Multiple Trenchless Methods Allow for Water Supply Installation through Wyoming Terrain

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1. ABSTRACT

The Jamestown–Rio Vista Water Supply project located in Southwest Wyoming was constructed during difficult winter conditions and included three trenchless waterline installation methods. Two crossings of the Green River (each approximately 800 feet long) were completed by Horizontal Directional Drilling (HDD); a 1,200-foot long section of 6-inch PVC pipeline was replaced with 10-inch PVC pipeline by pipe bursting; and four road crossings were completed by Horizontal Auger Boring (HAB) with 24-inch steel casing including one 600-foot long crossing of Interstate-80. Sub-freezing temperatures and flooding caused by ice jams on the Green River complicated construction. Hard rock encountered during HAB crossing of I-80 also provided complications. Fusible PVC was used for the waterline for each of the three trenchless applications on the project. The project engineer was Sunrise Engineering out of Afton, Wyoming and the General Contractor was Western Municipal Construction of Wyoming from Meeteetse, Wyoming. This paper is a case study of the project and a presentation of the lessons learned.

2. INTRODUCTION

Jamestown–Rio Vista Water and Sewer District services approximately 200 water customers and lies just west of the City of Green River, a City in Southwest Wyoming with a population of about 12,000. The Green River originates in the Wind River mountains to the north and meanders south through Wyoming meeting the City of Green River at the point where Interstate-80 crosses over the river and just upstream of where it enters Utah and eventually finds its confluence with the Colorado. The defining feature of the City of Green River region is the red and white banded cliffs and rock forms on the north side of town. The cliffs, known as the Palisades, and a bluff, known as Toll Gate Rock, shadow the project area (see Figure 1) and were originally made famous by the paintings of the frontier landscape artist, Thomas Moran, who visited and the region in the 1870s.

The picturesque hard-rock geology seen around the project area is an indicator of the material that was encountered during two crossings of the Green River by Horizontal Directional Drilling and a crossing of I-80 by Horizontal Directional Auger Boring. The project also included a pipe bursting section in ideal sandy soils. During construction, the contractors dealt with difficult weather conditions as most of the project was constructed during the Wyoming winter in sub-freezing temperatures, wind, and snow.

This paper discusses the three trenchless methods used (Horizontal Directional Drilling, Horizontal Auger Boring, and Pipe Bursting) as they pertain to the project and the lessons learned.
3. PROJECT BACKGROUND

The Jamestown–Rio Vista Water and Sewer District (District) serves approximately 200 water connections. Prior to the project, the District operated a water treatment plant, constructed in the early 1980s. Having reached the end of its useful life, a feasibility study performed by the Wyoming Water Development Commission (2010) found that the preferred alternative was to disconnect the plant from the system and connect the District to the nearby Rock Springs, Green River, Sweetwater County Joint Powers Water Board Treatment Plant (JPWB-WTP).

The project required the construction of approximately 25,000 feet of water transmission line including a combination of 8-inch, 10-inch and 12-inch lines (see Figure 2). This included two crossings of the Green River (each approximately 800 feet) and a crossing of Interstate-80 (approximately 600 feet), the construction of a 600,000 gallon water tank, and the installation of valves and controls to operate the system. In addition to connecting the District to a new water supply (the JPWB-WTP), the project constructed water transmission line to the western and northern portions of the District, which were included in the District’s legal boundary, however, did not historically have access to water.

The project budget was $6.4 million USD with 67% being paid by grant from the Wyoming Water Development Commission and 33% being paid by a USDA-Rural Development loan with repayment coming from annual assessments on the properties within the District.

The District hired Sunrise Engineering of Afton, Wyoming to complete the design and permitting, provide bidding and negotiating services and provide construction administration on the project. The general contractor on the project was Western Municipal Construction of Wyoming of Meeteetse, Wyoming.
4. DESIGN

The design criteria for the project required that the system be able to receive water from the JPWB-WTP at a rate of 1,000 gallons per minute. The water flows by gravity from the JPWB system to the JRV system with 150-feet of head available to move the water through the transmission line. Hydraulic calculations indicated that a 10-inch diameter pipeline would be required. Calculations also indicated that pressure in the pipeline would range from 90 psi to 130 psi. Based on the pressure and hydraulic requirements, two pipe material options were specified for the main section of the transmission line. The first was 10-inch PVC DR18 which has an inside diameter (I.D.) of 9.79 inches or 12-inch HDPE DR 11 which has an I.D. of 10.29 inches. The I.D. for 10-inch HDPE was too small to meet the requirements so the 12-inch HDPE was selected.

Similarly, the material for the new pipeline on the west side of the District, which contains segments of 8-inch, 10-inch and 12-inch, required that, if HDPE was used it would need to be upsized by one nominal size.

4.1 RIVER CROSSINGS BY HDD

Many references are available for the design of river crossings by Horizontal Directional Drilling (HDD). During design, the engineer consulted Trenchless Technology Piping (Najafi, 2010) as well as the Handbook of Polyethylene Pipe (Plastics Pipe Institute, 2008). However, after a review of the typical design requirements, it was very helpful to call HDD contractors to discuss the project and receive recommendations. Experienced contractors were familiar with
the conditions in the area as there are a handful of pipe crossings under the Green River within a few miles upstream and downstream of the project area. It was helpful to email a Google Earth path of the proposed crossing alignments to the contractors and then call and discuss possible approaches.

As a result of the design guidelines in the literature and the insights of contractors, the following design criteria were determined for the project:

- A minimum cover depth of 30 feet between the river bed and the pipe,
- An entry angle of 23% (drillers typically like to work in percent grade rather than degrees of angle), and
- A radius of curvature that corresponds to a 2% change of direction per 20-foot stick of drill pipe.

The HDD portion of the work was to bid by linear foot, so it was important to have an accurate proposed profile in the plans so the bid quantity would be known. That being said, the specs allowed for some deviation, but did not allow for payment beyond the length of pipe between the stationing shown on the plans as “Start Bore” and “End Bore.”

When drawing a drill path on an exaggerated-scale profile, care was taken to show the radius correctly to ensure the minimum cover was correct. A simple-radius is not accurate on an exaggerated scale and may show the pipeline has more clearance than reality. Drawing the profile at a non-exaggerated scale first with line segments representing the drill steel with the proposed deflection per stick worked well. Then, the “Y” scale was exaggerated by the desired factor (e.g. 5:1 in the Figure 3 below). This results in the correct presentation of the drill path curves which will appear parabolic on an exaggerated scale, not as a simple radius. The profile below in Figure 3 has been taken from the project design drawings.

![Figure 3. Proposed HDD profile for east river crossing.](image)

The safe bend radius of the pipe was verified versus the proposed bends in the profile. The radius that results from a 2% change in direction per 20-foot stick of drill steel is 500 feet. The safe bend radius for 12-inch HDPE DR 11 is about 30 feet and for 10-inch PVC DR 18 is 231 feet.

Also, the load capability of the selected pipe material and thickness were checked for pull force and pipe collapse. Load calculations were performed based on the equations presented by Najafi (2010) in Section 5.5.2. It was determined that the pipe thickness dictated by the operating pressure requirements, which resulted in a DR 11 for HDPE pipe or DR 18 for PVC as discussed above, are also sufficient to withstand the loads imposed by the HDD process with a reasonable margin of safety.
4.2 PIPE BURSTING

The majority of the pipe on the project was installed by open trench, however there is one section that required the installation of 10-inch pipe adjacent to State Highway 374 along commercial business frontage with several paved approaches that cross the pipeline alignment. The section also contains several adjacent existing utilities including a 4-inch gas line, fiber optic lines and a 6-inch waterline. The new pipe is in the highway right-of-way and the Wyoming Department of Transportation required that any paved approaches be “bored.” Typically, approaches in the WYDOT ROW are tackled by horizontal auger boring with a steel casing, however, this particular location had several back-to-back approaches which would require a 700-foot long bore. In a site visit with the WYDOT personnel, the engineer proposed installing the new 10-inch pipeline by pipe bursting the existing 6-inch water pipeline, which was planned for abandonment as part of the project. WYDOT agreed to the idea. The pipe bursting section is 1,200 feet long with one fire hydrant reconnection and four water service reconnections.

4.3 ROAD CROSSINGS BY HAB

The project included four road crossings by Horizontal Auger Boring with steel casing; two county roads (80 feet long each), one highway bore (110 feet), and one bore of the Interstate 80 (600 feet). The specs required a minimum 18-inch diameter casing with 0.3125-inch wall thickness. The carrier pipe was specified to be either fused HDPE, fused PVC, or joint-restrained PVC.

5. GEOTECHNICAL CONSIDERATIONS

Exploratory borings were completed at each end of the River Crossings. At each location there exists poorly graded gravel and sand to a depth of 2 to 10 feet below ground surface, at which point bedrock is encountered. The rock is marlstone, sandstone and shale which are considered firm to very hard.

The Geotechnical Report performed by Terracon notes “the encountered soil and bedrock appear suitable for use of HDD methods for installation of the planned utility pipe at the river crossing sites. The presence of shallow bedrock, shallow groundwater, and gravel and sand will require careful consideration during design and installation of the utility” (Wyoming Water Development Commission, 2012, see Appendix L).

As discussed in the introduction, rock is prevalent throughout the project area and bedrock is relatively shallow. However, it is deep enough that it was not a factor through 95% of the project area where pipe was laid by open trench.

The day before the pre-bid meeting, several backhoe test pits where opened up along the pipeline alignment for observation by contractors. The pits were 7 feet in depth (the specified depth of cover over the waterline was 6 feet). Bedrock was not encountered in any of the pits. The pits were spaced uniformly along the 25,000-foot long pipeline alignment and one pit fell on the north side of the Interstate bore where soil consisted of poorly graded gravel and sand. No pit was excavated on the south side, but surface topography and visible sandstone rock outcroppings indicate shallow bedrock in that area of the project. In hind-sight, a pit should have also been excavated on the south side of the bore. Hard rock existed in this area that had a significant impact on construction as described later in the report.

For the pipe-bursting section, pot-holes were excavated by vac truck at each end of the pipe-bursting section to confirm the pipe diameters at the interface with existing waterlines and to observe soils. The soil is sand loam with gravel to a depth of at least 8 feet.

6. PROJECT AWARD

With the design complete and all permits in place, the project was ready to go to bid in the fall of 2017. Wyoming winters are cold and snowy making utility construction very difficult during winter months. However, the District, hoping for a mild winter, was insistent on bidding the project as soon as possible because the water treatment plant could fail at any time.

Bids were received in late October and Western Municipal Construction of Wyoming, the low bidder, was selected to complete the project. Western Municipal Construction (WMC) sub-contracted the trenchless portions of the project.
to Americom (Horizontal Directional Drilling), Levi’s Backhoe Service (Pipe Bursting) and Coleman Construction (Horizontal Boring and Jacking). The project was bid on a unit price basis. The unit prices from the trenchless items on the bid schedule are shown in Table 1 as follows:

Table 1. Bid results for Trenchless work on the project

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Low Bidder Unit Price</th>
<th>Average Unit Price of Lowest Three Bidders</th>
</tr>
</thead>
<tbody>
<tr>
<td>East River Crossing by HDD (10-inch Pipe)</td>
<td>820-LF</td>
<td>$ 270.00</td>
<td>$ 313.00</td>
</tr>
<tr>
<td>West River Crossing by HDD (12-inch Pipe)</td>
<td>715-LF</td>
<td>$ 310.00</td>
<td>$ 332.00</td>
</tr>
<tr>
<td>Horizontal Boring and Jacking Steel Casing (24-inch)</td>
<td>830-LF</td>
<td>$ 480.00</td>
<td>$ 392.00</td>
</tr>
<tr>
<td>Pipe burst 6-inch Water Pipe with 10-inch Water Pipe</td>
<td>1,200-LF</td>
<td>$ 70.00</td>
<td>$ 101.00</td>
</tr>
</tbody>
</table>

WMC selected fusible PVC for use through the trenchless portions of the project. Recall that the HDPE alternative required one nominal upsize (e.g. 12-inch HDPE or 10-inch PVC) in order to satisfy the hydraulic requirements of the project. This was likely a factor in the selection of PVC. Gasketed joint PVC was used throughout the project in the open-trench construction, so having consistent pipe material with identical diameter and DR facilitated easy transitions at the bores, and provided a consistent product for the JRV District.

6.1 CONTRACTORS QUESTIONS DURING PROJECT BUYOUT

During the bidding process contractors expressed doubt that a triple upsize could be achieved through the pipe bursting section (6-inch to 12-inch, should HDPE be used) without causing surface disturbance. The pipe depth is 6 feet and the soils are a sandy loam with some gravel. In discussing the issue with contractors, some thought it would be fine, others did not. As a result, an addendum was issued prior to the bid opening that allowed 10-inch HDPE to be used through the pipe bursting section, although the pipe I.D. of 8.68 inches was not ideal. In the end, it did not matter, because the contractor used fusible PVC.

Also during bidding, contractors noted that it would be very difficult to achieve the 600-foot horizontal bore under I-80 without intermediate bore pits. The bore is located at the covered wagon interchange and transects the off-ramp, both sets of travel lanes, and the on ramp. In discussions with WYDOT, they agreed to allow bore pits to be excavated between the ramps and the interstate lanes. This reduced the maximum distance between bore pits to about 300 feet.

7. CONSTRUCTION

Construction began on the project on December 12, 2017. The first work on the project was the delivery and fusion of the PVC pipe segments. In three days of work, the 3,600 feet of PVC was fused and laid out at the appropriate locations on the project.

7.1 RIVER CROSSINGS BY HDD

The horizontal directional drilling work began on December 14, 2017. The contractor set up on the east river bore and successfully installed the pilot hole and then reamed the hole to 12-inches prior to taking a few days off for Christmas. The river was frozen, but the weather warmed and the ice broke up and then jammed, refroze, and backed up the river. When the crew returned on December 27, the river was over the banks and flooding the site (see Figure 4). After a day the river broke free again and the water dropped. However, a few days later, the same process occurred backing the river up and blocking the contractor’s access to the south side of the river, making it impossible to transport drill
mud or equipment to the other side of the river. The south side of the river is accessed by driving under a railroad bridge. The typical 11 feet of clearance was reduced to 6 feet (see Figure 5).

After a few days, the river had not broken through again, so with no other option to continue work, the contractor left the 18-inch reamer in the hole and mobilized the equipment to the west river crossing. The west river crossing went smoothly with the pilot hole being achieved in 3 days followed by the 12-inch reamer (6 days) and then the 18-inch reamer (5 days). The 12-inch fusible PVC pipe was pulled into the bore with no issues (see Figure 6).

Upon completion of the west bore, the river had broken through and the needed access was again possible. The contractor returned and completed the east bore with no additional problems. In all, the two HDD river crossings took one and a half months to complete.
7.2 ROAD CROSSINGS BY HAB

The first Horizontal Auger Bore (HAB) that the contractor completed was beneath State Highway 374. The boring operation went smoothly with the exception of some unexpected fractured rock (recall that geotech test pits or borings were not performed specifically at the horizontal bore sites, with the exception of a backhoe pit at the north end of the Interstate bore).

The main issue encountered with the bores was that, in order to meet the bore lengths shown on the drawings, the bore pits encroached into the toe of the road embankment. This is not uncommon, however in this particular WYDOT District, this practice was not acceptable. WYDOT staff had reviewed the plans that show that the bore pits encroach on the slope issued the license, however the license stipulated that the pipeline must be encased from toe of slope to toe of slope. The WYDOT field inspector interpreted that to mean that the bore pits could not encroach on the toe of the road slopes.

In the end, a change order was required to add 90 lineal feet of additional casing installation by HAB work to the project. Better communication and better attention to detail from the contractor prior to beginning work may have alleviated the situation.

Another issue arose at the I-80 bore. The contractor approached the 600-foot long bore from the north side with intentions of boring the off ramp and both sets of travel lanes (a distance of 460 feet) and then setting an intermediate pit prior to boring the off ramp. Everything went smoothly until the bore reached the intermediate pit location, at which point the contractor hit solid rock (see Figure 7). After attempting to bore the rock with a standard cutting head,
the contractor retooled with a “Christmas Tree” style rock cutting head and was able to achieve the remaining 80 feet of the bore in two days of work.

The owner and contractor discussed a change order for the work, but the owner determined that the specifications for the project regarded the HAB work as “unclassified excavation” meaning that, unless the bid schedule contains measurement and payment items for “solid rock excavation,” there is no consideration given to different kinds of subsurface materials that are encountered.

Figure 7. HAB process boring in rock at the off-ramp at the I-80 bore (left). South end of I-80 bore casing in rock with PVC carrier pipe inserted (right).

7.3 PIPE BURSTING

Prior to this project, the general contractor had not completed a project with a pipe-bursting component. The contractor and the District Water Operator questioned if the work could be accomplished without ground disturbance. In fact, the District Water Operator asked the engineer to re-approach WYDOT with the idea of completing the section with open trench. WYDOT agreed to the idea if the trench was backfilled with flowable fill (low cement concrete). The cost of the open trench option was more than double the cost of the pipe bursting per lineal foot, so the owner decided to assume the risk and stay with the pipe bursting option.

The first step was to set up temporary water service to the four affected businesses. This was accomplished with a 2-inch interlock joint PVC waterline laid “back lot” and supplied by a connection to a nearby fire hydrant.

An area was available near the midpoint of the 1200-foot long pipe busting section for a bore pit, so the bursting contractor set up at that location and burst the east half of the segment, then turned the machine around and burst the west half. The fusible PVC worked well and pulled in with no issues (see Figure 8). The pipe bursting work took two days.

The only unanticipated adjustment was that additional fittings were required to tie the new pipe back into the existing waterlines at each end. As the old 6” pipe burst and new pipe pulled in, the fracturing of the old pipe and expansion of the soil occurred upward, so the bottom of the new 10” pipe followed the invert of the old pipe. As a result, the centerline of the new pipe is about 4 inches higher, which required vertical adjustments to be made at the tie-ins.

Also, tracer wire was required throughout the project, but the higher strength tracer wire for pipe bursting was not specifically called out. The contractor attempted to pull standard wire with the pipe (the same wire used in open trench construction) and was successful on the first 600-foot long pull, however, was not successful on the second pull having the wire break somewhere along the path.
8. LESSONS LEARNED

In summary several lessons were learned about the design and construction of a project with trenchless components.

- Call contractors during design to discuss design criteria. Involving contractors during design will help alleviate contractor questions during bidding that may require design changes by addendum.

- Geotechnical data is critical to a successful project. On this project, the engineer assumed that the existence of visual rock on the surface at the east end of the I-80 bore would provide evidence of potential difficult HAB conditions. Like the HDD bores, Geotech investigation at the end of each major Horizontal Auger Bore is important.

- Review agency permits and licenses thoroughly prior to construction. Just because the agency reviewed the drawings and issued a license/permit, does not mean that they will like the way things look on the ground during construction.

- When upsizing a pipeline by pipe bursting, the new pipe grade will likely be higher than the old pipe grade and may require vertical adjustments to tie back into to existing pipes.

- Specify tracer wire designed for pipe bursting and directional drilling, otherwise it may not make it through with the pipe.

9. CONCLUSION

The day that JRV District turned water into the new pipeline and took their failing water treatment plant offline was a happy day for the board of directors and the water operators. Winter construction was difficult but ultimately worth it. Overall, the project was a major success and has provided a reliable drinking water supply to the Jamestown – Rio Vista area for years to come.

The contractor selected fusible PVC for the trenchless work on the project, which provided a seamless interface between the gasketed PVC pipe installed by open trench and resulted in a consistent pipe material throughout the project. There were no issues with the fusible PVC during construction.
Although the General Contractor and District water operator had doubts about the pipe bursting process, both were very pleased and impressed by the results. During construction, several locals stopped to see the process and it seemed everyone wanted to see how it worked.

The Engineer and General Contractor found that trenchless construction techniques were critical to the success of the project. Waterline installation by HDD is obviously the best method for the crossings of the Green River. However, in the other two trenchless aspects of the project the work could have feasibly been accomplished by open trench, which is typically the default approach to everything in rural projects. In fact, the preliminary plan was to install the waterline crossing of I-80 by open trench in the two-lane roadway under the interchange, however the complications with traffic control and extensive surface restoration ultimately led the engineer away from this option. Trenchless construction at both the I-80 crossing and the pipe bursting section of the project proved to be much cleaner and less costly than open trench alternatives.

Even in very rural projects with minimal surface improvements trenchless construction methods can be incorporated to provide value to the project.

10. REFERENCES


