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CONSTRUCTING TWIN 24 INCH FORCE MAINS IN A HIGHLY SENSITIVE ENVIRONMENT UTILIZING HDD

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ABSTRACT: In January 2009, Clean Water Services (CWS) began design of the Dawson Creek Pump Station and Force Main project. The project includes a 25 MGD pump station and 15,000 lf of dual 24" force main. To reduce overall force main length, construction costs, environmental impacts, and permitting requirements, the alignment included approximately 1,900 lf installed by HDD in two bores. The bores were vertically stacked and designed with 40-ft of separation and passed under wetlands and Rock Creek. The entry was located on an existing county road and the exit was located in a narrow cul-de-sac in a residential neighborhood. Creative pipe fusing, lay down and staging was required to facilitate construction within the narrow ROW while maintaining access by local residents. The roadway geometry limited the length of pipe strings requiring a multiple fuse approach. Conductor casings were driven at the entry location.

Both the Owner and Engineer had significant concerns about losing drilling fluids or "fracing out" in the wetland or the creek. The geotechnical data provided indicated a severe risk of inadvertent returns in the near-surface soils and beneath the creek; therefore, the bores were designed to mitigate these risks. The project was competitively bid and the low bidder, Mears, submitted the theoretical pressure the formation could withstand before a frac-out would occur. A down-hole pressure tool was used while drilling the pilot bore to mitigate the risk of frac-out; however, the tool was not used during the reaming phase. This case history details the geotechnical data¸ calculated limiting pressures for the formation, the actual pressures that were realized during drilling¸ reamer selection¸ pump rates and drilling mud data. Two very small frac-outs did occur during the construction of the bores. The location of each frac-out and the calculated limiting formation pressure along with the actual pressure data are compared at the frac-out locations.

1. INTRODUCTION

Clean Water Services District is a water resources management utility and special service district with more than 520,000 customers in Washington County, Oregon. The boundaries of the district are shown in Figure 1. Twelve member cities are encompassed by the District including Hillsboro, Beaverton, Tigard, Tualatin and Forest Grove. The District provides wastewater and stormwater infrastructure and services, flood control projects and environmental restoration and maintenance. The District operates four wastewater treatment plants and 41 pump stations and over 750 miles of sanitary sewer gravity and force main lines.

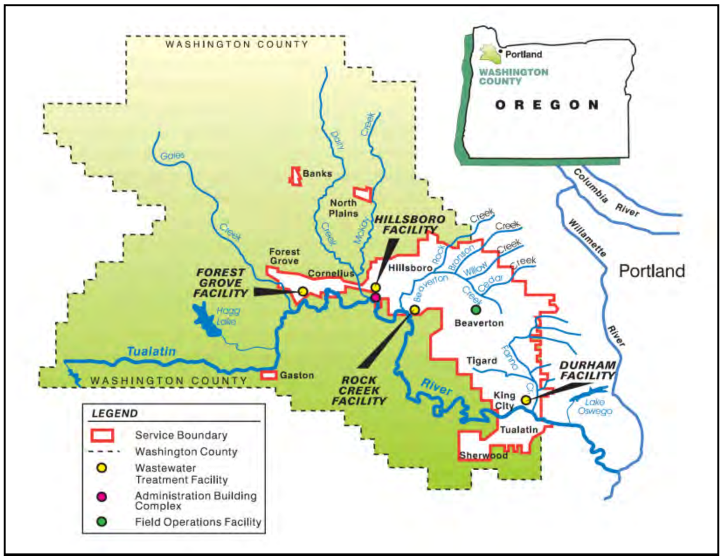

Figure 1. Clean Water Services District Service Area

The Dawson Creek Basin service area is located south of Highway 26 and north of the District's Rock Creek Advanced Wastewater Treatment Plant which serves the basin. The Dawson basin includes an area of high-tech industrial companies including campuses of Intel, Tri-Quint and Solar World. Many of these high-tech industries utilize large volumes of water and discharge large volumes of wastewater and are expanding. To accommodate the expansion and associated regional economic growth Clean Water Services is committed to providing the wastewater infrastructure required for the area.

The gravity sanitary sewer system serving the Dawson basin has historically drained to a 24-in trunk line that runs within and adjacent to Dawson Creek. The upstream sections of the 24-in trunk line have been replaced, in phases, with twin 42-in gravity lines. The most recent phase of this upgrade extended the twin 42-in lines to just south of the Hillsboro airport, approximately 3 miles north of the treatment plant, and combined the two 42-in in a single 16-in line that discharged to the existing 24-in. The capacity of the 24-in line was estimated at 5 MGD with full pipe flow, and 7 MGD with a 2-ft surcharge. The estimated required trunk line capacities for the Dawson Basin pipelines are presented in Table 1.

Table 1. Dawson Creek Trunk Flow Projections. (MG/Day)[1.]

Source	**Year**		
	2008	2030	2040 (Buildout)
Sanitary and I&I	4.5	11.3	14.4
Wet Industries	3.1	5.6	6.8
North Plains Basin	1.3	4.5	5.5
Total Capacity Required	8.9	21.4	26.7

To provide the additional system capacity required by further extending the twin 42-in gravity lines to the Rock Treatment Plant would have required deep excavation within the sensitive environmental corridor of Dawson Creek. Permitting and environmental restoration requirements would place further schedule constraints on the project potentially impacting the planned expansions of the high-tech industries in the area. Therefore, the District elected to intercept the twin 42-in gravity lines and construct a 25 MGD pump station and twin 24-in force mains. The District hired Carollo Engineers out of Portland, Oregon and Staheli Trenchless Consultants, Seattle, Washington to design the pipeline and provide trenchless consultation including determining the best method and risk mitigation for trenchless pipeline installation.

Of the approximately 15,000 lf of twin 24-in force main in the project, 8000 lf was scheduled to be constructed as part of a Washington County road widening project. This section of the alignment included one crossing of Dawson Creek in a section of back to back 90 degree curves in the road. An alignment analysis indicated that by deviating from the roadway alignment at the curves the force main alignment could be reduced by approximately 2500 lf. See Figure 2. However, this reduced length alignment required extensive wetland impacts and a creek crossing. To reduce environmental impact, disturbance and restoration and minimize environmental permitting requirements, trenchless alternatives were considered. After considering geotechnical data, alignment constraints and available technologies it was determined HDD was the most favorable trenchless alternative for the pipe installation.

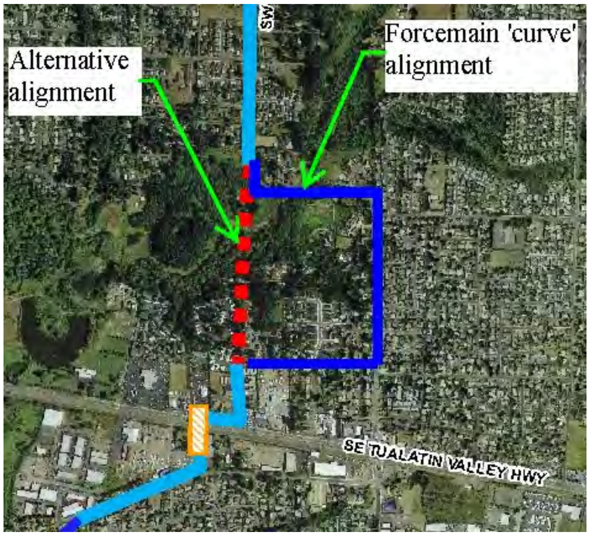

Figure 2. Reduced length alignment alternative

2. DESIGN CONSIDERATIONS

To eliminate the need for excavation within wetlands and reduce environmental impacts the HDD alignment needed to extend from the existing roadway near the curves on the north to an existing cul-d-sac in the south. These two points were off-set with three houses in the straight line path. To prevent the bore alignment from crossing under any existing structure the alignment included three horizontal curves. The curves were laid out with 1,000-ft bend radii with short tangent sections between the curves; however, the horizontal curves initiated beyond the vertical curves at the entrance and exit locations to avoid having the bore in a compound curve. Initially, the bores were planned to be side-by-side; however, due to soft soils that existed near the ground surface, it was determined that a separation distance of 40 feet was needed to ensure that there would be no cross contamination of drilling fluid between the bores. To maintain that separation and avoid crossing under existing structures required bore radii of less than 1,000 ft be used, a radius considered too small for the size of rig that would be required to install the pipelines. It was then decided to stack the bores vertically allowing each bore to maintain a minimum bend radius of 1,000 feet while avoiding existing structures. Again, to maintain an appropriate safety factor against the pressurized drilling mud traveling between the two bore paths, a spacing of 40 feet between the bores was designed. Stacking the bores provided the additional benefit of allowing the construction within a narrower easement, reducing project costs.

Vertical alignment considerations included Rock Creek and the existing Clean Water services 72-in gravity trunk sewer. The design included a 35-ft clearance from the bottom of Rock Creek to the top of the upper bore and 35-ft of separation between the HDD pipeline and the gravity sewer.

The pipeline was sized for hydraulics as 24-in ductile iron pipe size HDPE. Structural and installation load calculations determined that a DR equal to 11 was sufficient for external and pull-back loads. To minimize the risk of installing a pipeline that was not properly welded, the District required a pressure/leak test of the welded HDPE pipe prior to pull-back. This would require a continuous length of pipe be staged prior to pull back. This proved to be very challenging because of the limited space for layout of the pipe at the jobsite. Therefore, the design team evaluated three pipe and equipment layout scenarios:

- Drilling, reaming and pull-back from the north with pipe layout in the cul-de-sac
- Drilling, reaming and pull back from the south with pipe layout in Brookwood Ave
- Drilling and reaming from the north and pull-back from the south with pipe layout in Brookwood Ave

The first alternative presented a number of layout challenges. To drill and ream from the north the equipment layout would need to be contained within the existing roadway which was approximately 25-ft wide. In addition, one lane of traffic had to be kept open to allow access to local residents. Completing the road widening in this area prior to mobilizing the HDD equipment would provide an additional 20 ft to the HDD contractor. However the total width available would still be less than 35 ft. The other challenge presented by this alternative was pipe layout at the exit location in the cul-de-sac. The road serving the cul-de-sac on the south was approximately 500 lf before terminating in a sharp 90 degree curve and would not accommodate the 1900 lf required for a continuous layout of pipe.

The second alternative provided ample pipe layout length as Brookwood Ave to the north is much longer than the 1900+ lf required. However this alternative required setting up the drilling equipment in the narrow cul-de-sac in a quiet residential neighborhood. Noise, dust, access impacts and safety were major concerns with this alternative.

The third alternative evaluated included drilling and reaming from the north, then re-mobilizing the drilling equipment to the cul-de-sac in the south for pull back. This alternative would reduce the amount of time the residents were impacted by the drilling equipment and allow full pipe layout in Brookwood Ave. However, the additional time required to re-mobilize the drill rig posed additional risk of borehole collapse and negatively impacted the project schedule.

Ultimately traffic impacts drove the decision on the selected alternative. Although Brookwood Ave was scheduled to be closed to through traffic, the time required to layout, fuse, test and drain the full 1900 lf of pipeline in the centerline of the road was determined to be too great an impact on local traffic and access. Therefore the second and third alternatives were eliminated and the decision to drill, ream and pull back from the north was made. This alternative required pipe layout prior to pull-back in the 500 lf cul-de-sac on 45th Ave and a multiple fuse pull-back.

To eliminate the need to stop pull-back to fuse 500-foot strings of pipe together, and allow a leak test of the full length of pipe, the design included a layout and traffic control plan that included a 90 degree bend in the staged pipe. Calculations indicated the allowable short term bend radius of 24-in HDPE DR11 pipe would allow the pipe to extend down the cul-de-sac and bend 90 degrees allowing the full length of pipe to be staged for testing. However, the amount of force required to bend the pipe around the 90 degree corner was significant and would have required driving piles or other means to constrain the pipe and prevent potentially serious damage to the pipe, surrounding homes or existing trees. This design scenario required a short term road closure and 24-hr traffic control from the time the pipe was staged in the roadway until pull-back was complete. It also required temporary road widening for the full 1900 lf of staged pipe to maintain local traffic access. Although this alternative was included in the plans to meet the design constraints it was assumed that the contractor would propose alternative methods pipe layout, including possibly negotiating with local land owners for temporary use. During construction, the contractor proposed a revised layout, eliminating the 90 degree bend in the pipe, reducing the temporary widening required thereby reducing neighborhood impacts to residents and resulting in cost savings to both the Owner and the Contractor.

A geotechnical investigation was conducted along the alignment to characterize the soils that would be encountered during the drilling. A total of 3 vertical borings were drilled along the alignment. Review of the geotechnical information indicated a layer of soft materials at the entry location that was highly prone to hydrofracture or loss of drilling fluids to the ground surface while drilling. To mitigate this risk, a conductor casing with a minimum length of 110 ft was specified to minimize the potential for inadvertent returns and settlement at the entry location.

Beneath the soft surficial soils that were comprised of sandy silt, was a medium dense to dense layer of sand with silt which proved to be ideal for drilling. A cross section of the entry location of the bores with the geotechnical information is shown in Figure 3.

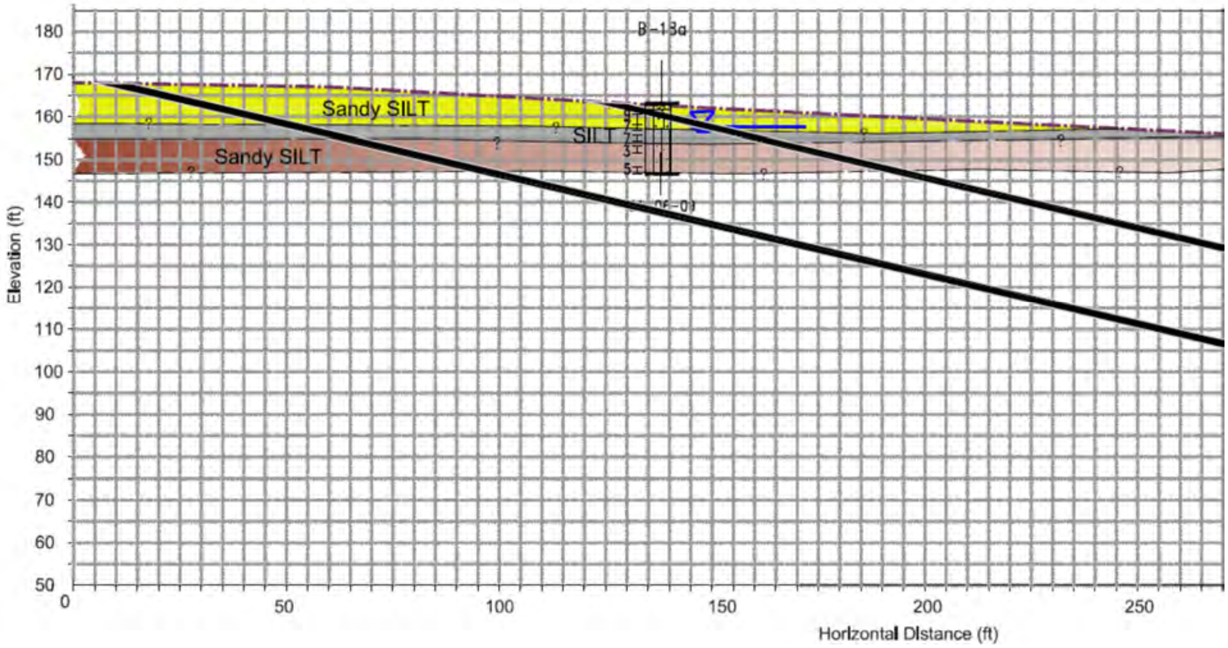

Figure 3 Entry Location of the bores with the Geotechnical Information

At the exit location, the vertical geotechnical boring was much deeper and revealed a layered geology with stiffer/harder material than existed at the entry location. The geotechnical conditions consisted of layered sand, silt, and some clay. Figure 4 shows the geotechnical conditions at the exit location.

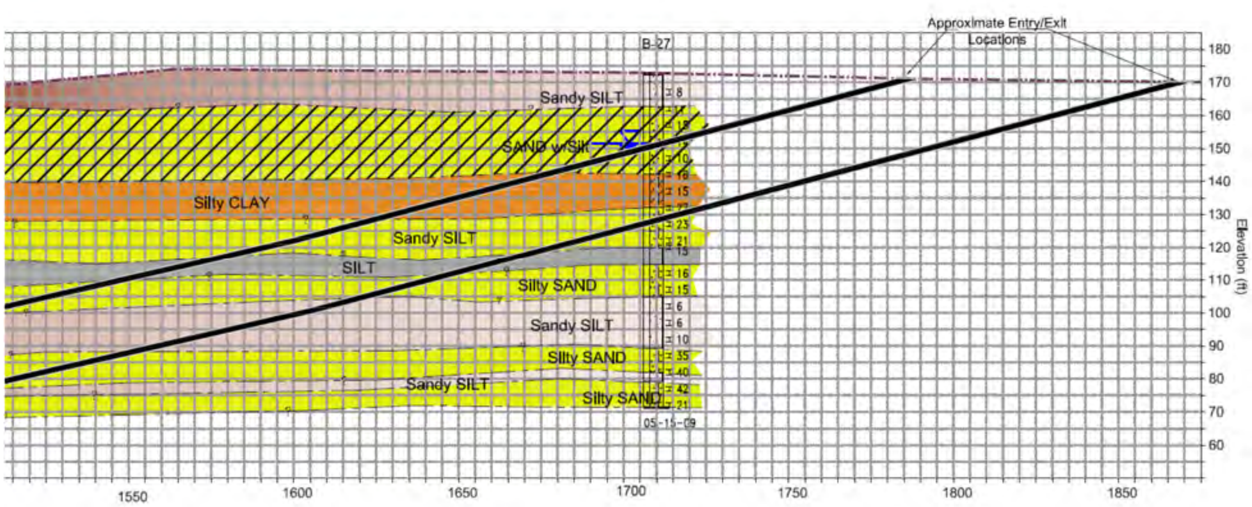

Figure 4. Geology at the exit location with layered sands and silts.

Due to the stiffer/harder material at the exit location, a conductor casing was not specified at the exit and was only required at the entry location.

3. CONSTRUCTION

To ensure qualified drilling contractors, Clean Water Services conducted a pre-qualification process. The list of pre-qualified drilling contractors was provided to prospective bidders. The project was competitively bid and awarded to Emery and Sons general contractors who subcontracted with Mears as the HDD sub-contractor. During the submittal process, Mears proposed deepening the upper bore to further protect against inadvertent returns to the ground surface. However, they did not propose moving the lower bore. Instead, they proposed decreasing the separation distance of the two bores. To offset the risk of having two bores within close vertical proximity, the Contractor elected to first drill the upper bore and then run the guidance tracking wire through the installed upper bore product pipe. They would then track the lower bore with the cable that was located in the upper bore pipe. This would increase the accuracy of the tracking equipment,which becomes less accurate with depth, and ensure that adequate separation of the bores was maintained by steering the lower bore from the previously installed pipe. The Owner required Mears to submit calculations showing that they would not generate downhole drilling fluid pressures that were high enough to cause frac-out between the bores. The Contractor provided the requested calculations and was willing to accept the risk of drilling fluid communication between the two bores. With the commitment, the Owner allowed the contractor to proceed with the newly proposed bore profile layout.

The layout room at the entry and the exit for the bores was very constrained. Figure 5 shows the drill rig set up in a linear fashion to allow keeping one lane of the roadway open to traffic during construction. To setup the drilling equipment at the entry site, the contractor elected to survey points prior to mobilization and carefully plan equipment arrival and sequence the mobilization of the equipment to fit all of the necessary equipment in the long but narrow work area that also included overhead power. It should also be noted that this task was performed while maintaining access to the various driveways and through-traffic via a single lane adjacent to the work site. Careful planning of the rig-side layout and set-up allowed savings of both time and resources since the Contractor was able to quickly remobilize to setup for the second bore.

Figure 5. Narrow Entry Site Work Area

The Contractor and Owner did a tremendous job of cultivating relationships with local residence early in the construction process to minimize impacts to their work. Communication with the neighbors in close proximity to the entry site where conductor casings were to be installed for both bores was important and effective in managing expectations and mitigating potential complaints. The exit site, located on a narrow cul-de-sac, posed further challenges with traffic control and community relations. To maintain access to houses on both sides of the narrow neighborhood street, the work area essentially quartered the road by taking half the road width for construction down the centerline, and leaving access lanes for the residence on either side, as shown in Figure 6. The Contractor was especially cognizant of the impacts caused to these local residences and worked continuously throughout the project to communicate with the neighbors. This relationship building paid off later when a small inadvertent return was discovered in a side yard of one of the residences located adjacent to the bore alignment. With a good relationship already in place and having previously discussed the directional drilling process, the neighbor was nonplussed with the minor eyesore and was accommodating to the Contractor during cleanup. The neighbor also allowed the Contractor to utilize his private property to fuse and string out 3-inch HDPE buoyancy control pipe prior to pullback on each bore.


Figure 6. 24-inch HDPE Pipe Layout Along Center of Roadway

The Contractor utilized a system of bolt-together centralizer casings as shown in Figure 7 that where inserted into the entry conductor casing to center the alignment during the pilot bore and provide support for the drill pipe during reaming.


Figure 7 Centralizers Inserted into the Conductor Casing

4. DRILLING THE UPPER BORE

The upper pilot bore was drilled first. The length of the upper bore was 1630 feet and was constructed in 4 days, averaging 410 feet per day. Figure 8 shows the annular pressure as measured by the down-hole pressure tool that was located within 10 feet behind the drill bit as a function of distance. The graph also shows the minimum drilling pressure as submitted by Mears and the limiting pressure, above which hydrofracture should occur.

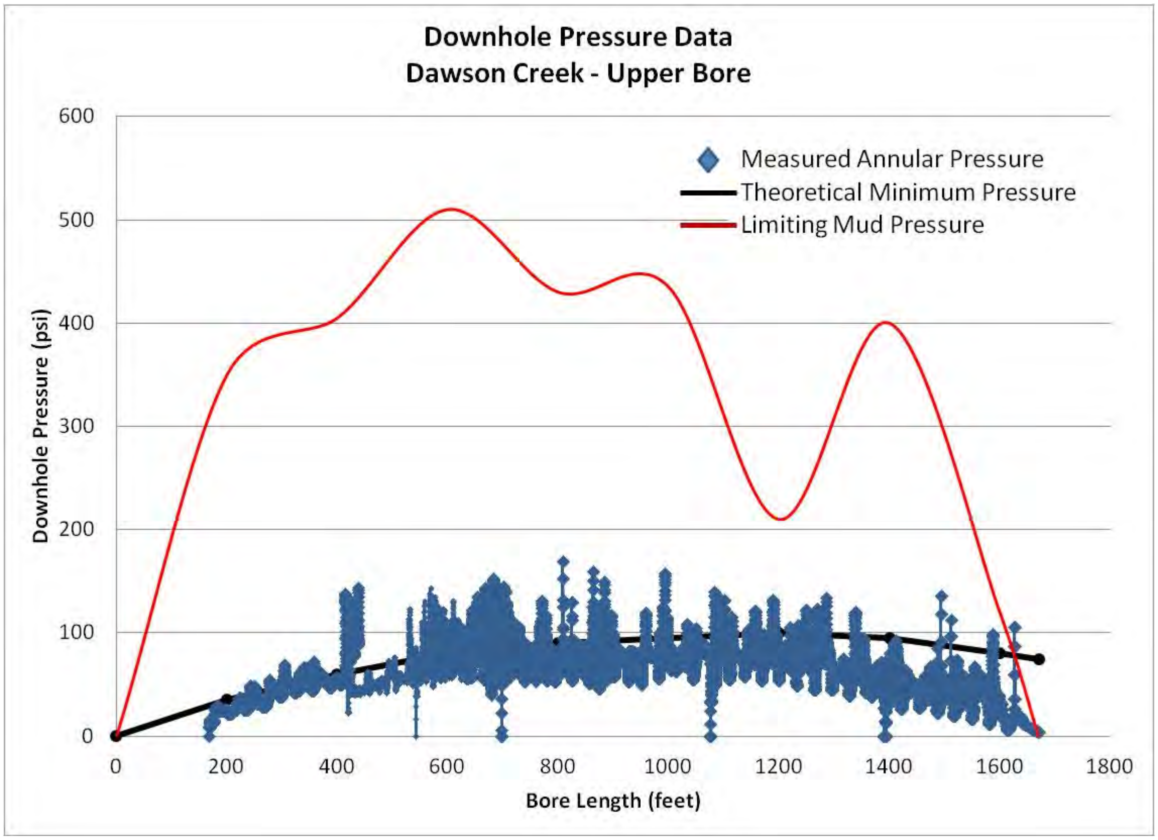

Figure 8. Measured Annular Pressure- Pilot bore – Dawson Creek upper Bore

From figure 8, it is clear that the actual drilling pressures were much closer to the predicted minimum drilling pressures that are necessary to create a borehole than to the limiting drilling fluid pressures. An inadvertent return occurred at approximately 1350 lf from the entry location while drilling the pilot bore for the upper bore. The down-hole pressure reading at the point of the inadvertent return was approximately 135 psi. The calculated limiting pressure at this location was 300 psi, based on the assumed soil properties used in the contractor's calculations. It is important to note that the minimum pressure at this location was calculated to be 100 psi; therefore, the actual pressure was much closer to the calculated minimum pressure than the maximum pressure. It is possible that at this location, the soil properties were much different than those assumed in the calculation or that a pre-existing weakened zone existed that allowed the inadvertent return of mud to the ground surface. Luckily, the drilling mud was contained and did not reach wetlands or water bodies. For the reaming, the contractor elected to ream the bore in two phases, reaming to a final diameter of 36 inches. The contractor also left the centralizer casing in place throughout the reaming process. Although it is highly recommended to have some kind of centralizer within the conductor casing for the reaming operations, the mud returns during reaming were laden with cuttings and the centralizer tended to restrict the flow at the entry location.

During the pullback for the upper bore, the Contractor had to stop to fuse the HDPE product pipe three times. The fuse duration from when the Contractor stopped pullback and then resumed pulling the pipe averaged one hour and forty-three minutes. The total duration of pullback was twelve hours, with five hours and ten minutes spent making the HDPE pipe fuses. For the lower bore pullback, the Contractor performed the same sequence of fuses, however one of the welds was suspect and the Contractor elected to cut out the fuse and refuse the pipe sections. This increased the overall duration of the pullback but resulted in piece of mind for all involved. The Contractor also utilized a buoyancy control water volume table to coordinate between entry and exit personnel for adding the volume of water required per length of pipe pulled to reduce installation forces. This procedure was performed for both the upper and the lower bores and assured that pullback would not outrun the addition of the required buoyancy control water.

5. DRILLING THE LOWER BORE

The lower bore was drilled after the completion of the upper bore. For tracking purposes, a wireline was placed within the completed upper bore and used to steer the lower bore. The length of the lower bore was 1940 feet and was constructed in 5 days, averaging 388 feet per day. Figure 9 shows the annular pressure as measured by the down-hole pressure tool that was located within 10 feet behind the drill bit as a function of distance. The graph also shows the minimum drilling pressure as submitted by Mears and the limiting pressure, above which hydrofracture should occur.

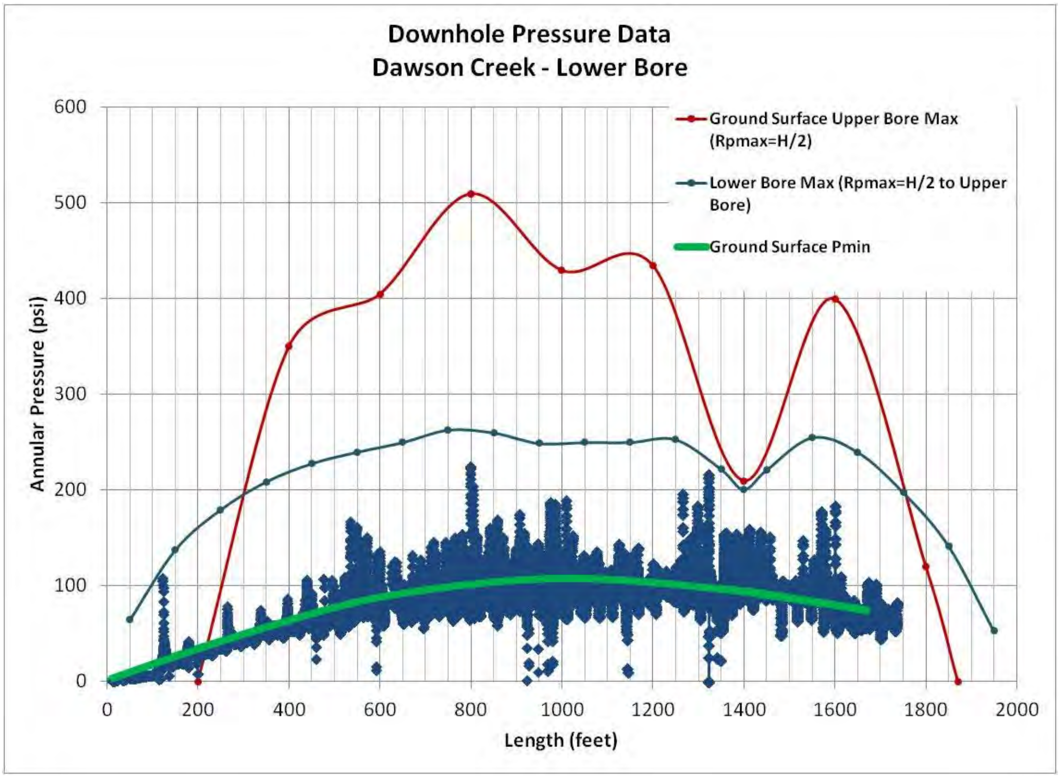

Figure 9. Measured Annular Pressure- Pilot bore – Dawson Creek Lower Bore

While drilling the lower pilot bore, the maximum drilling fluid pressures were established based on the location of the upper bore. Consequently, the actual drilling pressures were very close to exceeding the maximum allowable pressures at several locations. However, there were no observed inadvertent returns at the ground surface while drilling the pilot bore. If one compares the actual pressures versus the limiting pressures based on the ground surface, as is shown in Figure 9, the actual pressures are significantly lower than the maximum pressures with the exception of the location near 1400 feet where the creek is located. Although the actual pressures approached the limiting pressures for both the upper bore and the ground surface, no inadvertent returns were seen on either the pilot or the reaming operations during the construction of the lower bore.

5. CONCLUSIONS

For Clean Water Services, the use of HDD for the installation of the Dawson Creek Force Main pipelines was tremendously successful. Utilizing trenchless technologies allowed the project to be completed in an efficient and expedient manner and allowed the pipeline to be installed with minimum disturbance to sensitive wetlands and beneath Rock Creek while avoiding utility conflicts. Utilizing HDD as opposed to the alternative of open-cut excavation methods reduced force main alignment by approximately 2,500 feet, resulted in significant cost savings to the District and allowed the project schedule to be reduced. Through collaborative efforts with the Owner, Designer, Trenchless Specialty Consultant and the Contractor, project costs, schedule duration and impacts to the public were reduced while safety, quality and project value were increased.

4. REFERENCES

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