Yellowstone National Park Utilizes Directional Drilling to Install a 24-inch Diameter Pipe under the Yellowstone River

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1. ABSTRACT

The Yellowstone National Park was established in 1872 by President Ulysses S. Grant, making it America’s first national park. The first year it opened, it saw 300 visitors. Today, it has become an international tourist destination with more than 4 million visitors annually.

Infrastructure to support the ever increasing visitor numbers has also grown in size and scope. In recent years, needs were identified for increased utility capacity. One high priority project was the rehabilitation, replacement, and improvement of the Fishing Bridge and Lake Water System. An essential part of planned improvements was the replacement of the main service line from the supply on the west side of the Yellowstone River to campgrounds on the east side of the river. In addition to replacement of the water line river crossing, electrical and communications utilities also required increased capacity and redundancy. Rather than disturbing this pristine waterway with traditional open trench construction, designers decided that directionally drilling under the river, a construction method never attempted before in the Park, would provide the optimal installation methodology. The project consisted of a 1,400-foot-long 24-inch diameter casing pipe installed via HDD, within which were a 10-inch water line, three 3-inch, and three 4-inch conduits conveying power and fiber optic lines.

This paper will present the design and construction challenges of working in a pristine national park in a high alpine environment under schedule constraints to complete the work in the tourist offseason before the early winter snows arrived.

2. INTRODUCTION AND PROJECT BACKGROUND

In 1870, the first organized excursion set out to explore the lands currently known as the Yellowstone National Park. The Yellowstone Plateau contains some of the world’s most active volcanic, earthquake, and hydrothermal systems, featuring numerous hot springs, geysers, and mud pools, as well as large numbers of diverse wildlife. Upon completion of the expedition, the explorers pushed to establish a park bill in Washington with the intention of saving Yellowstone from private development, modeled after the Yosemite Act of 1864 that prevented settlement in Yosemite Valley. Continuous reports, the support of explorers, and artwork of the scenery inspired Congress to establish the Yellowstone National Park with the Yellowstone National Park Protection Act signed into law on March 1, 1872. This act states that the land is reserved from settlement and set apart as a public park “for the benefit and enjoyment of the people” (see Figure 1).
Park infrastructure developed slowly over the history of the Park. One factor was that administration of the Park changed hands several times with differing goals and philosophies regarding the visitor experience. In the early years, the Park was run by various superintendents. The U.S. Army was in charge from 1886 until 1918, when the National Park Service (NPS) took over. Notable developments in the Army era include the construction of Fort Yellowstone, most of the Park’s current road system, and lodging facilities to meet tourist demands. Around the time of these improvements, Park access by the public was vastly increased by railroad service and then by the automobile. The Northern Pacific Railroad reached the North Entrance of the Park in 1883, the Union Pacific Railroad began servicing West Yellowstone in 1908, and personal vehicles were allowed into the Park in 1915. The most recent round of infrastructure improvements prior to the present occurred from 1955 to 1966 during the Mission 66 project, a period when tourist visitation numbers were in the range of about one million per year. Since the completion of Mission 66, Yellowstone visitation has steadily increased with the latest annual visitor statistics approaching 4 million. The NPS has recognized the need for major improvements to infrastructure to accommodate increasing visitor numbers, resulting in the funding of major road, housing, and utility projects over the last decade.

Fishing Bridge is a historic bridge that crosses the river’s outlet at an elevation of over 8,000 feet. Fishing Bridge area visitor infrastructure is located on the east side of river and includes the Fishing Bridge RV Park and amenities, employee housing, one of the Yellowstone General Stores, and an NPS Visitor Center. The Fishing Bridge RV Park has more than 325 sites and is the only Yellowstone campground to offer sewer, electrical, and water hook ups. It also contains laundry and shower facilities. These features make Fishing Bridge an ideal RV destination; ensuring adequate domestic and fire suppression water to the RV sites, store, and museum is therefore a high priority.

The Fishing Bridge water system that supplies these facilities is part of the larger Lake area water system. The Lake and Fishing Bridge systems are supplied by wells, springs, and storage tanks located on the west side of the river. The potable water and electrical power systems at Fishing Bridge were identified as undersized and aging prior to this project. For instance, the main transmission line was installed over 70 years ago and crosses the river attached to the historic wooden bridge. The aged water system was known to have many leaks resulting in significant water loss. Built in the early ’60s, around the time the Fishing Bridge RV Park was constructed, the electrical distribution system was clearly outdated and aging. Upgrades to the electrical system were initiated after camp site electrical hook ups had to be cut off for the summer of 2010 due to a system failure resulting from overload of the undersized system. Additional capacity and redundancy of power supply across the river was a critical need prior to the project.

The exposed 10-inch cast iron water line crossing the river attached to Fishing Bridge (see Figure 2) was clearly identified by the NPS as the most critical deficiency in the system. The transmission line is the sole source of water from tank storage and supply on the west side of the Yellowstone River to the distribution system on the east side of the river. Partially corroded pipe and fittings exposed to the elements for decades had resulted in frequent leaks. Since the line was not insulated or heated, it had to be shut off and drained in the winter months to prevent freezing.
After studies identified the system as a priority infrastructure project, the NPS tasked Nelson Engineering of Jackson, Wyoming with the design of the Fishing Bridge Water Replacement Project in 2010. A multi-utility crossing of one of the most pristine waterways in the country was a critical component of the project design.

3. PROJECT DESIGN

The Fishing Bridge water system is supplied from a water storage tank located on low bluffs to the west of the river via a transmission line that follows the East Entrance Road then crosses the river attached to historic Fishing Bridge. The line supplies smaller transmission lines, distribution lines, and services at the RV Park, employee housing, the visitor center, and the Yellowstone General Store. The developed area and road are surrounded by pristine mixed forest, meadow, and wetland areas, transected by the Yellowstone River. The area is home to elk, moose, grizzlies, cutthroat trout, bald eagles, ospreys, otters, beavers, and numerous other species of wildlife. The bridge and surrounding pathways is a major visitor stop. Major design concerns were therefore minimizing impairment of the visitor experience during construction and minimizing disturbance of sensitive environmental areas. Timing of construction was crucial as major construction during the tourist season was not allowed, winter comes early to the high country, and Park roads close for the season in November or earlier if snow piles up. Consequently, construction was scheduled to start at the end of prime tourist season and end before the arrival of early winter snowfalls and closure of the Park in late November.

Having identified the need to replace the water transmission line crossing the Yellowstone River, project designers and the NPS evaluated alternative methods of construction. The analysis considered impacts on the environment and the visitor experience during construction, long term maintenance requirements, and winter usage requirements. Hanging the replacement line from Fishing Bridge was rejected for two reasons. First, this option would require actively heating the line as the sole method of assured freeze prevention in winter. The risk of a power outage and subsequent freezing and failure of the line was unacceptable, therefore a backup power source would have to be installed. Second, bridge repair or replacement, projected within the next 20 years, would necessitate a complete replacement of the line. Conventional open cut trenching across the Yellowstone River would create a significant sediment impact to the river while scenically impacting the visitor experience. Pristine and brimming with fish, sediment release from trenching was deemed unacceptable. It quickly became apparent that a trenchless installation would be the best option for the river crossing. Nelson Engineering recommended horizontal directional drilling (HDD) as the preferred, least intrusive option for crossing the river with the water line and dry utilities. The NPS had never used HDD for a project of this magnitude in Yellowstone; Nelson Engineering had designed and performed construction oversight of several similar water line HDD crossings of streams and rivers in western Wyoming in recent years.

Once it was determined that HDD would be used to cross the river, water main and utility conduit sizing analysis was performed. Water system modeling resulted in a 10-inch carrier pipe; the NPS determined that three 3-inch high density polyethylene (HDPE) and three 4-inch HDPE conduits were desired for power, telephone, and fiber optic
lines. Conduit burial continued beyond the river crossing as part of an ongoing NPS program to place electrical transmission lines underground in the Park as standard overhead power lines are frequently damaged by fallen trees. Nelson Engineering examined several HDD line and conduit installation alternatives and settled on a single cased bore housing all of the proposed lines as the least costly alternative with the shortest construction time.

The engineering team evaluated casing and carrier pipe type material alternatives. HDPE and fusible polyvinyl chloride pipe (FPVCP) were the primary pipe materials evaluated as both met the bending radius/bore path design criteria. Pipe type selection criteria included thermal expansion minimization, strength and bend radius in combination, ovality resistance under long-term load, and minimization of casing pipe and resulting bore diameter. FPVCP was selected as the best type of pipe for both the casing and the 10-inch transmission line. A 24-inch DR 18 FPVCP line with an inside diameter of 22.76 inches provided sufficient space for the 10-inch FPVCP water line, three 3-inch HDPE conduits, and three 4-inch HDPE conduits (see Figure 3). An HDPE casing would have required a 30-inch diameter to accommodate the same utility bundle, requiring a 42-inch bore diameter versus the 36-inch bore diameter required for the smaller FPVCP casing.

**Figure 3.** Casing cross section.

Design of the vertical and horizontal HDD bore alignment was primarily based on two factors, subsurface conditions determined from a geologic and geotechnical investigation and HDD construction equipment layout requirements coupled with site constraints. The geotechnical and geological investigation included analysis of historic well logs and a subsurface investigation. Two borings were advanced, one located on the west bank of Yellowstone River taken to a depth of 51 feet and one located near the midpoint of the bore at the east end of the existing bridge advanced to a depth of 41 feet. A test pit was advanced at the eastern terminus of the bore to a depth of 14 feet. Subsurface conditions in the borings, test pits, and historic well logs on the east side of the bore in the Fishing Bridge area, were relatively uniform. Lacustrine clays and sandy clays with occasional thin strata of alluvial obsidian sands and gravel predominated. Sand and gravel beds did not appear to be continuous across the bore path. Larger cobbles and gravels were not detected in either the current or historic drill holes indicating conditions conducive for HDD. Bank termination locations for the HDD installed casing were determined from the allowable set-up areas in parking lots on both sides of the river. Start and end point constraints resulted in a 1,360-foot bore with a depth of 30 feet below the river bed at the center. The alignment tied into trench depths at the terminations on the banks (see Figure 4). The bore depth of approximately 30 feet below the river bed was determined from both hydro-fracture and scour considerations. Scour depth was determined to be well above this elevation as the elevation of bedrock control in the river bed downstream limited scour at the bridge location.

**Figure 4.** HDD 24-inch casing centerline profile.
Designers determined the best option for installation of the remainder of the water transmission main and distribution system line upgrades was by direct burial. Trenching in the remainder of the project had reduced environmental concerns as most of the lines to be replaced run along existing roads and trails in the developed Fishing Bridge area. The majority of existing lines were 2-inch and 6-inch in size with some 8-inch sections. The system upgrade would increase most lines by one or two sizes. Standard ductile iron pressure class 350 pipe was selected for the 18,000 feet of open trench pipe installation in the project.

4. PROJECT BIDDING AND CONSTRUCTION

The “Replace Fishing Bridge Water System Project” advertised to bidders on July 15, 2014. The bid form designated the multi-utility crossing as a single lump sum item titled “Yellowstone River HDD Crossing.” Open cut pipe segments were bid as separate line items for each size of ductile iron pipe. Time constraints required a cohesive work effort to ensure the HDD installation was expeditiously completed. One way of encouraging this was to bid the HDD lump sum such that a single subcontractor could bid the entire HDD installation. The lump sum HDD item included all work required for the installation of the 24-inch DR 18 FPVCP casing, the 10-inch DR 18 FPVCP water line, and the three 3-inch and three 4-inch DR 11 HDPE conduits up to the point of tie-in to the conventional trench installed water main. The project bid in August of 2014 and was awarded to Scout Lake Construction of Selah, Washington who chose Nomad Pipeline Services of Rockville, Minnesota to perform the directional drill.

Due to the short work window between the end of prime tourist season, winter weather, and the closure of the Park for the year in late November, construction timelines started immediately after the project was awarded. Peak tourist season ends in late September with the closure of most of the facilities in the Fishing Bridge area. Yellowstone typically has medium to light visitor traffic in the month of October with variable weather including both snow storms and sunny warm periods. The contractor elected to perform the HDD work at the front end of the project in the fall of 2014 to take advantage of the low traffic through the construction area while understanding the risks posed by bad weather.

As part of the submittal process, initiated in the summer of 2014, the contractor was required to provide a proposed bore path complete with hydro-fracture analysis. This requirement was imposed to ensure the contractor’s proposed drilling equipment and techniques were compatible with Nelson’s design assumptions in hydro-fracture analysis. Brierley Associates of Burnsville, MN was tasked by Nomad to perform bore path evaluations. Brierley utilized more conservative assumptions for clay strength and mud pressures than the design assumptions; consequently Nomad proposed a bore alignment that crossed the river at about a 10 foot greater depth than the design alignment. The submitted alignment also moved the boring termination on the west side further west to accommodate equipment setup, resulting in a 1,450 linear foot total casing length. This alignment was approved by Nelson Engineering and was used in construction.

Nomad mobilized in October of 2014, setting up sending and receiving pits in the designated visitor parking areas on the east and west sides of the Yellowstone River. Constraints on set-up included the requirement to maintain 10 open parking spaces in each area and to provide pedestrian access from these spaces to the bridge. Casing pipe fusion layout was dictated by pipe length. Fusing the full length of casing and carrier pipe on the west side was not possible as pipe could not cross the Grand Loop Road; an intermediate fusion joint would have to be performed during pullback if the west side was used for fusion layout. Preferring to fuse the casing pipe without an intermediate fusion joint, the drill rig was set up in the west parking lot and the pipe was laid out and fused on the east side along East Entrance Road (see Figure 5).
A major challenge was the relative isolation of the project site. The closest town is Cody, WY, located two or more hours west via winding roads over a mountain pass and down the canyon of the North Shoshone River. The nearest major city is Billings, Montana, an additional two hours from Cody. Given the distance to tangible equipment and supplies, crews were required to plan carefully and pack in equipment, supplies, and spare parts to minimize time-consuming trips in and out of the Park. The secluded nature of the project made it high risk; if any equipment breakdowns occurred, a mechanic or any other specialized help would take days to arrive.

Disposal of the drilling slurry was a point of concern and focus for the drilling operation. No spilling of the drilling slurry would be tolerated in the environment of the installation. To prevent any incidents of frac-out or spillage, Nomad Pipeline Services methodically and slowly performed the drilling process, using caution during all phases of the job. As there was no facility for temporary storage of drilling mud generated during the bore, Nomad utilized multiple vacuum trucks to extract excess slurry, which was then transported out of the Park for disposal. Nomad used most of the month of October to complete a 36-inch bore hole for the 24-inch casing pipe. Pilot boring was initiated in early October, followed by a 24-inch ream mid-October, and finally a 36-inch ream completed in the last week of the month. Soil conditions were generally consistent with those expected from the geotechnical investigation although some clays with higher cohesion than anticipated were encountered. An interval where return flow was lost was encountered near the end of the bore. No surface indication of hydro-fracture was found and the engineer and contractor elected to continue the pilot bore to completion. The driller was able to follow the approved bore alignment reaching depths of 40 feet below the river bed.

In the same month, Underground Solutions Inc. (UGSI) began the fusion and layout of the 24-inch FPVCP casing and 10-inch FPVCP water line on the east end of Fishing Bridge. The October start posed a challenge due to the cold temperatures and snowfall typical of the month in Yellowstone. Short days and cold nights required longer warm up times for fusion equipment and had the potential to slow the fusion process of the FPVCP strings with ambient temperatures as low as 20° F. To prevent weather delays, tents and canopies were set up around the fusion machines to protect the fusion process from the elements and warm the pipe so that the joints could be properly butt-fused (see Figure 6). The 24-inch FPVCP was fused in a single length and staged on rollers to facilitate the insertion process. The 10-inch water line was fused simultaneously and staged in the same area (see Figure 7). The pipe strings were laid out along a small access road adjacent to East Entrance Road, allowing visitors full access to Fishing Bridge with no lane closures. Pipe strings were allowed to block entrances into the RV Park and General Store which were already closed for the season. Aside from the cold temperatures, the project site received good weather compared to the long term averages and no major storms occurred. The area saw light snowfall during pipe fusion; heavier snow was just starting to fall as the fusion process was completed.
Long-term vertical loading analysis on 24-inch DR 18 FPVCP indicated the allowable deflection of 7.5% would not be exceeded if the pipe was unballasted. This analysis assumed the bored casing would be installed under 10 feet of water and 30 feet of saturated soil per the design profile maximum depth. Therefore, the casing pipe was not ballasted during installation to avoid the process of removing the water from the casing before installing the carrier pipe bundle. Had it been ballasted, the contractor would have had to dispose the ballast water in a similar manner to the drilling fluids in the bore process.

Bore hole and pipe fusion completion schedules coincided such that the casing pipe was ready for installation upon bore hole completion. The 1,450 linear feet of casing pipe was pulled through the bore hole in early November 2014 on a brisk day with temperatures in the 20’s. The insertion took around six hours and was without incident (see Figure 8). Fluid management during pull back was carefully conducted to prevent any spills that could contaminate the pristine areas at the casing termini.

The water line and conduits were installed within the casing the following week. Fusing and staging the casing and water line carrier pipes at the same time greatly minimized delay between the casing installation and the carrier and
conduit insertion. HDPE pipe for the 3-inch and 4-inch conduits came on 500 foot reels which were thermally butt-fused at joints as the carrier bundle was pulled through the casing. Casing spacers were installed at designated intervals to keep a consistent cross-section of the utilities within the casing. HDPE pipe was strapped between the casing spacer skids; alternating two conduits, one conduit, two conduits, and then one conduit in each gap between the skids to evenly attach all six conduits to the 10-inch carrier pipe (see Figure 9).

![Figure 9. Carrier and conduit assembly.](image)

After successful installation, the pipe ends were capped and the holes at the HDD entry and exit were temporarily backfilled. Grouting between the casing pipe and the carrier bundle was not necessary. The spacer set-up allowed little movement such that the carrier and conduits are essentially locked in place. All work on the river crossing was completed a week before the Park closed for the year 2014. Reconnection and complete operation of the system would be completed at the end of the 2015 season in order to coordinate the tie-in from the crossing to the water transmission lines installed by open trench.

The 10-inch FPVCP water line passed hydrostatic pressure testing on September 9, 2015. The remaining water system construction, including transmission and distribution lines and a new water storage tank were largely completed in the summer of 2015. Remaining work will be completed in the summer of 2016. The existing water lines, which have remained in service for the duration of the project, will be capped off and abandoned once the new water system is in service.

5. CONCLUSION

Timely coordination between Nomad, the NPS, Nelson Engineering, and UGSI made it possible to complete the Yellowstone River crossing in the limited time available. The NPS and Nelson Engineering expedited submittals and permitting and responded promptly to questions regarding environmental issues. Simultaneous fusion of the casing and carrier pipes during boring operation eliminated delays in construction allowing for continuous progress from one phase of the installation to the next.

Plans and specifications prepared by the engineer provided the contractor with a clear guide to the performance of the work and specifically required the smallest possible environmental footprint in both area and consequence. The cautious boring and thorough monitoring practices of Nomad Pipeline Services resulted in a clean bore with no environmental impact due to frac-out or mud spillage. Cold weather and snow posed challenges to the bore that were overcome by the project team. Consequently, impacts to an international tourist attraction during peak visitor season were avoided. Fall construction did provide the benefit of a relatively quiet work area, permitting more room for equipment set-up and pipe staging than could have been permitted during the summer.
The successful installation of the multi-utility crossing in 2014 and the remaining Fishing Bridge water system upgrades to be completed in 2016 will increase the capacity of both the water services in the developed Fishing Bridge area and the electrical amenities to the infrastructure to meet the increasing tourist population travelling to Yellowstone each year. The new water system eliminates major issues present in the existing lines, namely water leakage and the required water line shut off in the winter since the exposed cast iron line hung under Fishing Bridge would freeze each year. This project stands as the first HDD installation within Yellowstone National Park, providing a critical utility link across the Yellowstone River.

6. REFERENCES


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