North American Society for Trenchless Technology (NASTT)
NASTT's 2015 No-Dig Show

Denver, CO
March 15-19, 2015

TA-T4-03

Pipe Ramming Through Challenging Subsurface Conditions in the Pacific Northwest

Matthew P. Olson, Staheli Trenchless Consultants, Lynnwood, WA
Christopher G. Price, Staheli Trenchless Consultants, Lynnwood, WA

1. ABSTRACT

This paper documents two case histories where pipe ramming was specified to install steel casing in challenging subsurface conditions. In Scappoose, OR, a 36-inch casing was rammed beneath the South Fork of Scappoose Creek for 130 feet in saturated soils. In Camas, WA, specifications required two 48-inch casings to be rammed beneath the Burlington Northern Santa Fe Railroad for 60 and 100 feet through boulder-rich ground. The saturated soil conditions in Scappoose and the boulders in Camas each presented unique challenges that needed to be addressed during design. This paper describes the design challenges of each project and compares and contrasts techniques and measures developed during design to mitigate project risk associated with those challenges. Both projects experienced difficulties during construction that were quickly remedied by the Contractors and the Design Teams working together in the field. Successful implementation of innovative plans from the Contractors allowed for successful installation of the casings. The effectiveness of the contract documents is discussed and compared between the two projects. The lessons learned from the design and construction of the two projects will aid the pipe ramming design and construction industry with future high-risk pipe ramming projects.

2. SCAPPOOSE INTRODUCTION

The Scappoose project was located in the vicinity of JP West Road in Scappoose, OR. An aging bridge spanning the South Fork of Scappoose Creek needed to be replaced and the pre-existing sanitary sewer system, two pipelines 6 and 8 inches in diameter, fixed to the bridge underside needed to be replaced as a result. The goal of the project was to install a new sanitary sewer approximately 15 feet south of the new bridge for 150 lineal feet (LF). Recommendation and selection of the preferred trenchless methods was based on the 30 percent design-level plans produced by Kennedy Jenks and the geotechnical report for the new bridge (Pfeiffer, 2012).

Two exploratory borings were drilled along JP West Road for purposes of designing and constructing the new bridge spanning the South Fork of Scappoose Creek. Beneath the creek, the bore logs indicated loose to medium dense silty sand with scattered organics, wood debris, and gravel with some silt and a trace of sand, underlain by medium dense to dense sandy gravel with scattered cobbles. Groundwater was believed to reflect the water level in the South Fork of Scappoose Creek.

3. SCAPPOOSE DESIGN

The Design Team believed pipe ramming would be feasible in the anticipated soil conditions and provided the greatest chance of successful sewer installation without significant settlement below Scappoose Creek. The anticipated settlement was thought to be small due to excavation not taking place during the casing installation. If groundwater and loose or running soils were encountered along the alignment, the soil within the casing would provide resistance at the face and generally counterbalance effective lateral earth pressures, holding up surrounding soils and preventing settlement.

The presence of wood debris in the geotechnical borings suggested that wood might be encountered as the casing was rammed along the alignment. It was uncertain as to the size and distribution of wood that might be encountered, and as such it was recommended that the casing be sized to a minimum 36-inch diameter to allow for manned entry of the casing if needed. A 36-inch casing would have also been sufficient to engulf the scattered cobbles along the alignment, as pipe ramming can generally accept objects up to 80 percent of the casing inside diameter without issue. It was recommended to maintain a depth of cover equivalent to two casing diameters, or 6 feet in this case, to disperse any near-pipe settlement that would occur so that it would be negligible by the time it propagated to the ground surface. At this depth, groundwater head at the casing crown was anticipated to be 8 feet. Due to the presence of water, the Contractor was required to maintain an adequate soil plug within the casing while the face was passing under the creek.

4. SCAPPOOSE CONSTRUCTION

The project was awarded to K/E Excavating with Gonzales Boring and Tunneling as the trenchless subcontractor. Pipe ramming began on Thursday, March 28th 2014. Staheli Trenchless Consultants (STC) was scoped to perform construction inspection for a total of two days on the project and was not present on the first day of trenchless activities that included launch of the first 10-foot casing. An STC inspector was on-site on the second day of trenchless activity, which began with setting up the second 10-foot casing in the launch shaft. Upon discussion with Gonzales' foreman, STC learned that the first casing was installed using an auger boring machine (ABM) without spoil removal with the augers. Thus, the spoils were still inside the first casing. Little progress was made the first day due to the significant rainfall throughout the day and the abundance of surface water making its way into the launch shaft (Figure 1).

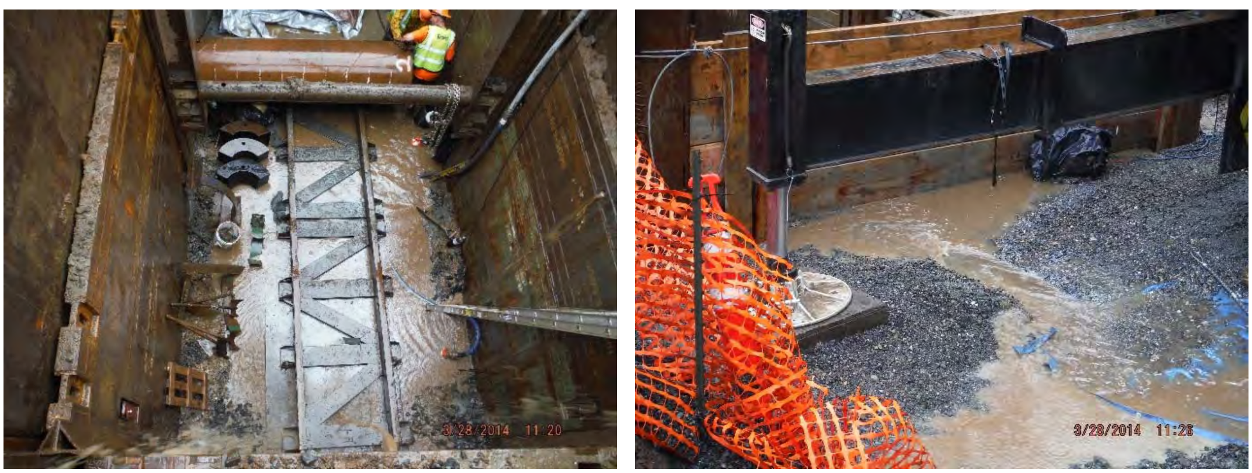

Figure 1. (Left) Flooding within the Launch Shaft; (Right) Channel of Surface Water Flowing into the Launch Shaft

STC was asked to come back to the site on Wednesday, April 02. By that time 42 feet of casing had been installed. The Contractor was required to keep soil within the casing during the ramming operations to provide resistance to flowing or running sand and to hold back hydrostatic pressures. In contradiction to this specified requirement, 35 feet of soil had been augured from within the casing leaving a 7 foot soil plug at the face. The fifth 10-foot casing was welded in place and ramming commenced without complications at an average advancement rate of 2 feet per minute.

The sixth casing was welded to the fifth, two hours after the fifth casing was rammed. The sixth casing was rammed 1 to 2 feet before the casing began to rebound; forward progress was immediately stopped as the air compressor recharged between blows. Gonzales allowed the hammer to strike the collets for a few minutes before closing the valve to the compressor and stopping the ramming process to evaluate the situation. The crew members informed the inspector that they believe they had hit an obstruction and proceeded to remove their equipment from the shaft and secure the site for the day.

Normally, if an obstruction is encountered with pipe ramming the hammer is disconnected, the casing is cleaned of spoils, and the obstruction is removed from the face manually. Unfortunately, the lead edge of the casing was located directly underneath the South Fork of Scappoose Creek, which was flowing strongly following the significant rainfall over the previous week. The Design Team was concerned that if Gonzales were to clean out the casing the soils at the face would flow uncontrolled into the casing given the 8 feet of groundwater head.

The crew returned on Thursday and began inserting auger flights into the casing. When they were asked for their construction plan they said they would insert augers all the way up to the face and attempt to auger out the spoils as they jacked the casing forwards with the ABM. They were hoping that whatever was stopping them at the face would be excavated by the cutterhead, allowing for forward progress of the casing. The Design Team was not alone with their worries regarding the groundwater head at the face; before auger boring began Gonzales used chain rigging on the ABM so that they would be prepared to lift the ABM out of the shaft should it flood upon cleaning out the casing (Figure 2).

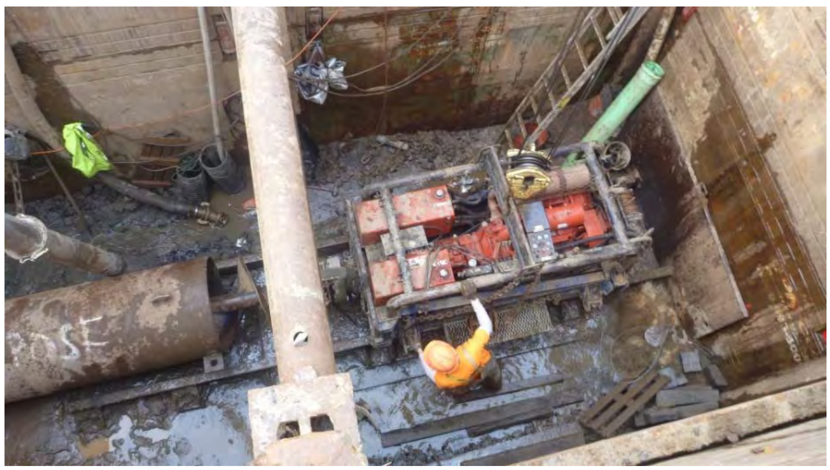

Figure 2. Crane Ready to Pick ABM in the Event of Significant Water Flow through Casing

The ABM was able to advance the casing and excavate the spoils without uncontrolled flow of groundwater. There was some water coming from the spoil chute along with the excavated cobbles, however, it was of a manageable flow rate. It took a total of three minutes to advance the remainder of casing six. It became obvious that there was no obstruction at the face. The reason for the inability to advance the casing via pipe ramming when auger boring was successful was still unclear. There were no signs of wood within the spoils, just gravel and small cobbles with silt and sand.

Casings six through eight were installed with the ABM without issue. Halfway through the installation of casing nine the augers bound up, got stuck, and caused the machine to roll approximately 90 degrees. No one was hurt, although, the tracks and ABM had to be realigned and the augers needed to be freed before further progress could be made. Upon moving the ABM back and forth and attempting to rotate the augers intermittently, they were able to free the bound augers and progress could resume once more. Cobbles and gravel were coming out of the chute throughout the auguring process. The casing was advanced another 2 feet before the crew turned off the ABM and exited the shaft.

The foreman informed our inspector that they had a problem with the augers and they suspected they had broken an auger flight. They proceeded to pull the augers from the installed pipe. At 33 feet, the auger flight connection was broken, leaving approximately 50 feet of flights in the casing. The crew spent the next two days attempting to rid the casing of the flights, but were unsuccessful in removing them in their entirety. It was decided that the remainder of casing nine would be installed via pipe ramming due to their inability to remove the augers.

Casings nine through 13 were installed via pipe ramming without noteworthy issues, completing the drive. The casing came into the reception shaft 1.5 feet lower than design; although, since the carrier pipes were to operate under pressure the misalignment was not problematic. Upon demobilizing the pipe ramming equipment, the crew began to work on removing the remaining augers and spoil from the casing.

5. SCAPPOOSE LESSONS LEARNED

The combined auger boring/pipe ramming project in Scappoose provided many valuable lessons. The first was centered on hitting refusal during the ramming of casing number six. Originally, it was thought that an obstruction was blocking casing six from advancing; however, wood was not observed in any of the spoils, a boulder did not prevent forward progress when the crew used the auger boring machine to jack the casing, and the hammer and casing combination should have allowed progress through the cobbles that were observed in the spoils. The Design Team questioned why auger boring was capable of advancing the casing past this location when pipe ramming was not. Analysis of the geotechnical report provided some explanation for this phenomenon.

Geotechnical boring #2 was located in close proximity to the launch shaft and indicated silty sand (SM) with scattered organics that were wet, loose, sand of fine to medium grain size, and organics consisting of wood debris. SPT blow counts ranged from 4 to 10 blows per foot. Boring #1 was located near the reception shaft and consisted of gravel (GP), with some silt and a trace of sand with the following characteristics: wet, medium dense to dense, fine to coarse sand, and fine to coarse sub-rounded to rounded gravel. It was expected that the soil adjacent to the casing alignment near the reception shaft would have SPT blow counts ranging from 19 to 50 per 2 inches of penetration. It is likely that the 50/2" value was attained as the sampler was hitting a cobble.

It was apparent that the soil transitioned from a looser material with limited gravel, to a dense to very dense poorly graded gravel. Furthermore, the soil at the casing spring-line was saturated and likely 9 to 10 feet below the water level in the South Fork Scappoose Creek. Upon evaluating the likely soil conditions along the alignment and anticipating the transition from the less dense silty sand to the more dense poorly graded gravel, it became apparent that with only 52 feet of casing advanced, there was not sufficient pipe-soil interface friction within the loose soil zone to resist the rebound generated at the face as the casing attempted to enter the dense soil zone.

When the hammer was hitting the casing with no advance, the inspector could see soil ooze out from around the bore along the casing outer surface. The loose saturated conditions, combined with the energy shockwaves traveling from the hammer to the casing to the soil, and the high soil resistance at the cutting shoe on the casing face, were the perfect ingredients for causing the casing to rebound forwards and backwards, essentially oscillating, without permanent advancement. When the crew decided to use auger boring in lieu of hammering, the constantly applied force from the ABM jacks combined with the augers ability to excavate from within the casing allowed for permanent advancement of the casing. Auger boring would not have been successful in other situations that would prevent advancement with pipe ramming, such as an obstruction.

6. CAMAS INTRODUCTION

The STEP Sewer/Garfield Waterline Relocation Project in Camas, WA was spurred by the Burlington Northern and Santa Fe (BNSF) Railway Company. The City of Camas (Camas) had a waterline within BNSF's right of way (ROW) and when BNSF decided to move their tracks, Camas was forced to relocate their main. The water main relocation consisted of abandoning the existing line and installing a new 16-inch ductile iron water main for 66 LF across BNSF property from SE Garfield Street to Camas' existing 16-inch water main in SE 6th Avenue. In addition to the water main installation, a 24-inch sanitary sewer force main was to be installed across BNSF property from the intersection of SE 6th Avenue and SE Polk Street for 94 LF to the other side of BNSF's ROW to be available for use upon further sanitary system upgrades. The crossings were approximately one third of a mile apart, on each side of the Washougal River.

Otak, Inc. was solicited as the prime design firm, who sought out Apex Companies, LLC to perform the geotechnical investigation. One of the most challenging aspects of the project was the subsurface conditions. Research into the geological characteristics of the area revealed that flood deposits with boulders, cobbles, gravels, and sands were to be expected. Boulders in excess of 10 feet in diameter had been found within the flood deposits. The geotechnical investigation program consisted of four borings, one at each of the proposed bore pit locations, drilled using mud-rotary techniques.

Geotechnical borings B1 and B2 were taken along the sanitary sewer alignment at the southern and northern ends, respectively. Generally, both borings indicated medium stiff clayey silt, loose to medium dense sandy silt, and loose to medium dense sand underlain by very dense gravel, cobbles, and boulders in a sandy/silty clay matrix. Standard penetration test blow counts within the underlying dense layer were primarily above 50 blows per 12 inches of penetration. The overlying soil layer had blow counts in the range of 4 to 10 blows per foot, with a blow count of 18 observed near the soil transition. Borings B3 and B4 were taken along the southern and northern water main alignment termini, respectively. These borings indicated a similar trend as the sanitary sewer borings, showing a softer soil layer underlain by a layer of sandy clay/clayey sand matrix with gravel and cobbles. Boulders were not encountered in the sandy clay/clayey sand matrix during boring B3, but were found in boring B4. Apex noted that groundwater conditions could not be accurately determined at the time of drilling due to the mud rotary drilling technique used to complete the borings; however, boring B3 was allowed to remain open for several hours at which time groundwater was measured at approximately 18 feet below ground surface, or at an approximate elevation 32 feet.

STC was hired at the 60 percent design level to evaluate feasible trenchless construction methods and develop trenchless related contract documents. To gain a stronger understanding of the frequency and size of the boulders and to gain first-hand knowledge of the soils and their behavior, STC met the Camas Public Works crew on site to observe the excavation of two test pits dug on each end of the sanitary sewer alignment. The southern test pit, located approximately 65 feet south of the railroad, indicated a distinct transition between the overlying medium stiff silt layer and the underlying sandy clay matrix with gravel, cobbles, and boulders. The largest boulders encountered were located near the transition between the two soil types. The first large boulder was unearthed 6 feet below ground surface, translating to an elevation of approximately 43 feet which coincides with the contact transition shown in boring B1. At a depth of 7 feet the soil transitioned from a brown sandy silt to a gray sand with numerous cobbles. Three boulders ranging in size from 2 to 3 feet were discovered by the time the test pit was 8 feet deep. Boulders/cobbles near 1 foot in size were slightly more abundant. Figure 3 (left) and Figure 3 (right) depict the bottom of the southern test pit at a depth of roughly 8 feet and the largest boulder (3 feet) encountered during the excavation, respectively.

Cobbles and boulders were not encountered in the test pit at the northern terminus of the alignment. Absence of boulders within this test pit is likely attributable to the ground surface being 7 to 8 feet higher in elevation than at the southern end and the maximum achievable excavation depth for the backhoe being 10 feet deep. Based on excavation of the test pits and correlation to the boring logs, it was anticipated that cobbles and boulders would be encountered at elevations less than 42 and 35 feet at the southern and northern ends of the sanitary alignment, respectively. Groundwater was not encountered in either of the two test pits, and the sides of the excavations were stable at a near vertical side slope for the duration of the exploration.

Figure 3. (Left) Southern Test Pit at 8 Feet Deep; (Right) Three Foot Boulder from Southern Test Pit

Around the time of the test pit excavations, Northwest Natural was on site to relocate their gas line in the vicinity of the Garfield Waterline installation. The pictures provided by Otak of the excavation indicated that boulders were present on the west side of the Washougal River and suggested that similar subsurface conditions existed at each of the proposed pipeline alignment locations. Groundwater was not observed in any of the pictures of the excavation made for the Northwest Natural pipeline relocation.

7. CAMAS DESIGN

Microtunneling and open shield pipe jacking (OSPJ) were trenchless methods that were evaluated during the feasibility stage of the design process. The upfront cost of the microtunneling equipment combined with the high risk of encountering obstructions beneath the railroad ROW steered the Design Team away from microtunneling. Although OSPJ allows for access to the face to remove obstructions, there is limited work space at the face due to the cutterhead. Additionally, encountering a boulder or obstruction would cause significant delay, as the conveyor belt would have to be moved to access the face for removal of an obstruction. Furthermore, since both installations were for pressure applications, the expense of using equipment capable of on-grade installations was unjustified. As such, the Design Team decided to use an alternate trenchless method.

Auger boring and pipe ramming were attractive trenchless construction methods for the project. Both options were considered relatively low cost installation methods and would allow obstructions to be removed from the face in a more efficient and less costly manner than other trenchless technologies, provided the casing is sized to allow personnel entry. Based on experience crawling into steel casings and upon talking to contractors, a minimum casing diameter of 48 inches was specified. Although, it’s possible to remove obstructions from the face of smaller casings, the larger casing would increase the size of boulder that could be injested as well as increase obstruction removal efficiency due to the increased working room. The increased cost to go from a smaller casing to a 48-inch casing would be more than offset by efficiency gains during installation. With regards to selecting auger boring or pipe ramming, there were advantages and disadvantages to each that were evaluated considering project goals and acceptable levels of risk and mitigation costs.

Pipe ramming required use of a pneumatic hammer to perform the installation and an ABM to clean out the casing upon completion of the drive. As such, equipment cost on a per day basis were likely higher for pipe ramming than auger boring. However, it would take longer to complete an auger boring drive due to the inability to ingest boulders greater than approximately 1/3 the casing diameter. Additionally, removal and reinstallation of the augers every time an obstruction was encountered would be detrimental to the productivity of installation with the ABM. Given the abundance of boulders and cobbles anticipated along the alignment, pipe ramming was the trenchless construction method of choice. In addition to carrying a lower cost, pipe ramming has several characteristics that mitigated construction risks to a greater extent than auger boring. Risk mitigation advantages of pipe ramming over auger boring included the following:

- Ability to ingest larger objects
- Ability to potentially break or split objects encountered by the cutting shoe without manned entry
- Less risk of settlement caused by over-excavation

Since both the water main and sanitary sewer installations were to be crossing underneath BNSF rail, settlement or heave of the railroad was of major concern. Pipe ramming is one of the least disruptive trenchless technologies in terms of ground surface movement and is often the preferred alternative for casing installations beneath railroads. Settlement during pipe ramming installations is generally negligible, as excavation only takes place from within the casing and is usually only executed after the installation of the casing. Heave is generally not an issue for pipe ramming installations, as very little soil is displaced as the casing is advanced.

Although heave and settlement are normally not expected, there was concern that the abundance of cobbles and boulders would increase the chances for ground movement due to the relatively shallow depth of the crossings. It was possible that the cutting shoe could hit a boulder and the boulder would roll to the inside or outside of the casing. Rolling to the outside would cause compression or heave of the surrounding soil, while rolling to the inside would leave a void where the boulder had been that could result in settlement. During design, it was recommended to maintain a minimum clearance of 8 feet, equivalent to two casing diameters, between the bottom ostaff
f the railroad track and the crown of the casing to reduce potential for ground movement at the tracks.

The casing for the sanitary sewer was designed at a depth below tracks of 12 feet, or elevation 40, and the casing for the water main was installed 6 feet below the tracks, or elevation 44. Exception to the 8-foot clearance recommendation for the water main casing was necessary due to the shallow elevation of the watermain on the downstream and upstream side and corresponding hydraulic reasons. Two-inch grout ports were required on the casings at the 2 o’clock and 10 o’clock positions at 10-foot center-to-center spacing to be used for contact grouting upon completion of the pipe ramming work to fill any voids that may have occurred.

Once the alignment and trenchless construction method had been selected the specification was written to minimize project risk for both the Contractor and Owner. Figure 4 illustrates examples of what can happen to a casing in the event of repeated hammering against an impenetrable object. It is not uncommon for the lead edge of an underdesigned casing to crumple upon repeated hammering against an obstruction. Since it was understood that the likelihood of encountering boulders along the alignment was high, significant design effort needed to be allocated to specifying the necessary casing minimum wall thickness, casing steel specified minimum yield strength (SMYS), cutting shoe minimum thickness, and cutting shoe steel minimum SMYS. The goal of specifying minimum strengths and thicknesses was to give the Contractor enough confidence to ram against a boulder until the boulder broke and the casing could be rammed through or the boulder deflected to the inside or outside of the casing. By increasing the up-front cost of the steel, the amount of times required to access the face and remove a boulder would decrease and accordingly, construction duration and associated costs would decrease.

Figure 4. (Left) Crumpled Casing due to Point Loading; (Right) Flattened Casing due to a More Uniform Load

The geotechnical report indicated that basalt boulders would be present, but did not describe the strength of the basalt. Basalt strength can vary significantly, but has been generalized to have unconfined compressive strengths ranging from a minimum of 15,200 pounds per square inch (psi) to a maximum of 52,011 psi, with an average strength of 31,053 psi (Johnson and DeGraff, 1988). It was desired to increase the strength of the steel casing beyond the standard ASTM A36 grade B steel (SMYS of 36,000 psi) to an A572/50 steel with a SMYS of 50,000 psi to increase the steel yield stress beyond that expected of the basalt. To ensure a sufficient casing thickness, a nominal casing diameter to thickness (D/T) ratio was specified to be a maximum of 64, resulting in a casing thickness of 0.75 inches or greater for a 48-inch diameter casing. Since the lead edge of the casing, or cutting shoe, would be the point of contact with a boulder, it was particulary important to ensure the strength and stiffness of the cutting shoe would be sufficient to withstand the stresses imposed by the hammer and point loading from boulders. A cutting shoe steel SMYS of 60 ksi and a D/T maximum of 27 was specified to ensure a yield strength above the maximum anticipated boulder compressive strength and rigidity sufficient to prevent collapse of the casing’s lead edge. As assembled, the cutting shoe would have a thickness greater than 1.7 inches.

The Design Team wanted the contracting community to be fully aware of the soil conditions and to consider the abundance of cobbles and boulders anticipated along the alignment when preparing their bids; however, it would have been unreasonable for the Contractor to have no mechanism for extra payment if they were obstructed by a large boulder. To address this challenge the Design Team defined “obstruction” in the pipe ramming specification, developed measurement and payment language specific to obstruction removal, and wrote a cobble and boulder baseline (baseline) to be used to administer the differing site condition (DSC) clause in the Washington Standard Specifications. The baseline read as follows:

> *“The Contracting Agency is hereby establishing a baseline for cobbles and boulders defined by the Unified Soil Classification System (USCS) that are located along the pipe ramming alignment*

(Cobble and Boulder Baseline). As provided for in the Contract Documents, the Cobble and Boulder Baseline will be used to administer the Differing Site Condition (DSC) Clause. Numerous cobbles and numerous boulders measuring up to 80% of the casing inside diameter, in the longest dimension, will be encountered along the pipe ram."

The baseline clearly states that numerous cobbles and numerous boulders with a largest dimension of 80% of the casing inside diameter would be found along the alignment. Therefore, cobbles and boulders meeting this criteria would not be considered a differing site condition; however, if boulders larger than 80% of the casing inside diameter, or 37 inches for a 48-inch ¾-inch wall casing, were encountered throughout the ramming process the Contractor would have a valid DSC.

The definition for obstruction had to be properly coordinated with the measurement and payment language. It is not uncommon to see measurement and payment language where the Contractor is responsible for removing obstructions less than or equal to a certain size and the Owner would be responsible for obstructions measuring larger than that. The Design Team chose to not define the size of boulder that would constitute an obstruction and warrant extra payment, but rather define obstruction as follows:

"Obstruction: An object or feature that lies completely or partially within the cross-sectional area of the cutting shoe and prevents forward movement of the casing after all diligent efforts to advance past the object by the Contractor have failed. Any and all material engulfed by the casing shall not be considered an obstruction."

By doing so, the Contractor would be eligible for extra payment regardless of the size of the object preventing forward progress. The following respective measurement and payment language accompanied the obstruciton definition:

"Measurement will be made for Obstruction Removal (as defined herein) on a Force Account basis beginning with identification of the extent of the obstruction and ending upon removal of the obstruction from the casing. No measurement will be made for removal of engulfed material or spoils from the casing necessary to access an obstruction encountered at the cutting shoe face. Regardless of composition, engulfed material or spoils will not be considered an obstruction."

"Obstruction Removal, Force Account, as described in Section 1.09.6 Force Account, the Obstruction Removal pay item shall not exceed the Allowance, and shall include all equipment, labor, and materials required to remove Obstructions at the cutting shoe face. No Payment shall be made for removal of engulfed material or spoils from the Casing."

Under this measurement language, expenses encurred related to removal of the obstruction would be measured according to the force account requirements in the Washington DOT Standard Specifications, but expenses encurred to clean out the casing and access the face would not be measured. The Contractor was required to clean out the casing upon drive completion and was to be compensated for the work under the pipe ramming bid item. This measurement language ensured the Contractor would not receive payment twice for removing engulfed spoil.

The payment language ensured the Contractor would be paid according to standard force account language for all expenses incurred to remove the obstruction up to a pre-determined allowance determined by the Owner and Design Team. It was estimated that less than $50,000 would be spent removing obstructions. $30,000 and $20,000 were allocated as allowances for the water main and sanitary sewer, respectively.

8. CAMAS CONSTRUCTION

The bid was awarded to 3 Kings Environmental, Inc. on April 15, 2014. Stadeli Boring and Tunneling, Inc. (Stadeli) was subcontracted to perform the pipe ramming work. The pits for the water main installation were complete and pipe ramming commenced on Monday, June 30, 2014 towards the end of the day. Within 45 minutes of starting the ram, and with 10 feet of installed casing, the casing hit an obstruction (Figure 5, right). The obstruction was hit along the casing crown, which caused the ground surface to heave 3 inches and the casing to deflect downward. At this point, the depth of cover to the casing crown was approximately 5 to 6 feet. Stadeli cleaned out the spoils within the casing (Figure 5, left) and proceeded to blast the boulder with an Ezebreak Micro-Blaster. The crew then proceeded to clean out above and below the casing, requiring the blasting of an additional boulder to provide room to jack the casing back on alignment. First attempts to realign the casing were unsuccessful, requiring the Contractor to rent an additional 100 ton jack. It took two days for the boulders to be removed and for the casing to be realigned to the design grade.

Figure 5. (Left) Soughing of Interspatial Soils; (Right) Obstruction at the 12 o'clock Position

During the two days the crew was removing boulders and adjusting the casing they requested to switch from pipe ramming to a combination of auger boring and hand mining to finish the drive. They were concerned that pipe ramming would cause unacceptable ground surface movements, which would be a significant problem in the vicinity of the railroad tracks. Their request for a method switch was granted. The obstruction measurement and payment specification language was stressed to the Contractor to reiterate that they would not be paid for removing engulfed spoils or retracting their augers to access the face.

Stadeli proceeded with installing the casing with auger boring and removing the augers and hand mining upon encountering obstructions. The drive was completed on July 16. Throughout the bore they encountered a total of nine obstructions on the water main drive, exceeding the allowance amount by about $15,000. Stadeli honored the allowance and was reimbursed for $30,000 of force account pay. Stadeli was granted permission to use auger boring and hand mining for the sanitary sewer drive as well, due to their success on the water main drive.

The crew began jacking the casing for the sanitary sewer on July 23. The casing was installed after six days of work on July 30, 2014. One obstruction was encountered near the end of the drive, which required force account work totaling $9,800. A total of $10,200 of the budgeted obstruction removal funds remained upon completion of the two installations. Surface heave and settlement were not observed in the vicinity of the railroad tracks on either drive, and the casings were installed within specified tolerances.

9. CAMAS LESSONS LEARNED

The specifications had been written in a way to give the Contractor confidence using the pipe ramming method to ram casing through a cobble and boulder rich environment. The steel casing and cutting shoe had sufficient D/T ratios and SMYS. Regardless, Stadeli had a greater degree of comfort using the ABM to jack the casing than using the hammer to ram the casing, and they proved to be successful using auger boring to install the water main and sanitary sewer casings.

Although the conservative casing and cutting shoe specifications likely resulted in a slightly higher bid price, the risk of catastrophic casing collapse, which would significantly escalate construction costs, was greatly reduced. This gave all relevant parties a greater comfort as construction ensued. The collaborative effort of Camas, the Design Team, and Stadeli resulted in efficacious project results. The measurement and payment language worked well for compensating the Contractor for extra work required to split and remove obstructions from the face, providing the Contractor with a fair and equitable adjustment to their bid for the extra work. The Contractor's diligent effort reduced the expenditure required to remove obstructions when they were encountered, and the Contractor, Design Team, and the City of Camas had a common understanding of how obstructions would be handled in the field and compensated.

10. SUMMARY

A combination of auger boring and pipe ramming were necessary to install casing beneath the South Fork of Scappoose Creek. When the pipe was rammed to refusal, auger boring was used to provide a constant load on the casing, preventing rebound as the casing face advanced from the loose soils into the denser soil strata. Fortunately, the Contractor was able to operate the auger bore with the augers retracted, creating a soil plug at the face that provided stability during casing advancement. The soil plug prevented uncontrolled flow of soil and groundwater into the shaft. Later, as the soil transitioned to include an abundance of gravel and cobbles, which bound up the augers, pipe ramming took over as being the most suitable method and was used to complete the drive.

The abundance of cobbles and boulders within the Camas alignments combined with the necessity to prevent ground surface heave and settlement near the BNSF railroad tracks led the Design Team to specify pipe ramming as the preferred trenchless construction method. Pipe ramming is generally more suitable for preventing heave and settlement of the ground surface and is often used for casing installations beneath railroad tracks. Auger boring has a lesser ability to install casing through boulder-rich ground than pipe ramming, due to the presence of the auger string within the casing that is not able to convey boulders larger than approximately 30 percent of the casing inside diameter. Despite these conventions, the Contractor felt more confident using the auger boring method with regards to surface heave. The Contractor did not attempt to get paid for the time required to remove the augers upon encountering an obstruction, which was precluded from Force Account pay in the specification. Attributable to the measurement and payment language in the contract and the Contractor, Owner, and Design Team’s willingness to collaborate effectively, the project was completed successfully with fair compensation for the work performed to remove obstructions from the face.

Both the City of Scappoose 130 LF, 36-inch diameter casing installation and Camas’ 66 LF and 94 LF, 48-inch diameter casing installations were performed successfully using a combination of pipe ramming and auger boring trenchless construction methods. It was found that depending on the soil conditions encountered during construction, one method that may have been preferred due to rule of thumb conventions, such as using pipe ramming in lieu of auger boring when there is significant groundwater head, may indeed be less preferable if the Contractor has more experience and is more comfortable with the method that is less preferred from a purely technical standpoint. Adjustments to the construction method mid-way throughout a project may be warranted, and project teams should work collaboratively to ensure a smooth transition if necessary. The auger boring and pipe ramming technologies allow a relatively effortless exchange between the two methods, which is an inherent benefit of these closely related methods.

11. ACKNOWLEDGEMENTS

Staheli Trenchless Consultants is thankful for the help of Kennedy Jenks, the City of Scappoose, K/E Excavating, Gonzales Boring and Tunneling, Otak, the City of Camas, 3 Kings Environmental, and Stadeli Boring and Tunneling. The collaboration between all parties resulted in successful projects for Owners of the Scappoose and Camas projects.

12. REFERENCES

Durspek, S. (2014) – Telephone Interview, October 30, 2014, Bothell, WA

Johnson, R. B., and DeGraff, J. V. (1988) – Principles of Engineering Geology, John Wiley and Sons, Inc., New York, USA

Pfeiffer, T.J. (2012) – Foundation Investigation, Foundation Engineering, Inc., November 6, 2012, Beaverton, OR

Washington State Department of Transportation. (2012) – Standard Specifications for Road, Bridge, and Municipal Construction, Washington State Department of Transportation, M 41-10, Olympia, WA