Willamette Water Supply Program Successfully Completes Initial Trenchless Crossing

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1. ABSTRACT

The Willamette Water Supply Program (WWSP), a partnership between the Tualatin Valley Water District and City of Hillsboro in Washington County, Oregon, is developing an additional drinking water source, the mid-Willamette River in Wilsonville. Other drinking water providers are considering joining the partnership. The system will provide a seismically resilient water supply, designed to meet future demand and provide redundancy in case of an emergency event. The system includes plans for more than thirty (30) miles of transmission pipelines, ranging from 36-inches to 66-inches in diameter from the Willamette River Water Treatment Plant (WRWTP) in Wilsonville, Oregon, north to service areas in Hillsboro and Beaverton, Oregon. The system will also include finished water storage tanks (terminal storage), a new water treatment plant, and an expansion of the existing WRWTP raw water facilities (see Figure 1).

The trenchless work as part of one of the early action pipeline sections included crossing Tualatin Valley Highway (State Highway 8) and the Union Pacific Railroad (UPRR). This paper will discuss review of alternative alignments and trenchless methods for the crossing as well as geotechnical conditions, risks, guidance systems, traffic and coordination with other construction projects, which resulted in successful completion of the WWSP’s initial trenchless crossing.

2. INTRODUCTION

The concept planned for the trenchless crossing included a 400-foot long pipe jacking section estimated at more than $1 million. To reduce project costs and risks, alignment options were further considered to reduce the trenchless crossing length to allow a greater range of trenchless methods. Profile options were also considered given existing utilities and clearances, soil/geologic units and groundwater levels. In addition, there were multiple public improvement and private development projects ongoing in the project vicinity which needed to be coordinated for project scheduling and traffic control.
Figure 1. Willamette Water Supply Program Map.
3. PRELIMINARY CONCEPT

The preliminary design alignment developed by the WWSP for the PLW_1.1 trenchless crossing at Tualatin Valley (TV) Highway showed the alignment on the west side of SE Cornelius Pass Road north of TV Highway, transitioning to the center of the SW Cornelius Pass Road extension on the south side of TV Highway (see Figure 2). Further investigation of the alignment as it crossed TV Highway was warranted to minimize the impact of construction on SW Cornelius Pass Road (north and south of TV Highway), improve accessibility for long term waterline maintenance, and reduce trenchless risks and costs, where possible.

Figure 2. Preliminary Concept Plan and Profile

4. DESIGN

4.1 Basis of Design

The following pipeline and casing pipe parameters were used for geometric layout of the trenchless crossing:

- Minimum carrier pipe size: 48-inch inside diameter
- Minimum carrier pipe wall thickness: 5/8-inch (0.6250 inch)
- Minimum casing diameter: 60-inch nominal ID (for 48-inch carrier), or minimum 12-inches larger than carrier pipe diameter
- Minimum casing wall thickness: 7/8-inch (0.8750 inch)
- Minimum depth of cover at railroad track crossing: 13 feet minimum (from top of rail to top of casing, 2.5 x casing diameter)
- Annular space between casing and carrier:
  - Use casing spacers and leave annular space empty with end seals
- Railroad track crossing angle: as close to 90 degrees as possible
In addition, the PLW_1.1 construction project overlaps and abuts three other project work areas on this site, including:

- **At-Grade Crossing Project – Private Developer.** This project consists of improvements to the Cornelius Pass and TV Highway intersection and extension of Cornelius Pass Road approximately 200 feet to the south of the intersection.
- **Reed’s Crossing Development – Private Developer.** This project consists of commercial and residential development of the existing farmland south of TV Highway. The construction activities during PLW 1.1 include preliminary grading and subsurface utility installation.
- **Cornelius Pass Road widening Project – Washington County and City of Hillsboro.** This project consists of roadway expansion along TV Highway tying into the At-Grade Crossing Project improvements.

### 4.2 Trenchless Crossing Alignment

Using the base map information from both the TV Highway Widening and Reeds Crossing Development projects, four alignment options were defined for consideration of the trenchless crossing of TV Highway. Each of these options is shown in Figure 3. Option 1 (red) and the shorter Option 2 (blue) could be accomplished with auger boring, microtunneling or open shield pipe jacking, depending upon final profile selection. Options 3 and 4 could be accomplished with microtunneling or open shield pipe jacking. Auger boring was removed as an alternative method for Options 3 and 4 due to the length of the trenchless crossing.

![Figure 3. Trenchless Crossing Alignment Options](image)

Each alternative’s alignment was reviewed to identify its advantages and disadvantages, which are identified in Table 1.
<table>
<thead>
<tr>
<th>Alignment Option</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Shortest length</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Multiple trenchless methods can be used for installation including auger boring, pipe ramming, open shield pipe jacking and microtunneling</td>
<td></td>
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<tr>
<td></td>
<td>Lowest cost</td>
<td></td>
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<tr>
<td></td>
<td>Jacking shaft located at curb line, less impact to Reeds Crossing Development</td>
<td></td>
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<tr>
<td></td>
<td>No utility impacts in Reeds Crossing</td>
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<tr>
<td></td>
<td>PLW1.1 piping continues south on east side of new roadway – same side as the jacking shaft</td>
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<tr>
<td></td>
<td>Receiving shaft site is too small</td>
<td></td>
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<tr>
<td></td>
<td>Will require significant utility relocates including buried power conduits, buried signal and local signs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No layout area for receiving process</td>
<td></td>
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<tr>
<td></td>
<td>High traffic volume impacts, receiving shaft located at the corner of TV Highway and SW. Cornelius Pass Rd.</td>
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<tr>
<td></td>
<td>Conflicts with existing buried power and convenience store sign located at the north-east corner of the intersection</td>
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<tr>
<td>2</td>
<td>Receiving shaft site located away from TV Highway, provides for work laydown area – laydown/staging area north of reception shaft</td>
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<tr>
<td></td>
<td>Same utility and location comments for jacking shaft as Option 1</td>
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<tr>
<td></td>
<td>Avoids both the new and existing power pole locations</td>
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<tr>
<td></td>
<td>PLW 1.1 piping continues south on east side of new roadway – same side as the jacking shaft</td>
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<tr>
<td></td>
<td>Second shortest trenchless length</td>
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<td></td>
<td>Length limits trenchless methods to open shield pipe jacking and microtunneling</td>
<td></td>
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<tr>
<td></td>
<td>Located in northbound turn Lane of SE Cornelius Pass Road will limit turn movements</td>
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<tr>
<td></td>
<td>Adjacent to convenience store north entrance and may impact business</td>
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<tr>
<td>3</td>
<td>Furthest from the existing power pole, avoids existing power pole foundation</td>
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<td></td>
<td>Longest trenchless crossing</td>
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<td></td>
<td>Length limits trenchless methods to open shield pipe jacking and microtunneling</td>
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<td></td>
<td>Highest impact to Reeds Crossing development, shaft is located in the center of the Reeds Crossing entrance roadway</td>
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<td></td>
<td>Receiving shaft located in south bound right turn Lane from SW Cornelius pass road onto TV Highway, impacting traffic flow</td>
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<td></td>
<td>Impacts to storm water piping and adjacent to sanitary sewer piping</td>
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<td></td>
<td>Longer connection to meter vault</td>
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<tr>
<td></td>
<td>Potential impacts to strip mall and adjacent restaurant location on West side of roadway which appears to have the highest utility concentration which may impact PLW 1.2 construction</td>
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<tr>
<td>4</td>
<td>Same as Option 3</td>
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<tr>
<td></td>
<td>Crosses railroad tracks at 90-degree angle</td>
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<tr>
<td></td>
<td>Receiving shaft located in south bound right turn Lane from SW Cornelius pass road onto TV Highway, impacting traffic flow</td>
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<td>Potential impacts to strip mall and adjacent restaurant location on West side of roadway which appears to have the highest utility concentration which may impact PLW 1.2 construction</td>
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</tbody>
</table>

Based on the advantages and disadvantages evaluation conducted by the Design team (shown in Table 1), and subsequent discussions with the WWSP and private property owners, Alignment Option 2 (shorter option shown in
blue) was the preferred option for the trenchless alignment. Alignment Option 1 is the shortest and lowest cost option; however, the following factors eliminated Option 1 from further consideration:

1) The curb to road right-of-way width is very narrow in front of the 7-11 store on the NE corner of TV Highway. Siting a receiving shaft at this location will be very tight. Room for laydown and staging is not adequate within the existing right-of-way without using part of the roadway, and access to private property will likely be difficult or time consuming.

2) There are buried power conduits at this NE corner of the intersection that will be adversely impacted and would need to be relocated. The extent of the impact of this relocation work is unknown.

3) The traffic impacts from a shaft located at the NE corner of the intersection would be significant, especially considering there is other traffic control issues associated with the TV Highway widening project that will be running concurrently. With staging not allowed in the private property it would have to be in the roadway, which would seriously affect north bound turning movements at the intersection.

4) Risk of schedule delays related to private property acquisition is unacceptable and not consistent with the schedule for this early action work.

4.3 Trenchless Crossing Profile

For the trenchless crossing profile consideration three geotechnical units were identified for the TV Highway Crossing vicinity, as follows:

**Fill:** including pavement sections and medium stiff Silt (ML) to Lean Clay (CL);

**Fine-Grained Missoula Flood Deposits:** very loose to loose / soft to stiff Silt to Sandy Silt (ML), soft to stiff Lean Clay (CL), and lesser amounts of medium dense Silty Sand (SM); stratified; (between approximate elevation 205 and 180-185 feet, or approximately from 13 to 33 feet below ground surface.)

**Hillsboro Formation:** medium stiff to very stiff Fat Clay (CH) and Lean Clay to Lean Clay with Sand (CL); trace layers of medium dense Silt with Sand (ML) to Silty Sand (SM) (below approximate elevation 180–185 feet, or approximately 33 feet below ground surface and deeper.)

Groundwater was found during geotechnical explorations at approximately 13 feet below ground surface (approximate elevation 207 feet). Review of other historical borings in the area showed groundwater levels ranging from about 7 to 13 feet below ground surface.

Based on the results of the geotechnical borings on the north and south end of the trenchless crossing, geotechnical conditions across the profile were inconsistent. Therefore, it was recommended that additional cone penetrometer tests (CPT) at the project site be performed to confirm geotechnical parameters at the ends of the crossing, and at a point midway through the crossing. Based on a review of the subsequent CPT data and boring log information, the shallower profile was viewed more favorably than the deeper profile. This recommendation was reached since the shallower profile has mostly silts with some sands with blow counts (STP N-values) greater than 10 with a few localized blow count readings less than 10 (meaning stiffer soils), less groundwater concerns, and thus less dewatering requirements, and is within a single geologic/soil unit.

Figure 4 provides the recommended profile for this trenchless crossing based on the Option 2 alignment (blue) with shorter length as shown in Figure 3. The trenchless profile is expected to be completed within the Fine-Grained Missoula Flood Deposits with groundwater near or slightly above the casing crown. Dewatering at each shaft will further reduce groundwater levels along the alignment. With the shallower, shorter trenchless segment, risks related to dewatering, settlement, shaft construction, casing alignment and grade, and costs are reduced significantly from the deeper (35 feet) and longer (410 feet) trenchless segments.
5. **BIDDING**

The WWSP utilized a prequalification process to define eligible bidders for the Program’s projects. Prior to advertisement of any of the construction packages, a prequalification request for proposals was published and subsequent applicant qualifications reviewed. Through this process, the Program identified nine contractors eligible to submit a Bid in response to the advertisement of the PLW_1.1 pipeline project. This prequalification list was specific to the general contractor, but did not prequalify subcontractors.

A second unique aspect of the PLW_1.1 bidding process was the Owner’s procurement of long lead items. The fabrication of the 48-inch diameter steel pipe and the large diameter inline and isolation butterfly valves were identified as long lead items that would not be available within the available construction window if the Contractor needed to procure these elements. In order to maintain the required construction schedule, the Owner solicited individual bids for both the pipe and valves prior to the completion of final design. The Owner then contracted directly with these suppliers. These components were then coordinated in the Bid Documents and furnished to the Contractor during construction.

The Contract Documents were advertised to the prequalified contractors on November 21, 2016 and a mandatory pre-Bid meeting was held two weeks later. The Bids were received and opened on December 22, 2016. Six of the nine prequalified bidders submitted bids. A summary of the bid prices received is provided in Table 2.

<table>
<thead>
<tr>
<th>Bidder</th>
<th>Total Bid Price</th>
<th>Trenchless Construction Items (^{(1)})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bidder 1</td>
<td>$3,516,630</td>
<td>$392,540</td>
</tr>
<tr>
<td>Bidder 2</td>
<td>$4,225,249</td>
<td>$619,250</td>
</tr>
<tr>
<td>Bidder 3</td>
<td>$4,386,240</td>
<td>$598,500</td>
</tr>
<tr>
<td>Bidder 4</td>
<td>$4,400,000</td>
<td>$510,750</td>
</tr>
<tr>
<td>Bidder 5</td>
<td>$4,458,879</td>
<td>$567,525</td>
</tr>
<tr>
<td>Bidder 6</td>
<td>$4,955,000</td>
<td>$709,700</td>
</tr>
</tbody>
</table>

Note: 1. Sum of the Launch Shaft, Receiving Shaft, and Furnish and installation of the Trenchless Crossing payment items.

Figure 4. Trenchless Crossing Profile
6. CONSTRUCTION

PLW_1.1 was awarded to Kerr Contractors (Kerr) out of Woodburn, Oregon. Kerr is a heavy civil and general construction management firm and is listed as the largest heavy civil construction contractor headquartered in Oregon. Kerr’s team included Gonzales Boring & Tunneling, Inc who was subcontracted for the trenchless construction scope of work. Gonzales Boring and Tunneling, Inc is from North Plains, Oregon and both Kerr and Gonzales Boring are familiar contractors in the Oregon market. Following review of the Bid Documents, the PLW_1.1 pipeline project was awarded to Kerr Contractors and a Limited Notice to Proceed issued in early February 2017 and the Notice to Proceed issued on April 12, 2017.

6.1 Construction Scheduling Constraints

As discussed above, the PLW_1.1 construction project overlaps and abuts three other project work areas on this site, including:

- At-Grade Crossing Project – Private Developer. This project consists of improvements to the Cornelius Pass and TV Highway intersection and extension of Cornelius Pass Road approximately 200 feet to the south of the intersection
- Reed’s Crossing Development – Private Developer. This project consists of commercial and residential development of the existing farmland south of TV Highway. The construction activities during PLW 1.1 include preliminary grading and subsurface utility installation.
- Cornelius Pass Road widening Project – Washington County and City of Hillsboro. This project consists of roadway expansion along TV Highway tying into the At-Grade Crossing Project improvements.

In order to facilitate construction of the PLW_1.1 pipeline, and accommodate these other projects, four Interim Project Milestones were identified within the PLW_1.1 Contract. These Interim Milestones prescribed the sequence of critical events and scheduling constraints and the required completion dates for specific elements of construction within the PLW_1.1 project. Development of these milestones was an important approach to limiting the Owner’s risk that the PLW_1.1 pipeline construction would impact, particularly delay, these other projects.

Interim Milestone 2 was developed specific to the trenchless construction scope of work and required the trenchless crossing, included complete installation, testing, disinfection, and all backfill of the trenchless crossing be completed prior to June 28, 2017. This would result in the Contractor being complete of the PLW_1.1 waterline work and out of the SW Cornelius Pass Roadway Right-of-Way prior to construction of the At-Grade Crossing Project. Additionally, interim milestone 2 limited the starting date for when the retrieval shaft excavation could begin, preventing work from proceeding prior to May 1, 2017. This limitation was needed to comply with the allowable activities and construction durations prescribed within the Oregon Department of Transportation (ODOT) access permit, which limited open cut construction activities north of TV Highway.

Following Notice to Proceed, Kerr submitted their preliminary project schedule which correctly identified these construction milestones. Given these constraints, the trenchless construction was identified along the critical path. Project coordination and pre-construction submittals were submitted and upon favorable review, Gonzales Boring mobilized to the Site in early May 2017.

6.2 Pre-boring Work

Protection of existing infrastructure was identified early in the design process as one of the most critical components to the Owner’s risk management. The design mitigated this risk by requiring the Contractor develop a series of baseline measurements to define elevations of existing surfaces and subsurface utilities prior to any construction activities. These locations were then actively monitored throughout construction.

The critical infrastructure identified for monitoring is shown in Figure 5 and included the dual 24-inch sanitary sewer pressure force mains (20 feet north of the launch shaft), a 42-inch water transmission line (45 feet north of the launch shaft), the at grade railroad (90 feet north of the launch shaft), and an 8-inch gravity sewerline (70 feet north of the launch shaft). Additional soil monitoring and surface settlement locations were also required along and adjacent to the alignment to allow overall monitoring of the existing surface.
During installation of these surface and subsurface monitors prior to excavation of the launch shaft, Kerr Contractors noted their potholing efforts found the 42-inch waterline to be encased in a Controlled Low Strength Material (CLSM). The record drawings had indicated a rock backfill, however through additional discussions with the waterline utility, they confirmed a CLSM cap was installed from the springline to 12 inches over the top of the concrete coated steel pipe. During design potholing activities, a cementitious material was identified on the potholing log, but expecting the concrete coated steel pipe, the potholing log defined this as top of pipe. As such, the anticipated elevation of the waterline was confirmed to be approximately 12 inches lower than anticipated during design, decreasing the clearance between bottom of pipe and top of casing from approximately 4 feet of clearance to approximately 2.4 feet of clearance. Additionally, given the CLSM cap, there was concern that the utility monitoring system installed atop the CLSM cap may not be indicative of actual water pipeline location or movement, i.e., the CLSM cap would remain in place even if the 42-inch pipeline began to move.

In order to provide useful monitoring of this critical location, a deep soil monitoring probe was installed five feet south of the 42-inch waterline, approximately 40 feet north of the launch shaft. In addition to monitoring this location as the cutting head approached, the cuttings were specifically monitored to see if any crushed rock bedding material was being mined. The cuttings were monitored while the cutting head approached, moved under, and progressed past the waterline. A contingency plan, including excavation and support of the 42-inch waterline was also established prior to boring operations to allow the team to be responsive to any movement or observation of pipe bedding material.

6.3 Launch Shaft and Boring Work

The 14-foot wide, 20-foot deep, and 40-foot long launch shaft was excavated using a Volvo EC 700 excavator. The launch shaft was excavated using a ‘dig inside the box’ strategy, utilizing a series of stacked trench boxes. This process consisted of an open cut excavation to approximately 8 feet in depth followed by placement of the first trench box. All subsequent excavation was within the trench box. Once the first trench box top was at grade, AZ 18-800 sheet piles were installed at the opened ended front and rear faces. A second set of trench boxes was then placed within the first and the ‘dig inside the box’ progressed to the target depth. This process allowed excavation inside the shaft while keeping the exterior shoring tight with the excavation walls. The sheet piles, which shored the leading face and the thrust wall of the excavation were installed with a 5-foot embedment below bottom of the excavation. The thrust wall was reinforced with an additional 1-inch thick steel plate which also provided a flat vertical surface to bear upon.

The launch shaft was actively dewatered using a redundant sump pumping configuration throughout construction. After initial excavation, the dewatering system stabilized and only produced between 5-10 gallons per minute. As long as the pumps were maintained, groundwater was not an issue during construction.
The bottom of the excavation was stabilized using a 12-inch thick layer of crushed rock, which Gonzales preferred in lieu of a concrete working slab. Following installation of the rock base, the boring rails were installed and line and grade was checked. Gonzales Boring mobilized an American Augers 60-1200 Earth Boring Machine for this work and a summary of its capabilities is presented in Table 3.

Table 3. American Augers 60-1200 Specifications

<table>
<thead>
<tr>
<th>Category</th>
<th>Specification</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boring Size</td>
<td>12” to 60”</td>
<td>Diameter</td>
</tr>
<tr>
<td>Output Torque</td>
<td>129,000</td>
<td>ft-lbs</td>
</tr>
<tr>
<td>Forward Thrust</td>
<td>1,200,000</td>
<td>pounds</td>
</tr>
<tr>
<td>Rated Horsepower</td>
<td>192</td>
<td>HP</td>
</tr>
<tr>
<td>Transmission</td>
<td>5</td>
<td>Speed</td>
</tr>
</tbody>
</table>

A 60.5-inch outside diameter (OD) cutting head was used on the leading face of the setup. The cutting head included a front steer micro steering head which consisted of four hydraulic driven steering flaps. The flaps could be operated independently to redirecting the steering head, if needed. Interior level monitors and guide reflectors along with a dutch level (water level) were used to monitor alignment, grade, and boring level.

The 60.5-inch OD cutting head was tapered with the interior diameter reducing such that the leading auger diameter was 54 inches. The leading auger was held behind the cutting face approximately 4 feet to maintain a soil plug. As the unit progressed, Gonzales reduced the auger diameter from 54-inch to 48-inch after approximately one-third of the casing length was installed. A second reduction, from 48-inch to 36-inch diameter augers was made again at the approximately two-thirds length mark. With the trailing augers only providing spoils removal, reducing the auger size decreased the overall auger system weight and subsequent drag.

6.4 Installation Results

Installation of the 260-foot long and 60-inch diameter casing with 0.875-inch wall was originally estimated by Gonzales Boring to take 13 working days. The 20-foot long casing segments resulted in estimated production of one segment per day. As the work progressed, the installation began to follow a consistent pattern, inline with this production estimate. Boring operations progressed at roughly 10 feet per hour however the full penetration butt welds typically required the remaining work day to complete. A summary of the production rate compared to the planned rate as well as the installation thrust required for the alignment is provided below in Figure 6 and Figure 7, respectively. As shown, the installed production rate was consistent with planned rate. The installation thrust pressure was also fairly uniform after the first 40 feet of casing installation. The thrust pressure did spike right at 250 feet installed length due to an auger coupling pin shearing. This required removal of the augers, replacement of the pin, and reinstallation, however the typical daily progression was able to be maintained.

Throughout construction all Settlement Plan monitoring locations were surveyed daily and compared to the baseline monitoring established prior to construction. Soil settlement points located immediately north of the launch pit were located within a heavy equipment traffic area being used by the Contractor. A number of these monitoring locations were damaged during construction and required replacement; however, no settlement was ever found to be present at this location.

The deep soil monitor used at the 42-inch waterline was also closely monitored. As the casing advanced towards this low clearance crossing, the settlement markers and boring cuttings were diligently monitored. No settlement was observed in any of the locations at or adjacent to this waterline and all the cuttings were consistent. No pipe bedding material indicative of cutting within the 42-inch pipe zone was observed. No additional utility support or contingency plan elements were needed throughout construction.
One location did require additional site investigation. During installation of the contact grouting on the exterior of the casing, the utility monitoring system on the 8-inch gravity sanitary sewer indicated a vertical rise. One potential cause of utility or surface rise is over-pressurizing of the contact grout, which was a potential cause here. Given the concern that the grout injection process could have resulted in lifting the sewerline, a closed-circuit television (CCTV) inspection of the pipeline was completed. The CCTV inspection did not uncover separated joints and found the sewer line to be freely draining across the alignment. Given this visual inspection, it was determined the existing utility was not impacted and no additional monitoring or corrective action was needed.

As the casing was advanced, the receiving shaft excavation began. The excavation was shored using a trench box and the excavation dug using the ‘dig inside the box’ methodology. This shoring method limited the duration of excavation and exposure prior to backfill while maintaining the full side support of the excavation and limiting the risk of ground and roadway sloughing.

The casing installation was completed in 13 working days per plan and required only slight adjustment during installation. Grade was installed to 0.01 feet (0.12 inches) of design elevation and alignment was installed to within 0.08 feet (1 inch), slightly east of design.

Following punch-through of the 60-inch diameter casing, an additional casing segment was pushed through to allow the cutting head to be removed. The augers were then retracted, and the boring machine was used to push the casing spacer supported 48-inch polyurethane lined and coated steel pipe into the casing. Neoprene rubber end seals were installed on either end and the annular space between the pipe and casing was left unfilled to allow flexibility of the steel pipeline under an earthquake event.

7. **CONCLUSIONS**

Installation of the 60-inch diameter casing under the Tualatin Valley Highway was successful; however, a number of lessons learned are available. The success of this project is a result of:

1. the design process and the identification of a shorter alignment to reduce overall length,
2. thorough geotechnical explorations used to identify the vertical alignment and to define the most appropriate trenchless technology;
3. thorough investigation and examination of affected utilities, clearances and settlement monitoring requirements; and
4. diligence during construction.

This diligence during construction included the following:
• Incorporate schedule constraints into the Contract documents – development of multiple interim milestones was used to sequence the work in concert with adjacent construction projects. The design phase coordination across all four projects resulted in identifying specific work windows for each construction project and help avoid impact or delay claims between the contractors.

• Consider findings developed during construction and be open to augmenting the construction approach if warranted: When the CLSM cap was identified on the 42-inch waterline, the team needed to consider the functionality of a utility monitor set atop the CLSM cap. An additional deep soil monitor was installed outside of the CLSM cap at the waterline invert elevation to better monitor the conditions at the low clearance crossing.

• Use monitoring data to help identify follow up investigations: When the gravity sewer settlement monitor indicated a vertical rise, an investigative CCTV inspection was completed. This allowed inspection of the existing utility and verification the utility remained unaffected.

8. REFERENCES


