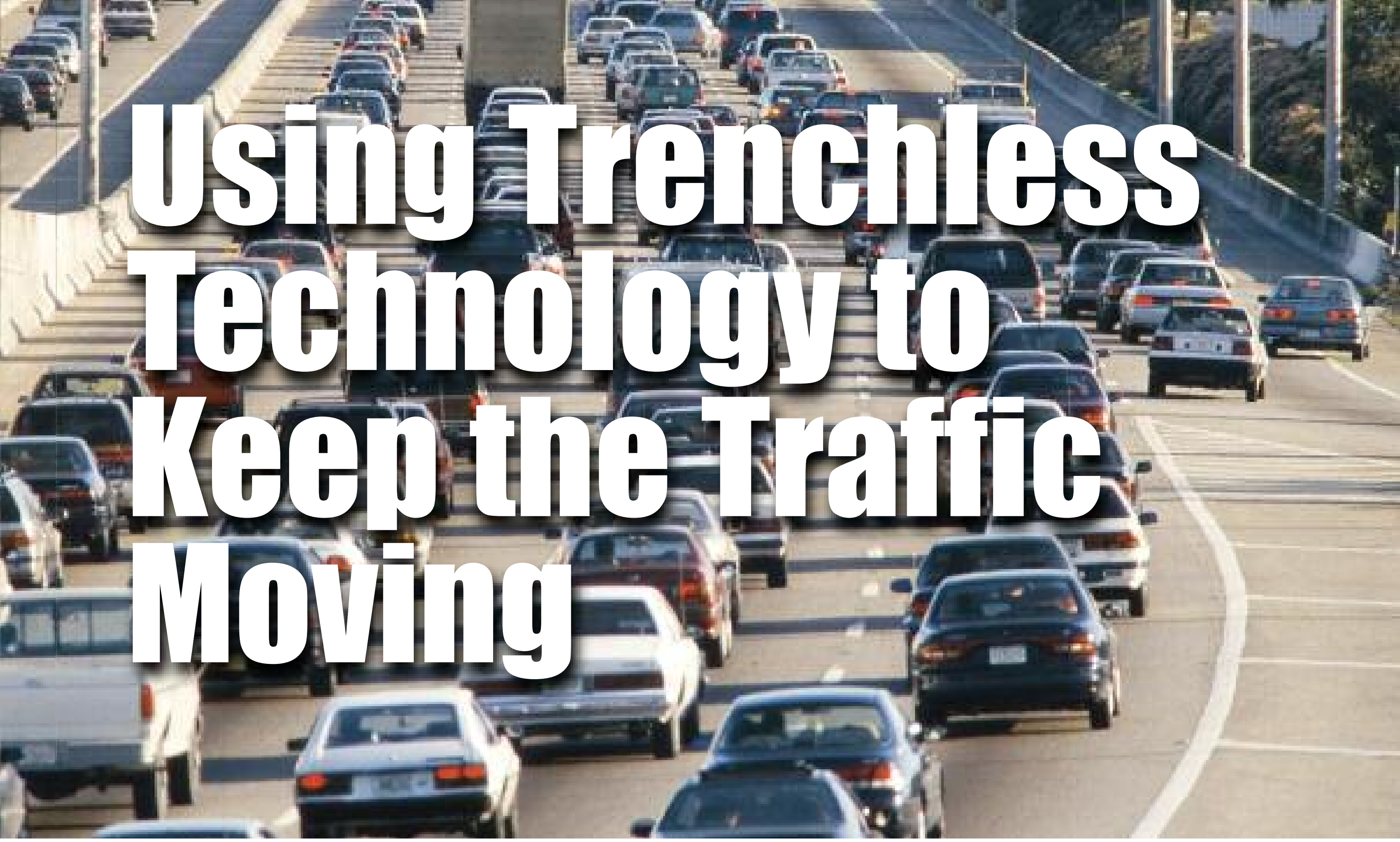
The slipline construction for the City of Port Angeles Phase I CSO Project proved extremely successful. Due to project constraints, a very conservative design was crafted to guard against unknown conditions and potentially high-impact issues. Historical and cultural impacts were identified early in the design process as potentially significant if artifacts were actually encountered in excavations, thus driving the slipline approach. 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 a test bundle to 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 allowed to demonstrate that the good practices would allow an exclusion of an intermediate pull pit, thus saving in schedule and costs.

Figure 6. In-pit HDPE fusion machines used to make connections.

Figure 7. In-pit fusion of the 14-inch pipe.

Using Trenchless Technology to Keep the Traffic Moving



The Alderwood Water & Wastewater District (AWWD) was faced with two major challenges: replacing aging yet critical waterlines for central Snohomish County in the Puget Sound region, while facilitating the entire project without the nearby Boeing Company knowing it ever happened.

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Alderwood Water & Wastewater District

The basic problem is common to many utility projects: installing new water and sewer lines or replacing old ones while minimizing both safety concerns and impacts to the motoring public. However, when the road involved is a six-lane arterial such as Highway 99 in Lynnwood, Washington, the challenge is to avoid any daytime road interference whatsoever. Making matters more complicated, the road serves a major business area that includes the Boeing Company's Everett plant, where 42,000 employees construct the 747s, 777s, and 787s that are among this country's most valuable export products.

The AWWD was formed in 1931 to provide water service to the people within Snohomish County. Being a short distance north of Seattle, the area has seen rapid growth, and the District now serves over 214,000 customers in several cities including Lynnwood, Mukilteo, Bothell, Brier, and Mill Creek.

The waterlines needing replacement were some of the utility's first major projects. In 1933, AWWD installed approximately 14,000 feet of 12-inch-diameter cast iron pipe along the east side of Highway 99 to create the 724 and 635 pressure zones. In 1946, AWWD constructed an additional 13,000 feet of 12-inch diameter steel pipe on the west side of Highway 99 as part of an expansion of the 724 pressure zone.

By 2012, both of these pipelines had exceeded their anticipated design life and were at risk of failure. The water system improvement project also

Auger bore under Highway 99 at State Route 525 Interchange

included the transfer of a portion of the existing 635 pressure zone to the 724 pressure zone to address an area with low-pressures.

Trenchless construction was identified as an early planning solution in replacing the pipelines while minimizing the impacts.

Trenchless Solutions Promote Project Success

During the preliminary design phase, in evaluating alignment and construction options, several project goals were identified:

- Minimize the possibility of damaging the fragile water mains during construction.
- Avoid existing utilities where possible to minimize construction conflicts and utility relocations.
- Minimize water service interruptions to businesses.
- Minimize surface restoration within the paved right-of-way.
- Minimize traffic impacts.

The design called for the installation of three waterline crossings of Highway 99 and one crossing of State Route 525. The Highway 99 crossings included both water main replacements and future pressure zone continuation. The crossing of State Route 525 was part of the rezone concept that eliminated a significant portion of high-cost work along the east side of Highway 99 and allowed the District to eliminate additional aging infrastructure.

Highway 99 Auger Bores

The first auger bore crossing of Highway 99 occurred approximately 300 feet north of the off ramp from State Route 525 to Highway 99. The design called for the installation of 115 feet of 36-inch-diameter steel casing, which would house the 12-inch-diameter ductile iron carrier pipe. The boring had to cross six lanes of Highway 99 traffic while avoiding all existing utilities: storm, fiber optic, phone, gas, water, and both underground and overhead power lines.

The jacking pit was constructed in an existing Washington State Department of Transportation (WSDOT) access road on the east side of Highway 99 while the receiving pit was constructed on the west side near an existing steel power pole. The size of the jacking pit was limited to a 40-foot-by-40 foot temporary construction easement. The bore was installed approximately 14 feet below Highway 99.

The second auger bore crossing of Highway 99 occurred just south of

Auger bore under Highway 99 – double carrier pipes

Manor Way in front of a property with a busy RV sales business. This road crossing was unique because it required the installation of two separate carrier pipe systems: a 12-inch ductile iron pipe for the 724 pressure zone, and a 16-inch-diameter pipe for future extension of the 635 pressure zone. This was accomplished through the installation of approximately 80 feet of 42-inch-diameter steel casing, which housed both carrier pipes.

The jacking pit was again installed on the east side of Highway 99, but this time it was within the RV sales lot. A temporary construction easement was negotiated with the property owner and required that the contractor construct the auger bore within tight site constraints. The receiving pit at this crossing was located within the Highway 99 ROW which required that the intertie be constructed at night. This crossing was installed at a depth of approximately 15 feet.

The final auger bore crossing was accomplished just south of the intersection of Highway 99 and Airport Road. Airport Road is a direct access point to Boeing's Everett Factory. The design called for the new pipe serving the 724 pressure zone to cross from the west side of Highway 99 to the east and then travel north along Highway 99 across Airport Road in parallel with a new 12-inch-diameter ductile iron waterline serving the 635 pressure zone. The pipeline crossing was constructed using a 36-inch diameter steel casing, approximately 77 feet long. The jacking pit was designed on the west side of Highway 99 in a vacant lot just south of a public storage facility. The receiving pit was located in the eastern turn lane for Airport Road, and again required night construction to make the final intertie. This final crossing of Highway 99 was installed at a depth of approximately 14 feet.

State Route 525 Auger Bore

The auger bore crossing of State Route 525 was a portion of the low-pressure improvement phase of the project. It was developed through collaboration between District and Stantec staff as a way to minimize construction on Highway 99 while eliminating additional aging waterlines. During design it was determined that a route alternative for the replacement of the 635 pressure zone piping could reduce the need for approximately 6,000 feet of pipe on Highway 99.

The auger bore consisted of the installation of 115 feet of 36-inch-diameter steel casing to allow for the installation of a 12-inch diameter ductile iron pipe across State Route 525. A jacking pit of approximately 20 feet by 35 feet was installed on the east side of State Route 525 roughly 190 feet south of 149th Place SW. The receiving pit was installed in the ROW for State Route 525 just west of the existing guardrail. At its deepest point, the casing was approximately 11 feet below State Route 525.

Auger bore under State Route 525

Analyzing Success

Success of this project rested heavily on the design details, construction sequencing, and selection of good bore and receiving pit locations. Additionally, selecting the appropriate method of trenchless construction avoided major problems during construction. The key district project team members were David McDonald, Brigitte McCarty, Bob Hastings, and Mike Johnson. Members of the Stantec team included Laurie Fulton, Scott Slifer, Jay Gibson, and Tim Tobin. This design team conducted a detailed alternatives analysis to determine the most cost-effective way of replacing the aging waterlines in Highway 99. In conjunction, the team oversaw the installation of new waterlines to improve the pressures in the project area while minimizing project risk and keeping the overriding project goals in mind.

How did trenchless technology influence the outcome of this project? The effort was facilitated without impacting existing utilities and maintained water service throughout construction. Additionally, surface restoration and traffic impacts during construction were minimized for members of the surrounding community. The combined strategies allowed the district to replace this critical infrastructure without significant impacts to the roughly 36,000 local customers, the near-by industries, including Boeing, or thousands of daily commuters. These important improvements are a vital section of the 660 miles of water main used to reliably deliver 9 billion gallons of potable water a year to the district's residents and businesses.

Court Upholds Contract Clauses in Recent DSC Dispute

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A recent court case arising out of a King County sewer project illustrates that the use of express contractual baselines – where clearly drafted – is an enforceable and effective means by which to allocate risk on a trenchless project.

Northshore Utility District (King County, Washington) is a water and wastewater district that serves roughly 65,000 residents in and around the north end of Lake Washington. In 2011, the District embarked on the construction of an underground gravity-fed sewage line to eliminate an obsolete sewage lift station. The bulk of the proposed line ran underneath a city park and adjacent city street. For this and other reasons, the District decided to bid the project as a trenchless installation. The project was put out to bid in 2011 specifying the use of the auger bore method of trenchless construction.

The District also engaged a geotechnical consultant to prepare a Geotechnical Data Report (or GDR), which was included in the bid documents. The District did not prepare a separate Geotechnical Baseline Report (GBR). Instead, it included express baseline statements in the project specifications for two subsurface conditions commonly encountered in Pacific Northwest projects: cobbles and boulders.

> **"The sub-contractor claimed that a combination of cobbles and groundwater was a differing site condition"**

As to cobbles, the specifications instructed bidders to assume that cobbles would be encountered along the trenchless alignment, and to provide trenchless equipment capable of ingesting "any and all quantities" of cobbles actually encountered.

Regarding boulders, the specifications instructed bidders to assume that boulders would be encountered, and that the contractor was responsible for excavating and removing any boulder up to three feet in its largest diameter. As for boulders over three feet in diameter, the District advised bidders that such boulders would constitute Differing Site Conditions to the extent they stopped the machine.

The project specifications also required the contractor to dewater the alignment "as necessary" to install the casing and prevent soil inflows into the casing.

After contract award, the contractor (at the request of its tunneling subcontractor) asked to substitute open shield pipe jacking (OSPJ) as the tunneling method instead of auger boring. The District allowed this change, subject to the terms of an agreed change order that put all of the design and construction responsibility for this new approach on the contractor.

Construction commenced in late 2011. Within a week, the tunneling subcontractor hit a mixture of cobbles and groundwater. A sinkhole developed. Ultimately, the tunneling subcontractor declared that the project was not buildable with either auger boring or OSPJ and pulled its TBM from the ground. The project was eventually completed using a mix of open-cut and microtunnel.

A dispute arose over responsibility for the sinkhole, delays in completion and extra costs to finish the project with open-cut and microtunneling. The subcontractor claimed that a combination of cobbles and groundwater was a differing site condition and that this condition stopped its TBM. It eventually sought an equitable adjustment to the contract of more than $2 million. Because informal settlement talks were not successful, the matter went into litigation in King County Superior Court.

The District brought a motion to dismiss the DSC claims. The District argued that such claims were barred by the clear language of the contractual baselines. The subcontractor disagreed, largely contending that the baselines were "unenforceable" and that its DSC was not the individual conditions that it encountered (i.e. cobbles or boulders or groundwater), but the combination of all three.

The Court agreed with the District and dismissed the cobble/boulder/groundwater DSC claim in its entirety. The Court first noted that the interpretation of unambiguous contract baselines was a matter of law for the Court to decide. As the following quote from the hearing transcript demonstrates, the Court in its ruling reminded all parties that the touchstone of the Court's analysis was the contract language itself:

> *But I'm going to remind everybody, again, the thing I look to first is the contract. And the baselines in the contract are both broad and clear. They require the contractor to be capable of excavating and ingesting any and all quantities of cobble actually encountered and limits the District's payment for boulders to those over 36 inches. It's crystal clear that groundwater is another disclosed situation in the sense of the parties being involved in working under the level of groundwater was disclosed even in the GDR, and that's just not disputed here. So with regard to whether we have a DSC claim based on encountering cobbles – cbbles and boulders or cobbles and boulders and groundwater, the answer to that question is no. The District advised the parties that cobbles and boulders and groundwater were going to be part of the site conditions.*

The subcontractor argued that the bore logs in the GDR showed only occasional cobbles and that this indication – rather than the express "any and all" indication in the contractual baseline – took precedence. The Court disagreed with the subcontractor in the following way, which again is a quote from the transcript of the Court's ruling:

> *And I find this [baseline] language quite clear. I also think that it's not reasonable to read a contract as saying something other than it does. I think I'm hearing [the subcontractor] actually arguing to me that there was some sort of guarantee in the contract that they would only run into an occasional cobble that they could tunnel through. That is not the language I'm seeing here and I don't think it's a reasonable interpretation of the contract.*

The Court's decision demonstrates that project baselines – again, when clearly drafted – are enforceable, regardless of whether such baselines are included in a separate GBR, or (as may be more appropriate for a smaller-scale trenchless project) directly incorporated in the project specifications.

Come to Denver for No-Dig

Richard (Bo) Botteicher
NASTT's 2015 No-Dig Show Program Chair

Jeff Maier
NASTT's 2015 No-Dig Show Program Vice Chair

Dear Trenchless Colleagues,

Why do you come to No-Dig?

There are a lot of reasons to attend North America's premier trenchless technology event – but we are especially excited to invite you to join us at NASTT's 24th annual No-Dig Show, March 15-19, 2015, because it will be in our home town of Denver, Colorado. NASTT's No-Dig Show will be held at the Colorado Convention Center next spring, bringing the world's largest trenchless technology conference to the doorstep of the majestic Rocky Mountains. Denver is a perfect fit for the No-Dig Show since it is centrally located, is a major hub for the engineering industry, and offers almost endless recreational and entertainment options for all.

No-Dig prides itself on providing a single event where attendees, sponsors, students and exhibitors can gather for trenchless education, promotion of new technologies, peer-to-peer networking, and of course, a little fun thrown in there as well.

The 2015 No-Dig Show Program Committee has put together another outstanding and comprehensive technical program, which is the crown jewel of the conference. The technical program contains nearly 160 papers of high-quality and non-commercial content in a six-track schedule offered throughout the week. Join us for our pre- and post-conference courses for even more in-depth trenchless training on topics such as cured-in-place pipe (CIPP) lining, horizontal directional drilling, lateral rehabilitation and more. There is certainly something for every trenchless professional at NASTT's 2015 No-Dig Show.

In between all the educational opportunities, attendees can enjoy great food, entertainment and networking. Monday begins with our Kick-off Breakfast and ends with NASTT's Annual Educational Auction and Reception. Make sure you bring your wallets and your vintage ski gear for the auction theme this year, as we celebrate with a fun and seasonally-appropriate Colorado tradition – the '80s ski party.

Tuesday evening's event is the annual Gala Dinner, which features a gourmet meal, awards presentations and some elevated entertainment. And finally, on Wednesday we will have our Closing Luncheon to wrap up the show. This year's show will once again include the very popular municipal scholarship program, providing municipal employees and decision makers from around North America with some outstanding educational opportunities and exposure to the trenchless industry. Registration for this program opens for eligible candidates this Fall.

When it comes to all things trenchless, there is no better value than attending the No Dig Show. There are many reasons to come to No Dig in 2015. We hope to see you in Denver to learn why you are there!

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