North American Society for Trenchless Technology (NASTT)
NASTT's 2016 No-Dig Show

Dallas, Texas
March 20-24, 2016

TM2-T4-02

# Into the Void: Case Study of an Emergency Pipe Burst under the West Seattle Bridge

Matthew Olson, Staheli Trenchless Consultants, Lynnwood, WA
Cody Nelson, Seattle Public Utilities, Seattle, WA

## 1. ABSTRACT

This paper presents a case study describing the design processes and construction results of an emergency size-for-size pipe burst replacement of an 8-inch vitrified clay pipe in Seattle, Washington. The existing combined sewer had a collapsed section of approximately 8 feet, causing a void above the sewer. The location of the void was within the embankment for the West Seattle Bridge, a major thoroughfare in and out of West Seattle, directly below the east bound lanes. The collapse had resulted in complete blockage and resultant surcharge of the combined line, and threatened a sanitary sewer overflow if not resolved. There was also major concern that the collapsed pipe and resulting void would propagate to the road deck and result in settlement of the West Seattle Bridge. As such, replacement of the pipeline was imminent and triggered Seattle Public Utilities (SPU) to seek professional consultation to evaluate the feasibility of using trenchless technologies to perform the replacement in-lieu of re-routing the sewer with open trenching. Staheli Trenchless Consultants worked hand-in-hand with SPU to develop risk profiles for feasible pipeline replacement methods, and the design team selected pipe bursting to achieve project goals while keeping construction costs and risk exposure to a minimum. Design and construction was challenging due to numerous site constraints and the necessity to burst a collapsed pipe under a thoroughfare that could not be shut down. Although the project was challenging and fast-tracked, the combined efforts of the design team and the contractor proved successful in replacing the collapsed pipe with minimal impact to adjacent residents and homeowners.

## 2. INTRODUCTION

This paper highlights the various stages of the SW Orleans Street Pipe Replacement Project, from feasibility analysis through construction. The purpose of the Project was to replace an 8-inch vitrified clay pipe (VCP) combined sewer that had collapsed, creating a void approximately 6 feet in diameter directly below the east bound ramp to the West Seattle Bridge (WSB). Due to the presence of the void and the subsequent risk of settlement to the eastbound ramp pavement deck, timely and efficient replacement of the 8-inch pipe and grouting of the void was crucial, resulting in the project being classified as an emergency replacement project. Besides risk to public safety, the collapsed pipe and resulting void threatened to further isolate the quiet neighborhood peninsula. To stress the importance of the emergency replacement, the WSB is the primary corridor for transit to and from West Seattle and downtown, with alternative access provided by a detour that could foreseeably add 30 minutes to the West Seattle/Downtown Seattle commute. Figure 1 identifies West Seattle, the WSB, and the approximate location of the collapsed 8-inch combined sewer.

Figure 1. Vicinity Map (Left), Project Location (Right).

Seattle Public Utilities (SPU) had performed closed-circuit television (CCTV) inspection of the existing sewer, indicating an 8-foot long section of the pipe had collapsed, 25 feet below the eastbound lane of the ramp. As a result of the collapse, combined sewer and storm flows had backed up at least 60 feet from the collapse, surcharging the nearby catch basin on the west side of the WSB ramp. In response to the surcharging, SPU crews had setup a bypass pump in the catch basin west of the collapse to reroute flows to a downstream location. At the time Staheli Trenchless Consultants (STC) was brought on board, settlement monitoring of the pavement deck indicated that settlement had not yet occurred. STC was hired to advise SPU regarding the feasibility of open-trench installation versus trenchless construction for purposes of replacing the existing pipeline and to backfill the void. Should further settlement monitoring have indicated signs of pavement settlement, remedial grouting of the void would have been scheduled immediately, influencing the applicable trenchless methods for replacing the existing pipe. As such, the feasibility analysis and resulting design and construction were under significant pressure to complete the Project.

## 2. Site Conditions

As with many Seattle neighborhood sewer replacement projects, the site constraints were substantial. Access to the site was restricted at the east and west ends of the alignment. The east side of the alignment could only be accessed from SW Orleans Street, a 50-ft wide residential street, which in turn was only accessible through 30th Avenue SW, a 15-ft wide alley. There was some room for staging along SW Orleans Street, upon placement of temporary no-parking signs, and underneath the WSB adjacent to the abutment, but both locations did not allow for much room to turn around, nor did they provide for a flat staging area; the slope on SW Orleans Street is approximately 22%. Neighbors were inconvenienced by the no-parking restriction directly outside their homes.

The west side of the alignment fortunately, was undeveloped; however three large trees needed to be felled and the site cleared of brush for access.  However, a disadvantage at the west side is that the work area could only be accessed as one was traveling west on the WSB, and by pulling over at the 150-foot long pull off on the west side of the ramp. From there, equipment and personnel had to traverse the side of the ramp approximately 200 feet to reach the upstream end of the existing 8-inch pipe. If one wanted to go from the east end of the alignment to the west, one would have to travel east on the WSB before making a u-turn and head west on the WSB. To accommodate the work, the outside lane of the WSB was closed overnight several times in order to offload equipment and materials to the west side of the project area. Operations such as this, required efficient and well thought out construction staging and work strategies.

At the time of the feasibility study, the subsurface conditions were described in a draft geotechnical report prepared by SPU prior to the declaration of an emergency condition. The geotechnical study involved reviewing readily available geotechnical and geological information, conducting a geotechnical exploration program consisting of two hollow stem auger borings (B-101 & B-102), and performing laboratory testing and engineering analyses. It was found that geologic formations in the project area include alluvium, Lawton Clay, and Olympia beds. Based on borings B-101 and B-102, the existing 8-inch VCP was likely to be within Mass Wastage deposits, which generally consists of loose to medium dense poorly-graded sand and silty-sands (SP-SM to SM) with varying amounts of gravel, soft to very stiff silt (ML), and stiff clay (CL). The standard penetration test N-values for the Mass Wastage deposits ranged from 2 to 30, with an average of 14. Lawton Clay was encountered beneath the Mass Wastage deposits in boring B-101 and generally consisted of hard silt (ML). N-values for the Lawton Clay ranged from 58 to 71, with an average of 65.

While drilling B-101 near the upstream portion of the alignment, groundwater was encountered 7.5 feet below ground surface (bgs) at an elevation of 138.5 feet. Groundwater was found 10 feet bgs, elevation 86 feet, while drilling B-102. A standpipe piezometer was installed in B-102 to measure fluctuations in the groundwater level. One groundwater reading had been obtained at the time of the draft geotechnical report, indicating groundwater at elevation 88.75 feet, or 7.25 feet bgs. This groundwater reading was taken February 10, 2015, when groundwater levels are anticipated to be at a high. The existing 8-inch VCP in the vicinity of borings B-101 and B-102 was at elevations 130 feet and 90 feet, respectively, leading the design team to believe the upstream end of the alignment could be 10 feet below the groundwater table elevation, but the downstream end of the alignment would be above the groundwater.

## 3. TRENCHLESS VS. OPEN TRENCH FEASIBILITY AND RISK ASSESSMENT

SPU desired for STC to evaluate the feasibility and risk of an open trench alternative (Option One) that SPU developed to re-route the 8-inch VCP on the northwest side of the WSB ramp in comparison to using trenchless construction methods (Option Two) to replace the existing 8-inch VCP along the existing alignment. Notable features of the two options are described as follows:

*Option One – Open Trench Re-routing*

Option One included installation of a new 8-inch pipeline and abandonment of the existing 8-inch VCP combined sewer. Figure 2 depicts a snapshot of the plan view of the open trench alignment. The new open trench pipeline would have intercepted flows from the existing system at a new MH installed on the west side of the WSB and would have discharged flows into the existing combined sewer at a new MH on SW Manning Street, to the north. The new pipeline would have traversed Seattle Department of Transportation (SDOT) right of way (ROW) between the connection points at depths below grade ranging from 7 to 19 feet. SDOT required the pipeline to be located 10 feet laterally from the WSB deck and foundation system. Private structures encroaching on SDOT ROW, left approximately 6 feet of working space along a portion of the proposed alignment, dubbed the “pinch point”. As such, Option One would have necessitated removal of a privately owned storage shed and fence, an option that was to be avoided if possible.

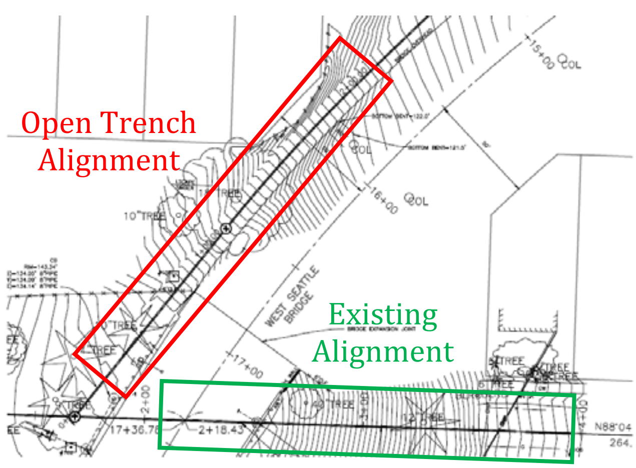


Figure 2. Open Trench Re-Route (Option One) – Plan View Snapshot.

Although open trenching is commonly thought to have low construction risks, when compared to trenchless technology for this project, certain site characteristics posed the following risks to the open cut installation:

- Encountering groundwater that is difficult to control and requires use of deep wells or well points,
- Installing the pipeline at a grade exceeding that which a contractor can efficiently lay pipe,
- Installing the pipeline at a depth that may require engineered shoring,
- Encountering infrastructure of poor condition at the upstream or downstream connections, and
- Increased ancillary expenses (private structure removal and replacement and associated potential legal costs).

To quantify these risks, a risk assessment matrix (Table 1) was developed in which risks were assigned a probability of occurrence and an impact or consequence should that risk come to fruition. Probabilities were ranked on a 0 to 10 scale, indicating a probability range from 0 to 100%. Impact was quantified on a 1 to 5 scale to represent mitigation costs ranging from less than $10,000 to greater than $200,000. The risk factor for each risk was found by multiplying the probability of occurrence by its impact, and the cumulative risk score was found by finding the sum of the individual risk factors.

Table 1. Open Trench Re-Route (Option One) – Risk Assessment Matrix.

| **Open Trench - Risk** | **Probability** | **Impact** | **Risk Factor** |
|---:|---|---|---|
| Dewatering Requiring Deep Wells or Well Points | 5 | 3 | 15 |
| Gradient Causing Non-Efficient Installation | 6 | 1 | 6 |
| Deep Excavation Affecting Ability to Safely/Efficiently Shore | 2 | 2 | 4 |
| Complications due to Poor Existing Infrastructure | 2 | 1 | 2 |
| Legal Implications (Shed/Fence Re-Location) | 7 | 3 | 21 |
| | **Cumulative Risk Score** | | **48** |

*Option Two – Trenchless Rehabilitation/Replacement using Existing Alignment*

The trenchless replacement Option Two, included feasibility analysis of both pipe ram engulfment and pipe bursting. Pipe ram engulfment involves ramming an oversized casing around the existing pipe from a launch pit to a receiving pit. Once the oversized pipe is rammed over the existing pipe, the engulfed soil and existing pipe is removed from within the oversized casing and a new pipe can be constructed in the clean casing. Alternatively, pipe bursting is a technique where a bursting head is pulled through an existing pipe, fracturing or splitting the pipe as it proceeds, while concurrently pulling in a new pipe. Unique to this project, a rope had been threaded through the existing pipe before it collapsed and could possibly be used to facilitate initiation of the pipe bursting methodology. Figures 3 and 4 illustrate the conceptual profile and plan, respectively, developed by SPU with pit locations, revised by STC, shown in red.

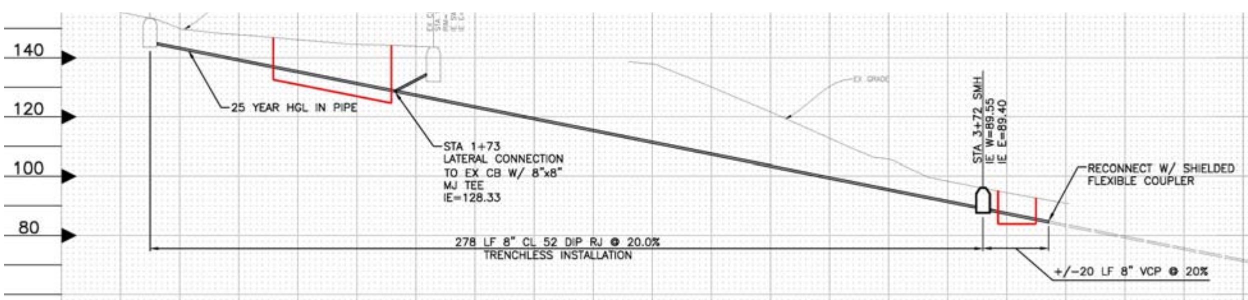


Figure 3. Conceptual Profile developed by SPU and edited by STC.

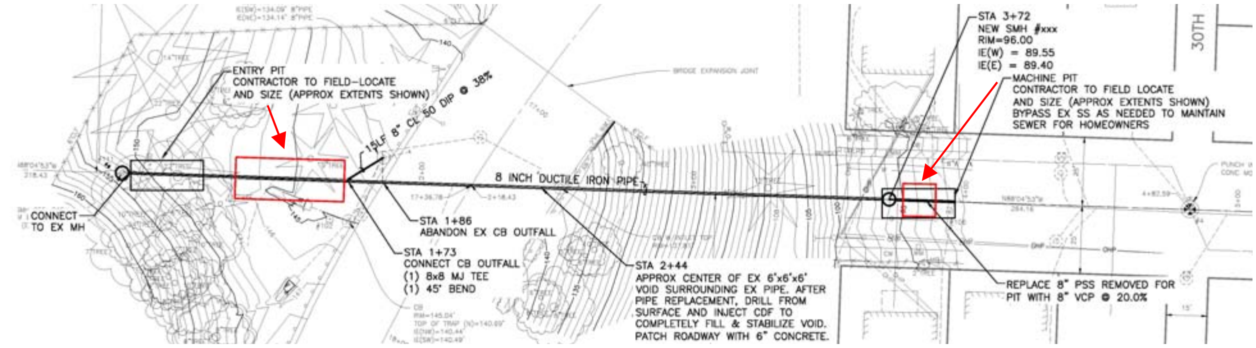

Figure 4. Conceptual Plan developed by SPU and edited by STC.

To provide room for pit excavation and shoring, as well as support for trenchless activities, SW Orleans St on the west side of the alignment would have to be temporarily closed to residential parking, inconveniencing the adjacent homeowners. The temporary closure could have been intermittent or may have needed to last for the duration of trenchless construction, depending on the technology. If the existing line were to have been replaced via pipe bursting, the pit would have been actively used for the duration of the burst, installation of the new MH, and connection to the downstream system. Access to this pit would not have been required for the duration of pipe ram engulfment; however, as the majority of the trenchless construction work would have proceed from the up-station pit.

To differentiate the risks between pipe ram engulfment and pipe bursting, Option Two was subdivided into Option 2A – Pipe Ram Engulfment and Option 2B – Pipe Bursting. Two risk assessment matrices, Tables 2 and 3, were developed based on the same probability and impact ranges that were used for Option One – Open Trench.

Table 2. Option 2A, Pipe Ram Engulfment Risk Assessment Matrix.

| **Pipe Ram Engulfment - Risk** | **Probability** | **Impact** | **Risk Factor** |
|---|---|---|---|
| Dewatering Requiring Deep Wells or Well Points | 3 | 3 | 9 |
| Getting Stuck | 1 | 5 | 5 |
| Excessive Alignment Deviations | 1 | 1 | 1 |
| Complications due to Poor Existing Infrastructure | 3 | 1 | 3 |
| Settlement/Heave of WSB pavement | 1 | 5 | 5 |
| Legal Implications (Shed/Fence Re-Location) | 1 | 3 | 3 |
| | **Cumulative Risk Score** | | **26** |

Table 3. Option 2B, Pipe Bursting Risk Assessment Matrix.

| **Pipe Bursting - Risk** | **Probability** | **Impact** | **Risk Factor** |
|---|---|---|---|
| Dewatering Requiring Deep Wells or Well Points | 2 | 2 | 4 |
| Getting Stuck | 1 | 5 | 5 |
| Excessive Alignment Deviations | 1 | 1 | 1 |
| Complications due to Poor Existing Infrastructure | 3 | 1 | 3 |
| Settlement/Heave of WSB pavement | 1 | 5 | 5 |
| Legal Implications (Shed/Fence Re-Location) | 1 | 3 | 3 |
| | **Cumulative Risk Score** | | **21** |

Groundwater/dewatering risks were limited to the pit excavations on the upstream and downstream ends of the alignment and were discussed in the previous section. The estimated probability and impact of dewatering risks was higher for the pipe ram engulfment method than for pipe bursting due to the larger size of the up-station pit used with pipe ram engulfment. The risk of encountering infrastructure in poor condition was slightly higher than that of the open trench method due to additional infrastructure of unknown condition in SW Orleans St.

Getting stuck, as a result of hitting an obstruction or a combination of prohibitively high frictional and end bearing forces, presented one of the greatest risks to the trenchless installations. This was primarily due to the relatively high impact that would result should the risk occur; however, the probability of getting stuck was low. The probability was low since the subsurface conditions as described in the *Draft Geotechnical Report* indicated favorable soil conditions along the pipe alignment. Cobbles, boulders, or other obstacles were not anticipated based on the soils report. With an installation length of approximately 210 feet, frictional and end bearing soil resistance were also not anticipated to be problematic.

There are ways to proactively manage the risk of getting stuck. One such measure could be to require specific tooling that follows best practices and to ensure that proper methods are followed during the trenchless installation. These mitigation measures would make it much less likely that the trenchless installation would get stuck. Yet another way to manage the risk could be to require the installation to proceed from the upstream side to the downstream side, allowing gravity to work to the contractor’s advantage.

Some remedial measures that could be considered should the installation get stuck, include digging up the bursting head or reinforced lead casing edge as well as ramming an oversized casing around the stuck casing or pipe. For pipe ram engulfment additional remedial measures such as prematurely cleaning out the casing and/or telescoping a smaller casing within the larger stuck casing could considered. Depending on the technology, the advancement length achieved before getting stuck, and the suspected reason(s) for getting stuck, remedial measures could approach the cost of open trenching a new alignment (Option One). As such, it is likely that abandoning the trenchless installation and proceeding with Option One would be recommended should the installation become stuck. The risk for legal implications regarding the storage shed/fence relocation were retained in the risk assessment, but assigned a low probability of occurrence due to the low probability of getting stuck. The impact of these legal implications was estimated equal to that of the open trench option.

The collapsed portion of the 8-inch VCP could have interfered with forward progress of a trenchless installation; however, due to the brittle nature of VCP this risk was considered small, especially if minimum equipment and tooling requirements were followed. Presence of the collapse and the likely decreased soil strength above the collapse increased the likelihood of the trenchless installation deviating from design line and grade above that of a traditional installation. The trenchless installation could trend upwards from the design grade in the location of the void due to the soil on the bottom of the pipe being denser and the path of least resistance being into the void space. Grade deviations could possibly have been sensed by an increase in installation forces. Use of pipe ramming to engulf the existing 8-inch VCP would allow cleaning of the casing to check grade at regular intervals, but there would be few available options to identify grade deviations if pipe bursting was chosen. Although grade deviations along the alignment may cause increased frictional forces, the increased forces were not expected to be of any considerable amount and were not anticipated to be of a magnitude that would increase the risk of getting stuck. Since the existing 8-inch VCP was at a grade of 20%, should grade deviations occur, they should not cause reverse grade and would not be detrimental to achieving project goals.

Risk of surface heave was small for this project and was not anticipated to occur due to the depth of the pipe. The risk of settlement propagating to the surface was higher than that of surface heave, particularly in the location of the existing void. Vibrations from trenchless installations may result in a redistribution of the soil adjacent to the void into the void space, if not already occurred. This redistribution of soil was not anticipated to cause settlement of the WSB ramp pavement; however, at the time of the feasibility analysis design, it was recommended to perform continuous settlement monitoring of WSB ramp pavement over the void location as the trenchless installation proceeded past the void. Damages due to settlement would be confined to that of the WSB ramp, as there were no other known structures or utilities along the trenchless alignment. Additionally, settled soils would not damage the steel casing (used with pipe ram engulfment) or product pipe (used with pipe bursting). Risk of settlement could be reduced through appropriate specification of requirements and by following construction best practices.

*Comparative Assessment of Option One and Option Two*

The cumulative risk scores from Tables 1, 3, and 4 are compiled in Table 4 allowing for a quick comparison of the risks associated with Options One and Two. Both Options were considered feasible options for replacing the existing 8-inch VCP with a new 8-inch pipeline, although Option One presented a greater risk exposure to the project. The main advantage to utilizing Option Two to replace the existing 8-inch VCP was the ability to complete the required work through the "pinch point" without necessitating removal of the private structures encroaching on SDOT ROW. Additionally, Option Two would prevent the contractor from having to dewater, shore, lay pipe, and complete other open trenching tasks at the pinch point. Upon review of the cumulative risk scores, SPU chose Option Two for design and construction, and STC recommended pipe bursting to complete the installation.

Table 4. Option One vs. Option Two – Risk Comparison.

| Option | Cumulative Risk |
|---|---|
| 1 - Open Trench | 48 |
| 2A - Pipe Ram Engulfment | 26 |
| 2B - Pipe Bursting | 21 |

## 4. DESIGN-BUILD: 8-INCH VCP REPLACEMENT VIA PIPE BURSTING

Since this project was classified as an emergency, SPU was able to exempt this public works project from competitive bidding process, as well as waive contracting requirements as they deemed appropriate and directly contract with a firm to address the emergency (State law, RCW 39.04.020 and 39.04.280.2(b)). Trenchless Construction Services (Trenchless Construction), out of Arlington, WA, was selected due to their qualifications, price and availability. Upon discussion of the project characteristics, risks, and goals between SPU, STC, and Trenchless Construction, it was determined that a non-traditional form of pipe bursting should be used to replace the 8-inch VCP. Trenchless Construction desired to use an HDD drill rig to push drill pipe through the existing pipe and to back-ream the existing pipe as they pull in the replacement pipe. Although this process does burst the existing pipe, and is in essence a form of pipe bursting, the process proposed by Trenchless Construction is commonly referred to as inne-reaming.

Since the STC did not want to limit the contractor's means and methods, performance-based specifications were produced to detail the work required to replace the existing 8-inch VCP and to grout the existing void above the pipe alignment. The performance based pipe bursting specification required submittal of the construction machinery, means, and methods planned to be used by Trenchless Construction. The specifications required the reamer, or bursting head, to be of a diameter greater than that of the product pipe and for drilling fluid to be used to lubricate the product pipe during pullback and to flush soil cuttings from the hole. Additionally, they provided requirements for the bypass pumping of upstream flows to the downstream MH for the duration of the construction.
Trenchless construction began on August 24th, 2015 (site preparation had been completed by the subcontractor the prior week, and included excavation of both the jacking and receiving pits). Trenchless Construction used a Vermeer D36x50 drill rig with a Vermeer LP 855 SDT Vac-Tron drilling fluid tank/pump. By 2pm Trenchless Construction was ready to begin inserting drill rods into the existing pipe at the necessary line and grade (21% slope, 8.5 degree entry angle). The drill rig was set back from the exposed 8-inch VCP approximately 40 feet, or the length of 4 drill pipe in order to achieve the entry angle. The existing rope through the pipeline was determined to be more of a potential detriment than useful, and it was cut and removed. When the drill bit on the lead drill pipe entered the trench box with the exposed 8-inch VCP, the pitch was a positive 6 degrees. Figure 5 illustrates the drill pipe entering the existing pipe. By 4pm 9 drill pipe had been advanced, extending roughly 50 feet through the existing 8-inch VCP. Since the extent of the collapsed pipe and subsequent surcharging upstream was unknown, it was desirable to refrain from puncturing the blockage so late in the day, and work for the day was wrapped up by 4:30pm.


Figure 5. Vermeer D36x50 Setup (Left); Drill Pipe Entering Existing 8-inch VCP in Trench Box (Right)

Drilling resumed the following day around 8:40am, after clearing a path in the brush for walkover locate. By 9am, 13 additional drill pipe had been advanced totaling a cumulative 22 drill pipe and 180 feet of advancement west of the existing pipe/drill pipe insertion point. At this point, the lead drill pipe had advanced through the blockage in the existing line, allowing for surcharged combined sewerage to pass through, extending to the downstream system. The surge flow was too great for the downstream system to handle, surcharging a shallow maintenance holes and requiring vactor-truck removal of the sewerage.

The remainder of the drill pipe were advanced by 2pm, marking the beginning of the pullback operation. SPU desired for Trenchless Construction to replace the existing 8-inch VCP with 8-inch restrained joint ductile iron pipe (DIP). This pipe had a bell of 13-inch outside diameter, and as such, Trenchless Construction brought a 14-inch diameter 54-inch long reamer to use as the bursting head. The reamer was fabricated for the job and was unique in that it allowed for the swivel and pull-head to be inside the reamer. This provided protection for the swivel and prevented any burst VCP pipe pieces or soil from contacting the swivel and preventing isolation of the 8-inch DIP product pipe from the rotating drill pipe. Between 2:30 and 4pm, Trenchless worked on connecting the reamer to the drill pipe and getting their drilling fluid lubrication process dialed in.

Pullback of the 8-inch DIP began at 4pm. To minimize the entrance pit excavation and pipe layout, the 8-inch DIP was pulled in one pipe section at a time, requiring a temporary pause of the pullback operation to connect subsequent 8-inch DIP sections. A few times during pullback of DIP number 2, the DIP began to rotate, indicating that the swivel was not operating properly. When this happened crew at the entrance pit radioed the drill rig operator and directed him to reverse the rotation direction. This “freed” the DIP. It was thought that the swivel had bound up and that by reversing the rotation direction the swivel was unwound and any blockage or interference was remedied. By 4:30, the second DIP was pulled in and the swivel was operating as it was intended.

During the pullback operation Trenchless Construction had plugged the downstream sewer to prevent drilling fluid from entering the downstream sewer system. As such, drilling fluid would collect in the trench used to expose the existing 8-inch VCP at the downstream end. Trenchless Construction used Vac-trucks to remove drilling fluid from this trench as necessary during pullback. By 7:30, two Vac-trucks had been filled with drilling fluid and the collar between the reamer and lead drill pipe was visible in the downstream trench, resulting in the reamer being just shy of the trench. It was determined that pullback would be ceased for the remainder of the day and the reamer and attached 8-inch DIP product would be excavated and exposed the following day. By 8 pm, the crews had cleaned up the site and left for the day.

All in all it took just over 2 hours to advance the drill pipe and 5 hours to pull in the 8-inch DIP product. Exposing the reamer and downstream DIP proceeded without complications the following day. A new MH was placed at the southern end of the replaced pipe alignment and SPU had a working system a few days later. The emergency pipe burst replacement was successful.

## 5. DESIGN-BUILD: GROUTING THE VOID

The approximate location of the void was estimated using CCTV of the 8-inch VCP to determine where the collapse was and by confirmation through the use of ground penetrating radar (GPR). CCTV indicated the collapse was roughly 8 feet long below the eastern eastbound lane for the WSB ramp. GPR was able to depict the void in three dimensions. Figure 6 shows the approximately 6-foot x 5-foot x 5-foot void as determined by GPR.

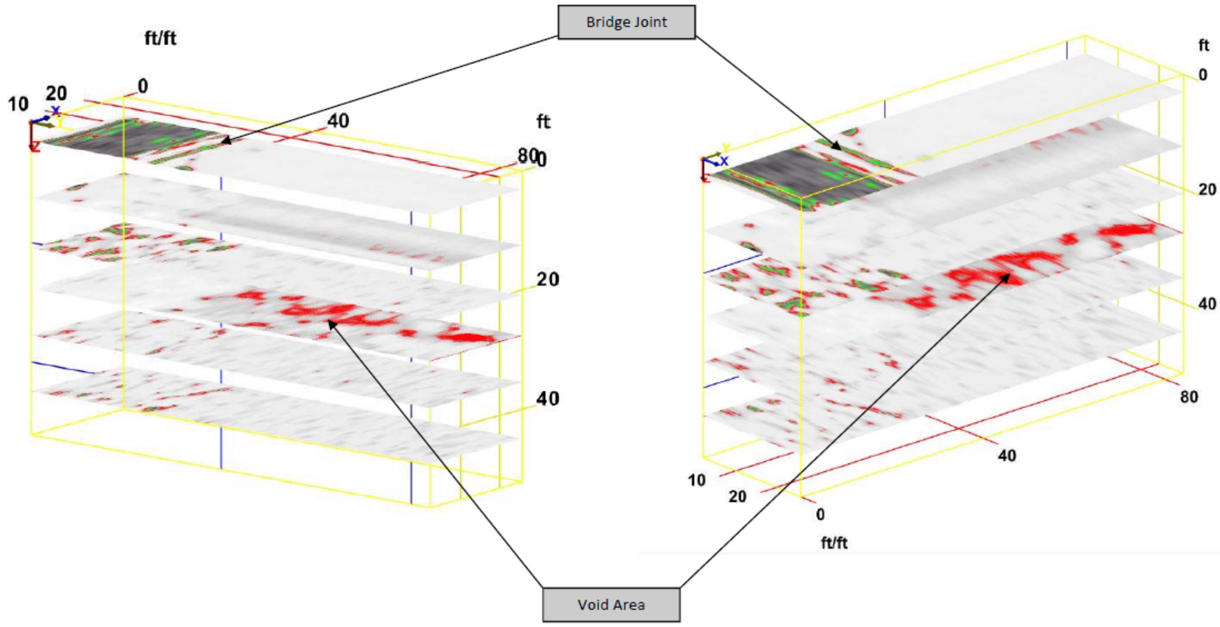


Figure 6. Three Dimensional Mapping of Void Using Ground Penetrating Radar.

As with the pipe bursting specification, the void grouting specification was performance based rather than prescriptive. The grouting specification required the contractor to adhere to the City of Seattle Standard Specifications, and some of the unique requirements included using grouting equipment capable of mixing and preparing a homogenous grout mix, meeting minimum compressive strengths, positively locating the existing void, and to providing proof that the grout had completely filled the void upon completion of the grouting operation.

Ongoing settlement monitoring indicated zero movement of the pavement deck. As such, grouting was postponed until after the trenchless pipe replacement had been completed. The entire grouting operation, from excavating a hole in the existing pavement to paving the hole after grouting, was required to be performed during nighttime to prevent impacting large traffic flows. Additionally, the work footprint was restricted to one inside traffic lane in either direction.

On September 9th, Trenchless attempted to grout the existing void by excavating a small 4-foot x 4-foot hole above the suspected void location. The construction crew attempted to excavate down to the void with a Vactor-truck, but encountered a concrete obstacle 6 feet below the pavement. The construction crew was not prepared to complete the excavation in any other manner, and the grouting operation was ceased. A temporary patch was placed on the backfilled excavation while the team regrouped to discuss penetrating the obstruction. The obstruction was most likely construction debris within the fill dating to the initial WSB construction.

A second, and more robust grouting attempt was made on October 23rd. The contractor was prepared to use a combination of excavating and vactoring to get past the concrete obstruction. Details of the second grouting plan are as follows:

- Work restricted to between 7pm Friday and 7pm Sunday
- Dual lane closure, inside lanes only
- 5-foot by 9-foot saw cut into concrete panel
- Excavate down (10 feet max), shore with trench boxes

- Vacuum excavate toward void location identified by GPR to locate void
- Backfill void and excavation with CDF
- Type 2 mineral aggregate road base (thickness > 6 inches)
- Planned for concrete road deck to be poured 5pm Saturday
- Traffic reinstated when concrete strength > 3,000 psi

To prevent another failed attempt at reaching the void, the contractor was prepared to vactor to the north and south of the obstruction in an effort to determine the extent of the obstruction, or get around it if possible. If it was determined that there is a linear obstruction preventing advancement towards the void then the location and nature was to be documented by the engineer and the void grouting procedure would be abandoned. If the contractor were to be able to get around the obstruction with the vactor, and continue to progress toward the void, then they would do so within the extents of their time limits.

The revised grouting plan went extremely well. Since the access hole through the pavement was larger than the first grouting attempt the construction crew was able to expose the edge of the concrete obstruction when it was encountered. Vactor excacvating was successful from around the edge of the obstruction, and angled down towards the void location. Further excavation exposed the void approximately 1.5 hours after excavation below the road deck began. It took roughly 2 to 3 cubic yards to fill the void, approximately half the size estimated by GPR. The remainder of the grouting, backfilling, and paving operation proceeded without complications, leading to a successful void grouting operation.

## 6. SUMMARY AND CONCLUSIONS

An 8-inch VCP combined sewer had collapsed beneath the WSB ramp, resulting in backups in the upstream system and a void in the soil above the location of the collapse. Replacement of the existing 8-inch VCP was under a tight time crunch due to the importance of the WSB being a major thoroughfare to and from West Seattle. SPU and STC worked in tandem to evaluate the risks and feasibility of two replacement options: re-routing the combined sewer via open cut; and replacing the existing line via pipe bursting. Pipe bursting was selected as the most preferred alternative and Trenchless Construction Services, LLC was hired to perform the trenchless installation. Trenchless Construction elected to use an HDD rig to perform an inne-ream style pipe burst where they replaced the existing line with 8-inch DIP.

The collaborative working relationship between SPU, STC, and Trenchless Construction resulted in a project well done. The existing pipe was successfully burst and replaced within two working days of the drill rig being on-site. Although, the first attempt to grout the void failed due to presence of a concrete obstruction, the subsequent attempt was successful and completed well within the work restrictions.

## 7. REFERENCES

Bennett, D., Ariaratnam, S. and Wallin, K. (2011) – Pipe Bursting Good Practices Guidelines, North American Society for Trenchless Technology (NASTT), Second Edition, USA.

GPR Data Inc. (2015). Ground Penetrating Microwave Radar Investigation for Void Investigation at West Seattle Bridge Eastbound Lanes Near SW Orleans Street.

Seattle Public Utilities. (2015). Draft Geotechnical Report: SW Orleans Street Sewer Replacement.

Staheli, K., and Olson, M. (2015). Trenchless vs. Open Trench Feasibility and Risk Assessment Memo – SW Orleans Street Sewer Replacement.

Staheli Trenchless Consultants. (2015). SW Orleans Street Sewer Repair Pipe Bursting Specification, Section 7-23.

Staheli Trenchless Consultants. (2015). SW Orleans Street Sewer Repair Void Grouting Above Installed Pipe Specification, Section 7-24.