ABSTRACT: The Macon Water Authority, in Macon, GA, needed to upsize and replace an existing undersized force main pipeline immediately adjacent to and feeding the Rocky Creek Wastewater Treatment Facility. Complicating the proposed installation was Rocky Creek proper and surrounding wetlands, both of which would have to be traversed for a successful project.

Carter & Sloope, the design engineer for the overall project, recognized that horizontal directional drilling (HDD) could be a viable solution, as well as a way to minimize the environmental impacts of the pipeline installation on the wetlands and creek. They used a pre-qualification process to assure properly qualified HDD Contractors and materials due to the complexity and scope of the installation. Mears Group, Inc was selected for the HDD portion of the project and elected to install the entire ~4,200 LF HDD length, with 24-inch DR-18 Fusible PVC pipe. Layout and installation for the project was a complex undertaking considering property and easement locations, required footprints for drilling and pipeline fabrication, and schedule of the work.

This project represents the largest HDD installation that C&S and the Macon Water Authority have been involved with to date. This paper will focus on the design of the project and modification of the design through the construction process. It will explore what it took to assure a successful installation, such as driller pre-qualification, landowner concerns, alignment adjustments, layout and fusion requirements, and general planning issues with a crossing of this length and size.

1. INTRODUCTION

Macon is nestled near the center of the state of Georgia and the Macon Water Authority (MWA) is the public utility board that provides drinking water and sanitary sewer services to the City of Macon and the surrounding areas of Bibb County. Bibb County is bisected by a geological feature called the “fall line,” where the piedmont geology in northern portion of the county meets the coastal geology in the southern portion. Macon, like any other established community, is always interested in bringing new industry to the area, promoting growth and cultivating a sound economy. Just such an opportunity was available when in 2007 an automobile accessory manufacturing plant was looking at relocation to Sofkee Industrial Park near the southern portion of Macon. The challenge that MWA was faced with, however, was that the projected wastewater flows for this new industry were more than the existing wastewater collection system could handle.

The bottleneck in the system that was responsible for this deficient capacity was a lift station known as the Allen Road Pump Station (ARPS). This wastewater handling facility was built in 1977 and received wastewater flows...
from two main basins, known as the Tobosofkee and Echeconnee basins. Flows from the Tobosofkee basin are delivered through a 30-inch interceptor and the area served includes an environmentally sensitive recreational use zone as well as the industrial park where the manufacturing facility was looking to relocate. Flows from the Echeconnee basin were gathered and energized by the Echeconnee Pump Station and delivered directly to the ARPS via a 16-inch force main (see Figure 1).

![Figure 1. Schematic of the Echeconnee and Tobosofkee Basins and flow diagram for how the Allen Road project was to be constructed as part of the existing system.](image)

The existing ARPS constricted flows through the system due to its undersized force main, which is only a 14-inch pipeline. This was exacerbated by the poor condition of the entire collection system in the two basins which allowed a high percentage of inflow and infiltration into the system during rain events. The ARPS experienced chronic overflows of raw sewage due to this situation, and oftentimes the large diameter interceptors of the system were used as temporary storage for flows to attenuate the peak hydraulic loads associated with such events.

Collection system shortfalls and operational issues associated with the ARPS could not be tolerated, particularly if they were stopping economic growth opportunity and new jobs from entering the community. MWA decided both on a staff member and board level to support this call for action and eliminate the bottleneck that was holding the wet weather flows and potential economic growth back. At the same time this was occurring, an unusually wet year was wreaking havoc on the ARPS. So much so, that the ARPS and supporting system failed. The overflow events became so commonplace that the Georgia Environmental Protection Division placed MWA under a consent order.

In order to alleviate the major issue in the system, the bottleneck had to be removed, and MWA staff added a sister pump station that was named “Allen Road II” pump station, which would operate in tandem with the existing ARPS to handle the excessive flows (see Figure 1). The new pump station would take all flows from the Echeconnee Basin and pump station and deliver them to the wastewater treatment plant through a new 24-inch force main. The new sister pump station would be sized for the entire build out of the Echeconnee Basin as well as flows from the industrial park. The existing ARPS would continue to handle the Tobosofkee Basin flows through the existing 14-inch force main, and the two pump stations would be interconnected to assure that one station could always act on the others behalf if necessary.

Construction of the new sister pump station would be straightforward, but the new 24-inch force main would prove not to be. The lands between the existing ARPS and the wastewater treatment plant are wetlands, with Rocky Creek running through the middle of them. This area carried an environmentally sensitive designation, and though the 14-inch pipeline had been installed by traditional means, the new 24-inch force main would not be afforded the same opportunity. The crossing design required initial research into all of the currently available modern techniques and technologies for trenchless construction. MWA and its consultants ultimately settled on horizontal directional drilling (HDD) as a primary tool to cross this difficult area. HDD lessened the permitting and agency involvement
in the project and the geology, consisting of Coastal Plain Sediments, present just south of the fall line, promised favorable conditions for drilling techniques.

2. PRELIMINARY DESIGN FOR THE CROSSING OF THE WETLANDS

The preliminary layout of the pipeline alignment for the crossing incorporated aligning the pipe at the wastewater treatment plant location to the existing easement location on the pump station side, and trying to determine the shortest and/or most feasible wetlands crossing location and length. The most feasible alignment placed the wetlands crossing length at around 4,000 feet, including depths of 50+ feet, and a horizontal curve in the alignment (see Figure 2). Due to the proposed length of the potential HDD, the design quickly focused on piping material for use with HDDs of this length and proposed depths.

![Figure 2. Plan view of the original crossing and layout as designed.](image)

Two pipeline materials were discussed for use in the project. Early on, high density polyethylene (HDPE) pipe was assumed to be the primary non-corrosive option for the HDD. However, discussions with drillers for a crossing of this length and depth revealed that if HDPE was to be used, a shorter alignment would be desired to limit the risk of the crossing and potential limitations of the material for pull force allowance and critical buckling during installation. With this in mind, temporary “Work Road” extensions were proposed (shown in red in Figure 3), which would shorten the potential crossing length to approximately 3,000 LF, and eliminate the horizontal curve location (see dark blue alignment notes in Figure 3). The use of the ‘Work Roads” however, brought up issues with the design that C&S was trying to avoid, the main one being keeping restoration and surface work out of the wetlands boundary.

Discussion turned to using Fusible PVC™ pipe (FPVCP) for the crossing as a means to maintain the initial design intent, length, and depth of the crossing as proposed. Use of FPVCP for the crossing meant that the entire ~4,200 LF crossing could be accomplished in a single HDD installation at the required depth (see green alignment notes in Figure 3). Additionally, due to the material strength differences between the two plastics, the same flow area and pressure class of the original 30” HDPE design would be possible with a 24” DR 25 (Pressure Class 165 psi) FPVCP pipe. Eventually, during construction, the wall thickness would be increased to DR 18 (Pressure Class 235 psi) due to additional depth realized for the actual crossing and perceived risk in the soils being drilled.

Due to these major design differences, FPVCP was chosen as the pipeline material for the crossing. The project was bid in January of 2011. It was awarded to Astra Group in March/April of 2011, and the project kicked off in July of 2011.
Figure 3. Vertical profile illustrating the design discussion based on pipeline material for the crossing. Temporary ‘Work Road’ construction, shown in red, would be required to shorten the alignment for HDPE pipe materials to about 3,000 LF, shown in dark blue. The use of FPVCP allowed the original alignment, shown in green, to be utilized.

3. DRILLING PROCESS

Along with the work that was done with drillers during the design phase of the project, a prequalification process was conducted to assure that an HDD installation of this magnitude, depth and length would be completed by a drilling contractor that had the appropriate experience, equipment, and knowledge to give the crossing the best chance at being successful. Through this process, the Mears Group, Inc. (Mears) was selected as the HDD drilling contractor for the project.

Figure 4. Prime 1.3 million pound rig used for the pilot, reaming, and pullback phases of HDD construction.
Mears mobilized to the project site and set up their drilling rig spread on the wastewater treatment plant side of the crossing location to begin their pilot bore. The 4,216 LF pilot hole was drilled in 5 days utilizing a Prime 1.3 million pound drill rig (shown in Figure 4) with 5-1/2” drill pipe, a 6-3/4” mud motor and 9-7/8” tri-cone drill bit. Around 200 LF of 12-inch “wash over” casing was used to support the drill pipe through the soft soils near the surface at the drill rig location on wastewater treatment plant side. The entry angle was set at 11.5 degrees; the exit angle realized was 10 degrees. The horizontal point of intersection near the drill side was 12 degrees, which included the horizontal curve necessary to meet the alignment constraints. The pilot hole was drilled to a maximum depth of 58 feet due to the soils encountered near the bottom of the pilot bore. Soft soils near the proposed depth of 50 feet made steering difficult and more competent material was found a little deeper in the alignment to work with at this vertical curve location. An additional challenge for the pilot hole process included drilling ‘blind’ for the middle 1,200 LF section of the alignment, using only the magnetic steering probe. Mears set up a 1,300 LF entry coil and a 1,700 LF exit coil with the Paratrack II steering system, but was not able to lay a complete coil through the wetlands area. As such, they needed to steer through approximately 1,200 LF of alignment path without location verification of their steering probe. When the probe entered the exit coil on the far side of the ‘blind’ spot, it was two feet higher and five feet to the right of the designed plan and profile, which was a very workable scenario to allow drilling of the pilot hole to continue.

The potential risk of inadvertent hydrofracture returns in the highly sensitive 1,200 LF section of the core wetlands was a critical component to the construction plan of the drill. Since inadvertent returns in this area were highly undesirable, Mears utilized a ‘down hole’ annular pressure monitoring tool during the pilot hole operations. This monitor provided real-time data of the drilling fluid pressures in the pilot hole which were compared to the calculated estimated strength of the overburden soils along the alignment. Figure 5 shows the comparison of the realized annular space pressures versus the calculated values. The calculated values shown as the “Min.” and “Max.” calculated pressures are based on the overburden soils present along the alignment and are estimates of what the formations should be able to hold in terms of fluid pressure.

![Annular Pressure Comparison](image)

Figure 5. Actual annular pressure (shown with gold line) comparisons to the calculated minimum (orange line) and maximum (red line) values.

Ideally, the annular space pressures would be best served if they remain under the minimum calculated pressure of the formation, and as shown in the figure (for the most part this was true of the Allen Road HDD pilot hole drilling process). The “wash over” casing within the first 200 LF took care of concerns with inadvertent returns within this
section of soft soils in the beginning. The increased depth of the final alignment, along with maintaining full circulation of the drilling fluid and returns throughout the entire pilot hole drilling process helped to assure that inadvertent returns would not be an issue.

To enlarge the bore hole to the appropriate size for the pipe insertion, two reaming passes were performed. The first pass utilized a 26” hole opener and was completed in 9 days. Mears used an American Augers 70 drill rig on the exit side, or the pump station side, to assist with the ream and provide tension on the drill string while forward reaming the bore hole from the wastewater treatment plant side to the pump station side with the primary drill. A ‘weeper sub’ assembly was used in front of the reamer to keep the pilot bore hole lubricated during this process. This was done as a preventative measure. Full returns were kept for the entire pass, with approximately 70% of the returns collected at the entry site on the wastewater treatment plant side and the remaining 30% at the exit site on the pump station side. The second reaming pass utilized a 38” hole opener and also ran the 26” hole opener in tandem with the larger reamer to keep the larger reamer centered in the bore hole. A weeper sub was also used with this configuration to maintain lubrication of the bore hole in front of the reaming operations. The second reaming pass took quite a bit longer to complete due to large amounts of clay on the exit side. This clay was also responsible for an inadvertent return of fluid about 200 LF in front of the exit pit on the pump station side of the crossing. A sump pit was dug at this location, and a 6-inch trash pump was set up to pump fluids back to the exit pit to be recycled by the mud cleaning system (see Figure 6). A final swab pass was completed on the borehole prior to pipe installation using a 32” reamer, which took three days to complete.

Figure 6. Picture of site layout with cleaning system and pumps shown.

4. CHALLENGES WITH PIPE ASSEMBLY AND LAYOUT

A sometimes overlooked component of an HDD installation is the staging and fusion of the pipe string that will be installed. When it comes to shorter lengths and simpler HDD projects, this sometimes is an afterthought to the more critical components of the HDD bore creation. On a project such as this, however, staging and stringing 4,200 LF of 24-inch pipe was going to be a major component of the successful crossing. Early on in the design process, Mears felt that it would be necessary to attempt to have the entire 4,200 LF fused and staged prior to the insertion process due to the perceived bore conditions that would be present with the perspective soils of the crossing. The alternative to this arrangement would be to pre-fuse shorter lengths of pipe that are then assembled during the insertion process with ‘intermediate’ fusion joints. This technique requires pauses in the insertion operation and these pauses could
be detrimental to a successful installation based on the estimated condition of the bore hole from the anticipated geotechnical nature of the expected soils.

Underground Solutions, Inc. (UGSI) worked with C&S to design a layout scenario where the entire length of the pipeline could be fused and staged in one segment. The primary complication to this scenario was the available easement and layout room obtainable for the team to work in and how that area aligned with the proposed bore. The existing easement that could be used contained a gravity sewer line and it was configured in a large radius through a natural area that was owned primarily by a private party and environmental advocate. The property owner applauded the project since it would reduce the overflow events that plagued the ARPS; however, he wanted work to remain in the existing easement.

UGSI utilized GPS positioning equipment, computer aided drafting and aerial imagery to lay out an alignment that could feasibly be attained within the easement, but also within the material limits of the pipe. A sample of this effort is included in Figure 7.

![Figure 7](image-url)

Figure 7. One of the proposed and potential layouts for fusion and staging of the entire alignment, including the insertion into the HDD crossing alignment.

While such an alignment was possible, it was by no means the simplest way to stage the pipe for insertion. The complications with this layout included:

- Use and maneuverability of equipment to move pipe segments, fuse the string together, pull and stage the string as it was being assembled and keep the entire string and all of this work in the required easement.
- Maintaining the safe allowable bend radius for the pipe during staging and insertion activities.
- Providing appropriate and adequate reactive forces to the pipe roller or support assemblies to assure that when pulling axially on the pipe for movement or insertion activities, the curved alignment was maintained.
- Easements needed to be adjusted and acquired near the exit pit of the bore alignment to allow for the required bend radius of the pipe.
- Internal ballasting set-up and procedure during the pipeline insertion would have to be coordinated with the alignment and length of pipe.
Even with these considerations and complications, if the bore demanded that a single string insertion be used, then the success of the project would require that this process be followed. However, once Mears began the pilot bore and they developed an actual “feel” for what the final alignment would be going through in terms of geology, their confidence grew in an intermediate fusion staging plan. With the favorable change in drilling conditions realized for the pilot bore, the team settled on five pre-fused string assemblies of ~850 LF of pipe (See Figure 8).

![Figure 8. Staging area shown here, cleared for fusion string assembly and laydown. Note the pre-assembled pipe strings on the right hand side of the picture.](image)

UGSI performed fusion joining of the pipe as a sub-contractor to Mears. Astra Group provided support for the fusion process, handling pipe, pulling the assembled string as needed and helping set up the layout of the pipeline. An area 1,100 feet long by 120 feet wide was cleared in a straight alignment with the borehole insertion point. When the pipe was inserted into the borehole, these five lengths of ~850 LF of pipe would be joined by four intermediate fusion joints to create the final length of ~4,250 LF of pipe needed to make the crossing. This provided a much less complicated assembly area and alignment (no bending to be considered, no easements to be adjusted, and a simplified ballasting procedure could be set up for the insertion).

5. PIPE INSERTION AND PROJECT COMPLETION

Pipe insertion began on November 10, 2011 at 4:30 PM. Approximately 320 LF of pipe was inserted into the borehole prior to shutting down the site at around 8:00 PM. This initial insertion was performed to make sure that all aspects of the insertion alignment, drill rig operations, staging equipment and insertion team were coordinated and ‘all lined up correctly.’ The rest of the pullback operations would begin in earnest first thing in the morning on November 11th. Since intermediate fusion joints would be required, the team wanted to perform as much of the insertion during daylight hours as possible.

Operations resumed the next day at 8:15 AM. Internal ballasting was utilized with the insertion procedure to reduce the pull force loading on the pipe as much as practical. This involves progressively filling the pipeline with water as it is inserted into the borehole. This is done using a hose that is inserted into the pipe, which delivers the water into the pipe at the location of the borehole entry. This ensures that the water is delivered to the pipe at the location where buoyancy modification is desired, which is in the borehole, not above grade where the added weight of the water only adds drag to the insertion and actually increases pulling forces required. For this ballasting operation, limited water was available on site; consequently, 90,000 gallons of water had to be stored and pumped from frac-tanks. 4-inch HDPE hoses were staged with quick-connects in the pre-assembled FPVCP lengths to facilitate the ballasting operation quickly and efficiently considering the intermediate fusion operations required (see Figure 9).

Intermediate fusion joints were performed in the following manner. The drill rig would cease pulling the pipe string into the borehole when the end reached the location of the intermediate fusion staging area and the fusion machine.
After pulling operations were halted, the fusion machine would lock the end of the pipe in the borehole on one side and then another string of pipe would be positioned in the machine on the other side. This next string of pipe would also be positioned on rollers to reduce drag for the fusion process as well as the continued insertion operation. After this handling step, the fusion process would be performed, including the cooling of the joint, and when complete, pulling and pipe insertion would resume. When the pipe end reached the fusion staging area again, the process would be repeated with another intermediate fusion joint.

The ballasting operation was facilitated by a metered fill line (left picture) with quick connects (right picture) that allowed for the easy assembly and reconnections needed for the intermediate fusion operation.

On average, including the time it took to handle the pipe strings and perform the intermediate fusion joints, the process took about 1 hour and 45 minutes per joint, for a total time of 7 hours. If handling is not considered in this time, then the four fusion joints took about 4 hours from the beginning of the fusion process to the end of cool down. Pipe handling, which accounted for the remaining 3 hours of total intermediate fusion joint time, was a critical component of the intermediate fusion joint process. All members of the team were well coordinated to keep this time to a minimum, however, it did take significant time and effort to move each of the 840 LF to 880 LF strings into position, get them aligned in the fusion machine, and set the rollers properly. The first intermediate fusion joint took approximately an hour to position due to the cold overnight temperatures and also since it was the first one and the team gained efficiency with each joint. The second and third fusion joints only required approximately 30 minutes each to position. The fourth joint took about an hour and was completed after sunset when temperatures began to drop again and there was extra time required for excavator movements in limited light conditions. The entire FPVCP pipe length was successfully pulled into the entry pit at 1:30 am on November 12, 2011 making the total time to assemble and install the pipeline approximately 20 hours and 45 minutes. See Figure 10 for a picture of the pipe being received at the wastewater treatment plant side of the crossing.

The published allowable safe pull force for the 24 inch DR 18 FPVCP is 307,100 lbs. During preliminary evaluation, calculations for the installation estimated the maximum pull load would be 370,000 lbs if it were pulled in empty, and 127,000 lbs if it was internally ballasted during pull in (Ariaratnam, 2010). The actual maximum pullback force realized during the installation was ~60,000 lbs, as calculated from the drill rig hydraulic system (less the known pull force requirements for the rig operations). The disparity between the estimated maximum load and the actual loading (approximately half of what was calculated for a ballasted situation) was primarily due to conditions in the field being less conservative than what was considered for the pull force estimations. For example, in considering the weight of the drilling fluid for buoyancy calculations, it was assumed at ~12 pounds per gallon, which is a conservative estimate, however due to adhering to a very strict drilling fluids program developed by Mears’ drilling fluids specialist, drilling slurry with a weight of 9.0 to 9.5 pounds per gallon was able to be maintained during the installation. This difference in drilling slurry density had a major impact on the buoyancy of
the pipeline and resultant friction between the borehole and the product pipe as it was the largest contributor to pull force realized during pullback.

The pipeline was completely filled, all air was evacuated, and it was hydrostatically pressure tested to 150 psi of internal pressure at the highest point of the crossing to verify the installation and integrity of the pipeline. After passing this test requirement, the pipeline was accepted. The HDD pipeline was tied into the rest of the piping for the new pump station and force main when those items were completed and is currently online and in use.

Figure 10. 24-inch FPVCP and pull head assembly in entry pit upon successful completion of the crossing.

6. CONCLUSION

In the end, this successful crossing met the original goals of the design and what was expected of HDD as an installation methodology. It had little to no impact on the wetlands area of concern and no impact on the core 1,200 LF section of the wetlands crossing that was critical. The use of HDD effectively mitigated the issues that were of importance for the design, including minimizing permitting complications to the project, utilizing trenchless construction under an unforgiving surface condition in the Rocky Creek wetlands area, and doing so in a reasonable amount of time. There were several lessons confirmed with this long crossing using FPVCP. The first was that the layout and fusion of the pipe string is a vital component for success for a long crossing such as this and must be considered on the front end of design. The second was that flexibility within the design constraints is not only a nice luxury to have; it is a must if a long crossing such as this is to be attempted. Variations in alignment design control of the HDD process by the drilling contractor, and appropriate expertise and flexibility with the product pipe all played critical roles in the success of this project.

As with any project where different groups come together to form a critical team to compete a task, coordination was the key to success for this long HDD installation. All parties were coordinated and focused on a successful crossing and an operating 24-inch force main when it was all said and done. When a single, specialized installation such as this is the only viable option, success hinges on a team that is up to the challenge and not only understands the mechanics of the installation methodology, but are experts with it.
7. REFERENCES