1. ABSTRACT

The Cole Junction Pump Station and forcemain was designed to eliminate wet weather overflows in Jefferson City, Missouri. It is capable of conveying 14,000 gpm to the waste water treatment plant. The pump station is located on the south side of the Missouri River and the treatment plant is located on the north side of the river. It was determined early on in the design process that a horizontal directional drill (HDD) would be the preferred method for crossing the Missouri River with the required alignment.

Donohue and Associates (Engineer) was retained by Jefferson City to provide overall design services for the pump station and forcemain. The preferred alignment for the pipeline provided significant challenges based on coordination with levee districts, USACE, railroads and land owners. The Missouri River crossing, in particular, would require a 2,350 foot HDD at a depth of greater than 70 feet below top of bank and approximately 40 feet below the river bed.

This paper will provide a review of the HDD design process for the Missouri River crossing, including geotechnical investigation, HDD geometry, material selection, pull force calculations, and other relevant design elements. In addition, there will be a detailed review of the HDD construction process and the issues that arose during the installation. Finally, a discussion will be provided on how those construction issues were addressed to end up with a finished product that met the owner’s expectations.

2. INTRODUCTION

Jefferson City, named for Thomas Jefferson, the third president of the United States, is the capital of the state of Missouri and located in the central portion of the state between Cole, Callaway, and Osage Counties. The city is situated near the northern edge of the Ozark uplift, and consists of 35.95 square miles of land area and 1.63 square miles of water area (see Figure 1). As of the 2010 census, the population was 43,079, making it the 15th largest city in the state.

The Jefferson City Regional Water Reclamation Facility (JCRWRF) is located next door to the municipal airport on the north side of the Missouri River and just east of Highway 54. Jefferson City provides regional wastewater collection and treatment for the citizens located inside the corporate limits and sections of Cole County located between Jefferson City and St. Martins. Wastewater from Jefferson City residents and the surrounding area flows through underground pipelines into the collection system. Wastewater generally flows by gravity and in some cases is pumped to the JCRWRT facility where it undergoes treatment and is then discharged into the Missouri River.
The original Cole Junction Pump Station was located approximately 4.5 miles northwest of the existing JCRWRF. The original pump station was capable of pumping approximately 2,000 gallons per minute to a point at which gravity could then convey the flow to the JCRWRF. There were multiple issues that made the original system less than ideal. First, the existing pump station and accompanying gravity system did not have the capacity to handle the wet weather flow rates necessary to comply with Missouri Department of Natural Resources (MDNR) requirements. In addition, there were significant odor complaints along the existing gravity system that were a direct result of the age of the wastewater being conveyed via the forcemain into the gravity system. Considering both current and future conditions, the city needed to address these concerns with the primary focus to remove wet weather overflows from the system at the pump station location.

3. OVERALL PROJECT DESIGN

Donohue and Associates was selected by Jefferson City to evaluate alternatives that would eliminate wet weather overflows. Initially, the Engineer looked at multiple scenarios involving pump station sizing, wet weather storage and forcemain sizing to determine the most cost effective manner of handling and conveying the additional flows during a 10-year storm event. As a result of the engineering effort it was determined that the solution would include a 14,000 gallon per minute wastewater pump station and approximately 23,000 linear feet (LF) of 24-inch forcemain to carry the sewage all the way to the Jefferson City Regional Water Reclamation Facility. Eliminating the lift station flows from the downstream gravity system allowed the city to avoid the significant cost associated with increasing capacity in the downstream system saving the City approximately ten million dollars.

The location of the new pump station was selected based on the proximity to the existing pump station and the ability to do minimal routing of the gravity sewer to make the connections. The new location could not have moved north based on the location of Grays Creek. In addition, existing development prevented siting the pump station any significant distance to the south or west of the proposed location. Ultimately, the new pump station was sited approximately 200 feet south of the existing pump station a little more than 100 feet off of Missouri Highway 179 (see Figure 2).

The force main would connect the new pump station to the existing JCRWRF. The new force main alignment runs easterly along the north side and parallel to the Union Pacific railroad, until it crosses the Missouri River into Callaway County. The alignment continues along 4th Street in North Jefferson City, then along Mokane Road to the JCRWRF. The proposed alignment is predominantly within the Missouri River floodplain and its tributaries. The design of the forcemain contained many challenging features including two highway crossings, crossing levied sections of Grays Creek, a railroad crossing, a Missouri River crossing, a Turkey Creek crossing, and extensive coordination/permitting with multiple agencies.
Significant time and effort was expended during the design process making adjustments to the proposed alignment based on easement acquisition, highway crossings, creek crossings and railroad crossings. Based on all of the obstacles, just being able to make horizontal and vertical alignments that would be constructible was a challenge. In order to cross Missouri Highway 179, the railroad tracks and Grays Creek at three separate locations a 42-inch steel casing was installed using conventional jack and bore with 24-inch PVC installed inside the casing. HDD was not feasible in these locations based of the tight site constraints. It was much better suited to jack and bore with multiple bends and more abrupt elevation changes.

After navigating the alignment challenges adjacent to the new pump station location the alignment followed a southwesterly path for approximately 4,000 feet, sandwiched between the railroad alignment and back side of a flood control levee until turning west to setup for the Missouri River Crossing.

The area of most concern for pipe installation involved crossing the Missouri River, which affected approximately 2,400 LF of the alignment. The Missouri River runs through the center of Jefferson City and divides the service area between the pump station and treatment plant. In addition, there was a second crossing at Turkey Creek, which affected approximately 800 LF of the alignment, located on the north side of the river that also needed to be taken into consideration. With open trench eliminated as an option for both crossings, Donohue focused their attention on looking into trenchless methods to install the pipelines at both areas. It was at this point that they engaged Brierley and Associates (Sub Consultant) to aid in the trenchless design.

It was clear during the design process that the south (or east) side of the river would be the location where the drill rig would be setup for the Missouri River HDD. While the area was able to be cleared to allow rig, recycler, and all supporting equipment to be situated, based on access, the site was less than ideal. However, it was imperative that the pipe string be fused and laid out on the north (west) side of the river as that was where ample room to fuse the entire 2,400 foot string was available (see Figure 3). This was determined during the design phase based on the need to acquire temporary construction permits for drill rig setup, and pipe assembly and layout area.
When looking at pipe material for open cut portion of the alignment, The Engineer contemplated high density polyethylene (HDPE) and polyvinylchloride (PVC) pipe materials. Based on estimates of total installed cost, 24 inch DR 25 bell and spigot PVC was specified for the open cut portions of the project. The 165 psi allowable working pressure was more than adequate to meet the operating conditions of the forcemain. In areas where the pipe was installed inside steel casings, or adjacent to fitting locations, the pipe was restrained to eliminate the potential for joint separation.

The Engineer and their Sub Consultant looked closely into the design of the pipeline crossings under the Missouri River and Turkey Creek. The two pipe material options that were being taken into consideration were fusible polyvinylchloride pipe (FPVCP) and HDPE. The crossing under the Missouri River measured about 2,400 LF, and the depth of cover reached up to 80 feet. The pipe would need to provide the strength and stiffness required for pullback and post-installation operations.

In addition to the installation stresses exerted on the pipe, the inside diameter (ID) of the pipe material that was to be used for the HDD portion of the project was considered. The inside diameter of 24 inch DR 25 bell and spigot pipe is 23.61 inches. While the FPVCP utilized for the direction drill sections was specified as DR18 with an inside diameter of 22.76 the slight difference in pipe dimensions did not have an overall impact on the system hydraulics. The HDPE specified was 30 inch DR9 in ductile iron pipe size which provides an inside diameter of 24.45 inches.

4. GEOLOGY

When looking at the complex design that is involved in a 2,400 LF HDD utilizing 24-inch pipe the first step is to determine the overall geology along the alignment. The Engineer utilized Engineering Surveys and Services (ES&S) to provide an overall project geotechnical investigation. Extensive exploratory boring was done along the alignment to classify the existing soil conditions including deep borings on each side of the Missouri River at the location of the Missouri River HDD.

In general, soils along the project alignment that were located within the floodplain areas were described as alluvium with significant variation in sand, silt and clay content. The soils in the region are typically derived from residual clay weathered from bedrock or loess (a fine, yellowish-gray, clay-like sediment) that occurs on hilltops and undissected slopes. In the two deep bores adjacent to the Missouri River the geology was described as exhibiting varying proportions of sand, silt, and clay with random gravel zones. It was determined that the random gravel zones
would not adversely affect the drilling process. In addition, weathered and highly fractured limestone deposits were encountered beginning at 80 and 85 feet deep with competent limestone beginning at 90 to 95 feet deep.

Borings at the Turkey Creek crossing showed similar soils to Missouri River Crossing and surrounding areas. The exploration was terminated at approximately 45 feet deep based on the anticipated depth of the HDD crossings. At the termination depth the soils were reported as dense sand.

5. HDD DESIGN

By combining the horizontal alignment with the soil information that was determined in the subsurface investigation The Engineer in combination with their Sub Consultant could put together the HDD profiles and analyze the installation and long term operating stress that would be seen by the pipe material.

Both drills were designed with entrance and exit angles of approximately 10 degrees. The proposed locations for the entrance and exit pits, in relation to the river/creek banks, was designed to achieve significant depth prior to crossing under the waterways. The depth achieved prior to entering the stream zone on the Turkey Creek Crossing was approximately 40 feet below top of bank with approximately 25 feet clearance provided at the bottom of channel. For the Missouri River Crossing the drill achieved greater than 50 feet of depth prior to crossing under the bank and maintained greater than 30 feet of depth under the river bottom.

Both drills were designed using a maximum radius of curvature of 1,200 feet in making the transition from the 10 degree entrance and exit angle to the flat portions in the bottom of the drill. The 1,200 foot radius would accommodate either pipe material that was selected with room for adjustment should the driller desire to make slight modifications when preparing their bore plan. Based on a desire to reduce overall pull forces, the contract documents required that the pipe be water ballasted during pull-in. This reduces the overall buoyance of the pipe and drops the frictional forces that are generated during pull-in as the pipe will ride on the top of the bore hole. In addition to reducing buoyant forces, utilizing water ballasting also provides and internal hydrostatic pressure that provides resistance to critical buckling forces that are exerted on the pipe during pull-in at greater depths. Even though the pipe material selected in the design process provided significant resistance to critical buckling forces it was considered an added benefit.

6. PROJECT BIDDING AND CONSTRUCTION

The project design documents were completed and the project was advertised to prospective bidders. The bid form had one bid item for 2,938 LF of 24-inch FPVCP or 30-inch HDPE forcemain installed via HDD which included both the Missouri River and Turkey Creek Crossings. Rosetta Construction of Springfield, Missouri was the low bidding contractor and was awarded the contract for the forcemain installation. Lone Star Directional Drilling was hired as the Subcontractor to perform the directional drilling sections of the project.

Taking into account the design factors that both the Engineer and their Sub Consultant had researched for months before bid day, the Contractor and Subcontractor determined that FPVCP would be the best pipe and most cost effective option for the HDD portions of the project, due to the difference in required product pipe outer diameters (see Figure 4). Using FPVCP would allow cost savings resulting from the smaller bore hole required for installation, as well as the ease of reconnection back to the bell & spigot pipe used in the open cut segments on either side.

Construction began in December of 2012. The first HDD installation was the shorter of the two underneath Turkey Creek. The Subcontractor began the process by drilling a pilot hole along the bore path from the east side of the creek to the west side. Once the pilot hole was drilled, the reaming process began. During this process, the contractor noticed that they were losing return flow of the drilling fluid. Although they were aware that the flow was not consistent, the reaming process was completed and the Subcontractor elected to move forward with pulling the pipe through the bore hole. During the pipe pullback, approximately 200 feet into the drill section, the installation of the pipe came to a halt and the pipe was no longer able to move. The Subcontractor originally attempted to remove the pipe using an excavator, by pulling on the pipe side using straps, but was unsuccessful. After more unsuccessful efforts to free the stuck pipe, The Subcontractor decided to abandon the pipe, pull-head,
reamer, and drill rods, and to install the pipeline in a new location nearby. The abandoned pipe was grouted and collars installed around the pipe to protect levees and the abandoned drill path.

![Diagram showing pipe sizes](image)

**Figure 4. Proposed Pipe Sizes for Fusible PVC® and HDPE Pipe in HDD Sections**

The pipe was to be drilled deeper than the initial pipeline. Once the new location of the pipeline was selected, the HDD was completed and the forcemain was installed successfully (see Figure 5).

![Image of forcemain](image)

**Figure 5. Assembled 24-inch DR 25 FPVCP on Rollers during pull-in.**

Soon after the forcemain was installed under Turkey Creek with no further issues, the Subcontractor then directed their attention toward the 2,400 LF crossing under the Missouri River. Starting from the west end of the river, the crew drilled the pilot hole and reamed with no major complications. Layout of the pipe took place on the east side of Missouri River and the crew prepped the pipe on the north side of Missouri River. Since the surrounding area was vacant, the laydown and preparation of pipe installation was not an issue. The bore pit was excavated, and pipe rollers were properly placed. Just before the pipe pullback, the Subcontractor determined that the length of the bore pit was not enough for the FPVCP to meet its minimum bend radius as it entered the bore path. As a result, they constructed an embankment using backfill starting from the end of the bore pit, and measuring approximately 6 feet
in height and 80 feet in length to elevate the pipe entering the pit. Lone Star proceeded with the pullback of the pipe, starting from the pipe rollers, over the embankment, downward into the drill pit, and into the bore path. Approximately 800 feet into the installation, over-bending of the PVCP caused a break of the pipe at the peak of the bank and the roller placed there (see Figure 6). While the construction of the embankment and use of a roller eased the insertion angle into the insertion pit, it was not properly supported at grade on the back side of the alignment, creating a bend radius of the pipe over the roller – a single point load – that was excessive. This resulted in the failure at that location during the insertion process.

Figure 6. Construction of the embankment in front of the insertion pit with a roller placed on top.

With several hundred feet of pipe already installed, the Subcontractor attempted to remove the pipe by pulling it back out of the bore hole. Efforts to remove the pipe were ineffective which ultimately led to the abandonment of the pipe, and the crew moved to install the pipe at another location nearby. Once the new location was selected, the length of the bore pit was extended, per the Subconsultant’s design recommendation, which allowed for the pipe to meet its minimum bend radius requirement during the pipe installation (see Figure 7). The pipe was installed successfully in August of 2013 without any additional issues.

Figure 7. Pull-In FPVCP on rollers with extended insertion pit appropriate for the angle of insertion
7. CONCLUSION

The process involved in the design, bidding, and construction of the Cole Junction Pump Station and Forcemain was not without challenges. In the beginning the challenges were design based and included pump station operational strategy, forcemain sizing, forcemain material selection and alignment. As the design progressed the issues turned to easement acquisition, permitting, highway crossings, railroad crossings, and creek/river crossings. During construction the challenges were equipment positioning, varying soil conditions and pipe over-bending. While it is not uncommon to experience these challenges when dealing with a large infrastructure improvement project, the key to successful resolution is to work through the issues while keeping the end goal as the primary focus. Ultimately, the project team was able to keep making progress towards the end goal.

The forcemain was successfully hydrostatically tested in accordance with American Water Works Association Standard C-600 The transfer of flows from the old pump station to the new pump station occurred in June of 2014. Jefferson City is now capable of meeting Missouri Department of Natural Resources requirements for wet weather flows and has removed the odor issues that had been such a nuisance. Despite the setbacks during the design and construction, this project will continue to serve Jefferson City and its residents for many years to come.

8. REFERENCES


United States Environmental Protection Agency
http://iaspub.epa.gov/enviro/fii_query_detail.disp_program_facility?p_registry_id=110054135707
