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DIRECTIONAL DRILLING IN MUKILTEO – LESSONS LEARNED FROM AN HDD WITH 330 FEET OF ELEVATION DIFFERENCE

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ABSTRACT: The Mukilteo Water and Wastewater District has constructed a portion of their gravity sewer through the Big Gulch in Mukilteo, WA using Horizontal Directional Drilling (HDD). This paper presents case histories for the construction of a 2,600 lineal foot, 20-inch DR18 fusible-PVC gravity sewer line and a 1,500 lineal foot, 12-inch HDPE lateral sewer pipe using HDD. Both drills proved challenging with significant elevation differences between entrance and exit. The alignments were designed in very stiff to hard lacustrine silts that were overlain by landslide deposits. At the entry locations, both bores had to penetrate the looser/softer landslide deposits prior to entering the more competent lacustrine soils, leading to concerns about slope destabilization and landslide risk. The designers considered the challenging geotechnical conditions during design; however, many problems occurred during construction of the first bore that led to over-excavation, grade deviation, and landslide mobilization. The lessons learned from the problems encountered during the first bore were applied to the construction of the second bore, which was completed without any significant problems. This paper details the challenging design aspects, the problems that manifested during construction and the mitigation efforts developed in response to the problems that were then successfully applied to the second bore.

1. INTRODUCTION

In August of 1999, Mukilteo Water and Wastewater District (District) conducted an evaluation of a deteriorating sanitary sewer trunk line within the Big Gulch, a steep-sided coastal ravine located just south of Mukilteo, WA. The existing trunk sewer was an unrestrained bell and spigot concrete pipeline approximately 8,650 feet in length which was constructed in 1970 to convey wastewater to the District's sewage treatment plant on the shores of Puget Sound. Since the construction of the sewer main, increased flow in Big Gulch Creek had lead to incision of the ravine and undermining of the sewer trunk line at several locations. The 1999 evaluation ultimately recommended replacement of the sewer, and suggested that the Big Gulch Sewer Repair Project be divided into four segments four design and construction. Segment 3, the focus of this paper, included the construction of both a new trunk sewer and a lateral sewer installed via horizontal directional drilling (HDD). The two drills are shown in plan view in Figure 1 and are described in greater detail below:

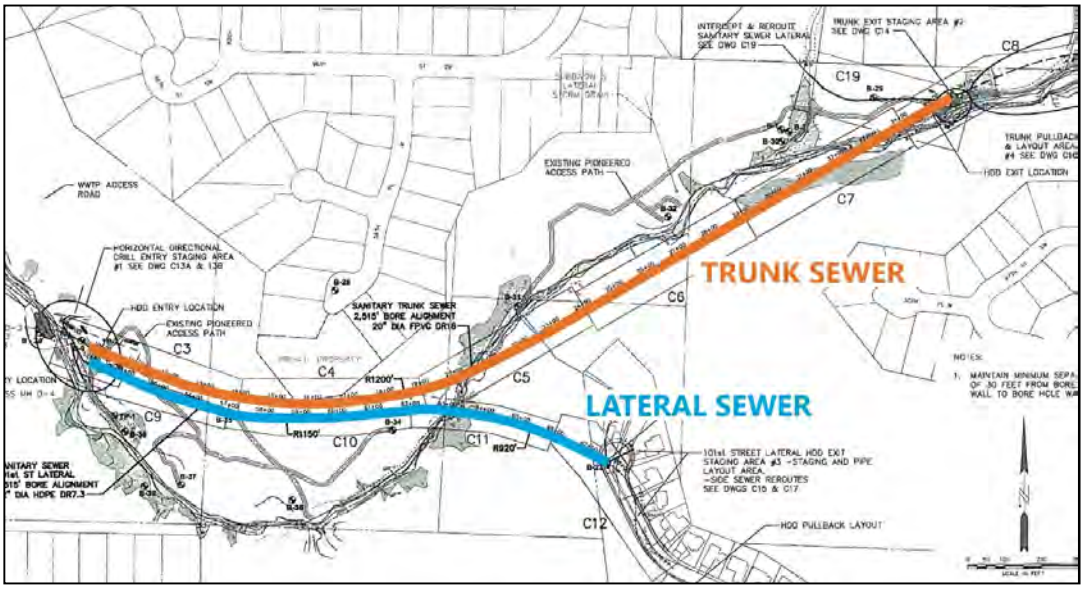

Figure 1: Plan View of the two sewer alignments

- **Trunk Sewer**
  The replacement trunk sewer consisted of approximately 2,600 linear feet of 20-inch (nominal diameter) fusible polyvinylchloride (fPVC) pipe installed via HDD. The trunk sewer profile is shown in Figure 2, and extended from a staging area, shown on the left side of the Figure 1near the District access road bridge across Big Gulch Creek to the west end of Segment 2 (manhole D-18). The vertical elevation difference between the HDD entry and exit points was approximately 140 feet. The alignment was designed on a 1,200-foot horizontal bend radius and utilized a 1,500-foot vertical bend radius. Both bores were drilled from left to right as shown in the figures where the rig was at the lowest end of each of the two drills.

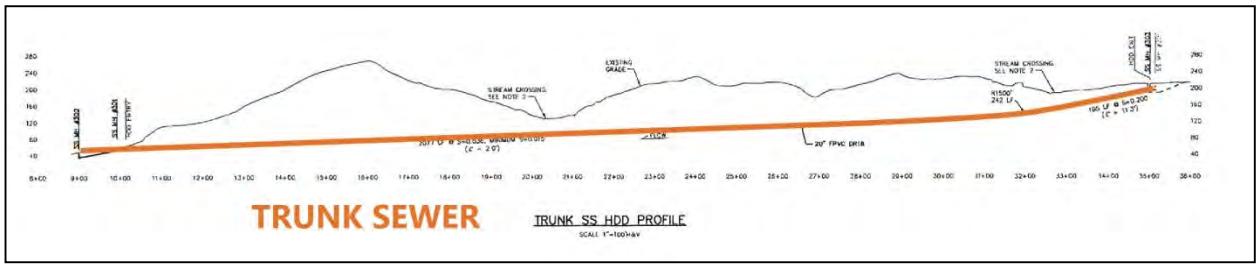

Figure 2: Profile View of the trunk sewer alignment

- **101st Street SW Lateral Sewer**
  The proposed lateral sewer consisted of approximately 1,500 linear feet of 12-inch (nominal diameter) high density polyethylene (HDPE) pipe installed via HDD. The lateral sewer profile is shown in Figure 3, and extended from the District access road bridge across Big Gulch Creek to the 101st Street SW cul-de-sac. The vertical elevation difference between the HDD entry and exit points was approximately 280 feet. The alignment was designed with compound curves containing an 1150-foot and a 920-foot horizontal bend radius in conjunction with an 800-foot vertical bend radius.

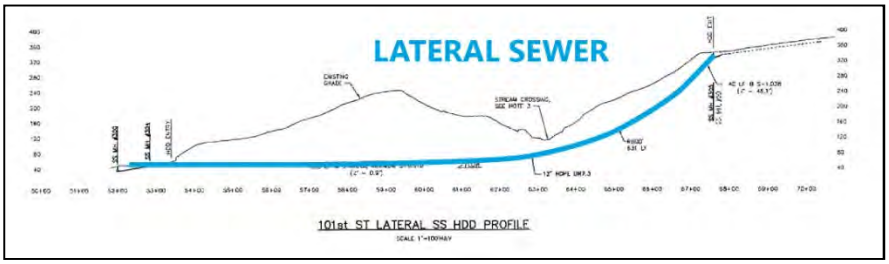

Figure 3: Profile View of the lateral sewer alignment

2. GEOTECHICAL CONDITIONS

The geologic investigation conducted for Segment 3 included 20 borings taken between August 2007 and January 2008, and determined that subsurface conditions in the project area generally consisted of colluvial (landslide) and alluvial (stream) deposits underlain by glacial lacustrine deposits. The distinct density difference between the landslide deposits, which generally consisted of very soft to stiff silt and clay with variable sand and gravel content, and the underlying glacial lacustrine deposits, which consisted of very stiff to hard silt and clay, led to significant concerns about slop stability at the HDD entry point. These concerns were reinforced by the prominent head scarps and colluvial masses observed throughout the project area, indicating both recent and prehistoric landslide events in the Big Gulch ranging from hundreds to thousands of years old.

Figure 4: Temporary shoring at the entry location

In order to negate this risk, conductor casings were specified on both drills to bridge the bore into the more competent glacial lacustrine deposits. 80 and 100 feet of 36-inch and 20-inch conductor casings were specified for the trunk and lateral sewers, respectively. Additionally, temporary shoring piles and steel plates were used to stabilize the slope at the HDD entry points in order to restrict potential movement of the slope toe while expanding the available contractor work area (Figure 4).

3. TRUNK SEWER – PILOT BORE

Construction of the trunk sewer began in May of 2009 with the installation of the 80 foot 36-inch conductor casing. Having elected to install the casing via pipe ramming, the Contractor ran into difficulty at 48 feet when the casing advancement slowed to approximately 1 inch every 10 to 12 minutes. After hammering for almost two hours with no movement, the Contractor elected to halt the installation at 52 feet due to concerns about damaging the leading edge of the casing.

The pilot bore for the trunk line began in June, with 300 feet of drill pipe advanced on the first day of drilling. The Contractor elected to use a downhole mud motor for excavation, a high pressure and high volume tool that is commonly used for rock drilling. This quickly proved to be problematic, as hydrofracture on the slope above the bore centerline 200 feet into the alignment was discovered on the second day of drilling, likely from excessive downhole fluid pressure. As the pilot bore advanced,

excessive volumes of spoils coming out of the mud pit began to clog the screens on the slurry plant and to overtop the spoil containment area beyond the defined boundaries of the construction work limits adjacent to a creek. (Figure 5). Repeated attempts to remove the drill string and re-drill the hole resulted in higher and higher mud volumes coming out of the mud pit, and significant flooding of the work area with mud and spoils. Despite these complications, the Contractor elected to keep trying to advance the bore beyond the 310-foot mark using the original mud motor. Within the first eight days, the Contractor had re-drilled the same ~120 foot section of the alignment 12 times and had excavated several times the anticipated soil volume of the bore.

Figure 5: Excess mud flows out of the spoils pit

This continued over-excavation had a dramatic impact on the ninth day as three trees suddenly fell into a large sinkhole that developed on the surface more than 50 feet above the alignment. At this point, the Contractor elected to switch to a more traditional slanted head bit, with which 1,160 feet of the pilot bore was successfully drilled. Hard ground prompted the Contractor to switch to a different mud motor after 3 days of progress. One with less volume output was selected in order to restrict mud flow. After a few episodes of tripping and re-drilling, the Contractor successfully finished the 2,600-foot pilot bore after a combined 14 days of drilling.

4. TRUNK SEWER – REAMING AND PIPE PULLBACK

Reaming started in the third week of June with a 31-inch forward reamer (Figure 6). A problem was encountered almost immediately when the Contractor could not advance the reamer beyond the edge of the 36-inch conductor casing. It seemed probable that the edge of the casing had partially collapsed upon installation due to the repeated blows with the pneumatic ramming hammer. A crew member was sent into the 36-inch casing with a cutting torch to remove a portion of the collapsed section, and returned with a 1 foot by 1 foot section of the leading edge. At this point the Contractor was successful at advancing the reamer past the end of the conductor casing.

Figure 6: 31-inch forward reamer

However, once free of the casing, the reamer still had significant difficulty in advancing due to the near continuous collapse of the borehole, presumably through the section that had been significantly over-excavated during the pilot bore. The Contractor elected to advance a 12-inch washover casing behind the 31-inch reamer to maintain stability of the hole through this section, ultimately chasing approximately 250 feet of the reamed bore with washover casing. However, poor circulation and continued loss of mud into the formation led to an attempt to clean out the 12-inch casing. Insertion of an extra section of drill pipe succeeded in removing the "plug," at which point a tremendous amount of drilling mud rushed out the end of the 36-inch casing and flooded the working area. Visual inspection of the hillside above the bore after the dramatic mud release showed that the existing sinkhole continued to increase in size and that surrounding trees appeared to be sinking as well.

5. LATERAL SEWER – PILOT BORE

Construction of the lateral sewer started in the last week of August. The 20-inch conductor casing had been installed prior to the start of the drill, but it was determined upon advancing the drill pipe out to the end of the casing that the leading edge had been damaged, presumably during installation. Given the difficulties experienced on the trunk sewer installation due to the damaged end, the Contractor elected to ram out the 20-inch casing and replace it with 75 feet of 24-inch casing. After the new casing installation was completed, a plan was developed to drill a pilot hole about 250 feet and then ream out the hole to an approximately 18-inch diameter for the installation of 18-inch washover casing. This installation was quickly performed, ending with 240 feet of 18-inch casing.

6. LATERAL SEWER – REAMING AND PULLBACK

The lateral sewer was reamed from entry to exit to within a 100 feet of the exit location. The reamer was then pulled back to the rig and taken to the exit side where the Contractor then pulled ream from the exit side back towards the rig approximately 100 feet while installing the 18-inch washover casing simultaneously behind the reamer until the reamed holes were within 20-feet of being "connected". The pipe was successfully pulled in about 8-hours which included and intermediate fuse of two pipeline sections.

7. CONCLUSION

This challenging project, which pushed the limits of the current technology, was ultimately successful because of the efforts of a diligent, if not prudent HDD Contractor, a vigilant and fair CM and inspection staff, and a forthright and understanding project owner.

REFERENCES

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