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CHALLENGES IN DESIGNING AND CONSTRUCTING AN EXPANSION TO THE DELTA DIABLO SANITATION DISTRICT'S RECYCLED WATER DISTRIBUTION SYSTEM UNDER URBAN CONSTRAINTS

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ABSTRACT: The City of Antioch and Delta Diablo Sanitation District (DDSD) undertook a joint project to expand DDSD's existing recycled water system into Antioch. The DDSD recycled water system began providing service to the City of Pittsburg in 2001. This first Antioch expansion phase will provide recycled water to parks, medians, fill stations, and a golf course and serve as the backbone pipeline to be utilized by future phases to expand the system. The project consists of over 30,000 feet of pipeline on major thoroughfares in Antioch which includes 6,900 feet of pipeline sliplining, a 1.1 million gallon concrete reservoir and pump station at the Lone Tree Golf Course, and installation of an additional pump at DDSD's Recycled Water Facility (RWF).

The pipeline portion of the project consists of open cut construction, sliplining an abandoned 18" raw water pipeline, jack and bore beneath the W. Antioch Creek, and pilot tube guided boring to cross the East Bay Municipal Utility District's (EBMUD) aqueducts. The paper will discuss the successes, challenges and lessons learned during design and construction of the following pipeline elements:

- Innovative technology (Fusible PVC™) to slipline and reuse an existing pipeline to maximize capacity, meet the required pressure rating, and ensure structural integrity.
- Construction method selection (directional drilling, jack and bore, and open cut vs. pilot tube guided boring) to cross EBMUD's aqueduct corridors.
- Highway 4 Widening Project impacts.
- Pipeline alignment selection with over 200 utility crossings.

INTRODUCTION

The City of Antioch (City) and Delta Diablo Sanitation District (DDSD) undertook a joint Recycled Water Project to expand DDSD's existing recycled water system into the City of Antioch. The existing DDSD recycled water system went into service in 2001 and currently consists of a 12.8 million gallon per day Recycled Water Facility (RWF) located adjacent to the DDSD's wastewater treatment plant and a distribution system within the City of Pittsburg. The RWF currently provides water to two Calpine power generation plants, the Delta View Golf Course and several parks within the City of Pittsburg. This first Antioch expansion phase will provide recycled water to Fairview Park, Antioch City Park, Mountaire Park, Chichibu Park, street medians, fill stations, and the Lone Tree Golf Course and serve as the backbone pipeline to be utilized by future phases to expand the system. The project consists of over 30,000 feet of pipeline on major thoroughfares in Antioch which includes 6,900 feet of pipeline sliplining, a 1.1 million gallon reservoir and pump station at the Lone Tree Golf Course, and installation of an additional pump at DDSD's RWF. An overview of the project location and pipeline route is shown in Figure 1.

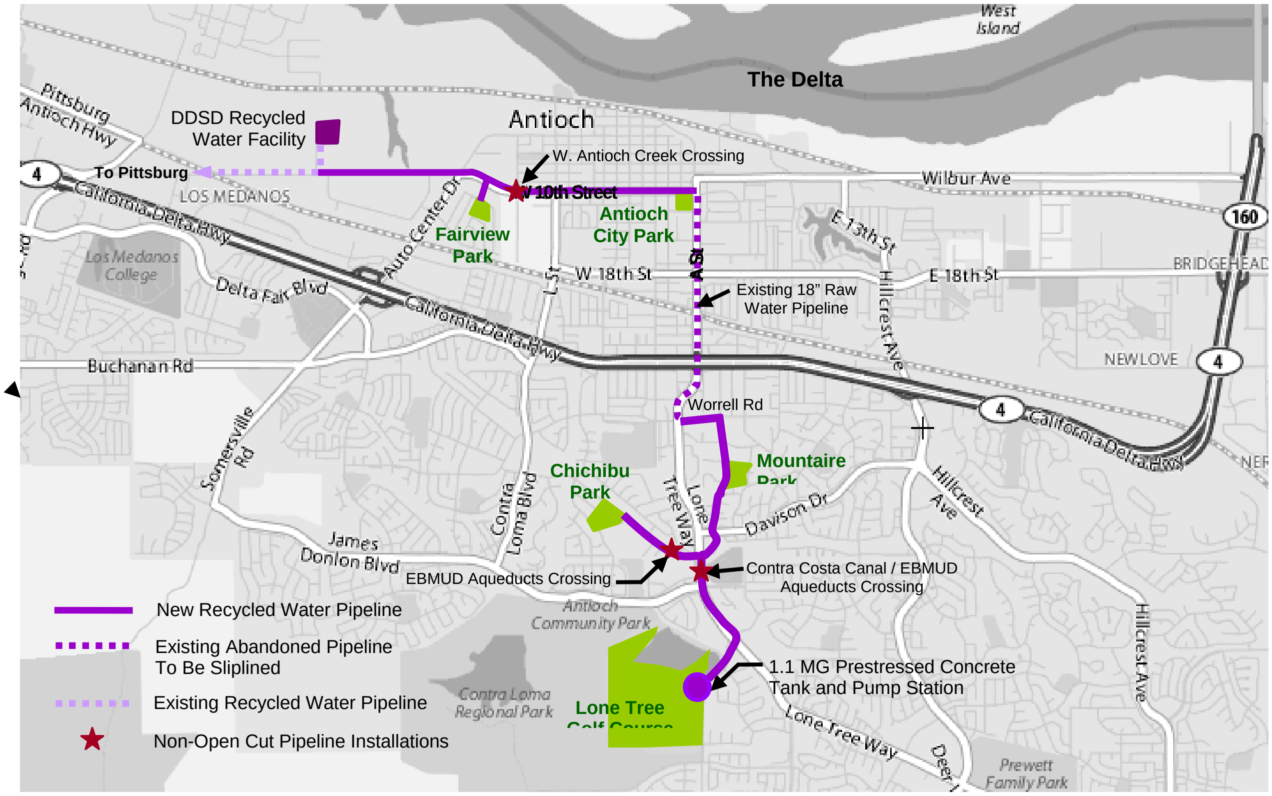

Figure 1. DDSD / City of Antioch Recycled Water Project Location and Pipeline Route.

The pipeline portion of the project includes installation of 4-inch to 16-inch diameter pipeline through an established community. The work consists of open cut construction, sliplining through an abandoned 18" raw water pipeline, jack and bore beneath the W. Antioch Creek, and pilot tube guided boring to cross East Bay Municipal Utility District's (EBMUD) aqueducts. This paper will discuss the successes, challenges and lessons learned during design and construction of the following pipeline elements:

- Innovative technology (Fusible PVC™) to slipline and reuse an existing pipeline to maximize capacity, meet the required pressure rating and ensure structural integrity.
- Construction method selection (directional drilling, jack and bore, and open cut vs. pilot tube guided boring) to cross EBMUD's aqueduct corridors.
- Highway 4 Widening Project impacts.
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INNOVATIVE TECHNOLOGY

The Recycled Water Project utilized an innovative technology, Fusible PVC pipe, to slipline and reuse approximately 6,900 linear feet of an existing 18-inch raw water pipeline on A Street between W. 10th Street and Worrell Road (see dark dashed purple line in Figure 1). In the 1940s, the City installed an 18-inch cast iron pipeline, of which a portion is located within A Street, to convey raw water from the Delta to their water treatment facility. In 1997, a portion of the pipeline was abandoned when the City constructed a new raw water pipeline. During the preliminary planning stages of the Recycled Water Project, the intent was to directly reuse approximately 6,900 feet of the existing raw water pipeline to reduce project construction costs, traffic and business impacts, construction within the new rubberized pavement areas of A Street, and permitting issues related to crossing the Southern Pacific Railroad and Highway 4. However, the condition of the existing pipeline was unknown and not explored in detail at that time. At the commencement of detailed design, no television inspection, potholing information, original plans or specifications were available for the abandoned 18-inch raw water pipeline. Available information was limited to conversations held with the engineer who designed the new raw water pipeline and his observations of the pipeline during tie-in to the existing system. Information obtained only included the pipeline's original operating pressure and joint type. To obtain additional information to facilitate the design process, the City television inspected the abandoned pipeline. The inspection showed that the pipeline was in good condition with no appearance of corrosion. Sample coupons were cut and removed to gain access to the pipe interior for television inspection. The television inspection encountered closed valves and identified a location where a portion of the existing abandoned raw water pipeline had been removed and plugged to facilitate the installation of a perpendicular water line. The pipeline's joints were also confirmed to be leaded. Due to these conditions, direct reuse of the existing pipeline for pressures of 150 psi was not viable and alternatives to rehabilitate the pipeline for reuse were researched.

The alternatives researched were Cured In Place Pipe (CIPP) and sliplining, including two methods by Insituform (polyflex and polyfold). CIPP was eliminated from consideration because at the time when CIPP technology was researched, it was not available at the 150 psi operating pressure rating required for the recycled water pipeline. Both Insituform technologies are a tight fit process and there is no annular space to grout. There are no local suppliers for either of these specialty technologies, only in the midwest and southeast United States and Canada. Although the pipeline can perform at an operating pressure of 150 psi, Insituform did not appear to be a cost effective alternative. Due to cost and performance considerations, these technologies were eliminated and sliplining with a carrier pipe was pursued.

Sliplining is not a new technology. Sliplining is a trenchless method which enables a smaller carrier pipe to be installed into an existing, larger host pipe. This technology is often used to rehabilitate pipelines. In this case, it is being used to reduce project construction costs, impacts to the public, and permitting issues.

Two types of material were considered for sliplining the carrier pipe, high density polyethylene (HDPE) and fusible polyvinyl chloride (FPVC™). Since this pipeline is the backbone for the recycled water distribution system and must meet initial and future demands, capacity was one of the main factors in selecting the pipe material. Based on the sample coupons obtained by the City when performing the television inspection, it was determined that the 18-inch host pipe has an inner diameter (ID) of approximately 17.875-inches. The working pressure rating required for the recycled water pipeline is 150 psi. For the carrier pipe to fit within the host pipe and meet the required 150 psi pressure rating, appropriately sized HDPE and FPVC pipes were identified. The sizes of pipe evaluated included 14-inch DR 25 FPVC and 16-inch DR 11 HDPE. As illustrated in Figure 2, the respective ID and outer diameter (OD) of the 16-inch HDPE pipe are 12.92-inches and 16-inches while the respective ID and OD of the 14-inch FPVC pipe are 14-inches and 15.30-inches. The HDPE pipe necessitates a greater wall thickness to meet the required pressure rating which results in a 15% reduction in cross-sectional flow area. Due to additional flow area and reduced system headloss, FPVC was selected for the pipe material.

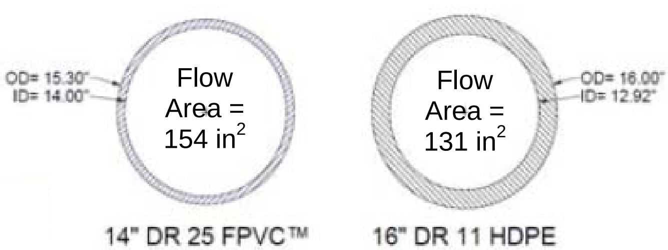


Figure 2. Cross-sectional flow areas of FPVC and HDPE were evaluated for sliplining.

Additional considerations for selecting FPVC as the carrier pipe material included oxidative degradation of HDPE, mechanical connection compatibility, and existing use of PVC within DDSD's recycled water system. Over 15 research papers published since 2004 document the failure of HDPE pipe in the presence of water disinfectants. Polyethylene is a polyolefin family plastic which is subject to oxidative degradation, a chemical degradation process by which polyolefins are broken down over time by oxidants. Polyetheylene piping is manufactured with antioxidants to protect against such attack. However, common water disinfectants such as chlorine provide a chemically oxidizing agent which first consumes the antioxidants in the pipe and then begins to attack the polymer itself, resulting in cracking. The nature of a pressurized main provides stress to the pipe wall which continues to propagate the newly created crack and the oxidative chemical attack through the pipe wall, eventually breaching the pipe wall entirely causing a leak and/or pipe failure. Higher temperatures as well as disinfectant concentration exacerbate the chemical degradation process. DDSD uses hypochlorite in their recycled water facility for disinfection and has indicated that they typically tend to overdose. The conveyance of recycled water with a high chlorine residual would provide an infinite supply of chlorine to react with the antioxidants in HDPE. Due to this operational practice and other factors previously identified, HDPE was not identified as the preferred carrier pipe material. In addition, PVC pipe in the water industry has shown no historical issues with chlorine based disinfectant products or oxidative degradation.

Another benefit of FPVC is its mechanical connection compatibility and ability to use industry standard fittings and couplings to connect to DDSD's new and existing PVC piping systems. FPVC utilizes standard ductile iron pipe sizing and is compatible with connections, fittings, and other appurtenances specifically designed for PVC pressure pipe, including restrained and non-restrained couplings for connecting to pipe of similar or differing materials. HDPE utilizes typical iron pipe sizing and often requires adapters, reducers and increasers, or other specialized components to connect to existing and standard waterworks piping materials like ductile iron and PVC. The most robust HDPE connections require fusion equipment and specialty trained technicians. These specialized parts and installation requirements can lead to increased maintenance and repair costs. PVC is DDSD's standard pipeline material for their recycled water distribution system. It has already been installed within the City of Pittsburg and it will be installed within the City of Antioch under this Recycled Water Project. Since DDSD personnel are knowledgeable on PVC pressure piping, they are therefore already trained on how to maintain, connect, and repair FPVC. No fusion equipment nor special knowledge or training is required to work with, maintain, or repair a FPVC pipeline after it has been installed.

Construction of the sliplining portion of the project proceeded smoothly. Two different procedural methods were implemented. The first method required fusing six lengths of FPVC pipe and then pulling the entire 240 foot section through the host pipe. This method required a large laydown area which the Contractor, JMB Construction, had available near Antioch City Park (Figure 3). As the work proceeded

Figure 3. Large laydown area for sliplining procedure near Antioch City Park.

further south down A Street, away from Antioch City Park, it became more difficult to transport the 240 foot lengths of fused pipe to the insertion pit locations. At this point, the Contractor modified the installation method by relocating the fusing equipment to each insertion pit and individually fused and pushed each 40 foot length of pipe. This method proved to be efficient since the Contractor was able to push approximately 400 feet of pipe per day.

A number of challenges were encountered during the sliplining construction. Based on the City's television inspection work, it was known that two 90º vertical bends were located just south of Highway 4; however, the exact location was unknown. This area included two PG&E high pressure gas lines that ran parallel to Highway 4. To be conservative, the project plans indicated no excavation within 15 feet of the PG&E high pressure gas lines was allowed. When the Contractor potholed for the two 90º bends, it was determined that they were located within 15 feet of the PG&E high pressure gas lines and within the "no excavation" zone. To resolve the issue, a field meeting with PG&E was held to discuss the options. PG&E was accommodating and only required a representative to be on site when the work within the vicinity of their pipelines occurred. This portion of the work was completed without any issues or conflicts with the PG&E pipelines.

At the intersection of Texas Street and A Street located just north of Highway 4, the project plans showed bends within the 18-inch abandoned pipe within a church parking lot. The plans were based on inferences made from the City's water system maps and visual observations of the television insertion pit locations since no as-built drawings existed for the abandoned pipe. During construction, it was determined that the bends were located within Texas Street and not within the church parking lot. Although this discovery required the Contractor to perform additional traffic control, the sliplining construction work went very well considering the limited existing information available. The lesson learned from the sliplining work performed on this project is to perform as much potholing as the budget allows to locate bends and verify existing conditions.

CONSTRUCTION METHOD SELECTION TO CROSS THE EAST BAY MUNICIPAL UTILITY DISTRICT'S (EBMUD) AQUEDUCT CORRIDORS

The project includes two locations where the recycled water pipeline crosses the EBMUD's aqueducts: Lone Tree Way and Longview Road (See Figure 1). The EBMUD aqueducts consist of 65-inch, 69-inch, and 87-inch steel and/or reinforced concrete pipelines which are 50 to 90 years old. The top of the aqueducts are located approximately 8 to 9 feet below grade. A reinforced concrete protection slab is located within the roadway close to finished grade above the aqueducts at both locations. EBMUD has developed extensive written requirements for other utilities to cross their aqueducts and protection slabs. EBMUD requires that a permit be obtained from them to perform work within their 100 foot right-of-way. Requirements include minimum pipeline separation, pipeline encasement, cathodic protection, and minimum concrete protection slab strength prior to allowing traffic. Despite having obtained EBMUD's as-built drawings for the two locations, numerous unknowns with respect to the protection slabs still existed. This paper only discusses the EBMUD crossing on Lone Tree Way as it is more critical to the project since it is a part of the recycled water distribution system's backbone. In addition, the Lone Tree Way location includes significantly more traffic impacts to the community and utility crossings than the Longview Road location.

The EBMUD aqueducts are angled across Lone Tree Way at an angle of approximately 45º. The recycled water pipeline crosses the aqueducts at a location where a number of factors coincide, thus complicating the design. These include: 1) the location is directly in front of the Sutter Delta Medical Center, a hospital which has a single entrance/exit on Lone Tree Way; 2) the Contra Costa Water District Canal crosses the EBMUD aqueducts and the new recycled water pipeline at an angle of approximately 45º; 3) the City has a raw water pump station located on the west side of Lone Tree Way with multiple 18-inch and 24-inch pipelines entering and exiting the roadway to/from the pump station; 4) several high pressure gas lines (Calpine, Chevron, and Kinder Morgan) are within the vicinity; 5) typical utilities (e.g. telephone, cable, sewer, etc.) are located within the roadway; and 6) Lone Tree Way is a major thoroughfare within the City which most residents use to access Highway 4. Figure 4 shows a layout of the EBMUD aqueducts corridor area on Lone Tree Way.

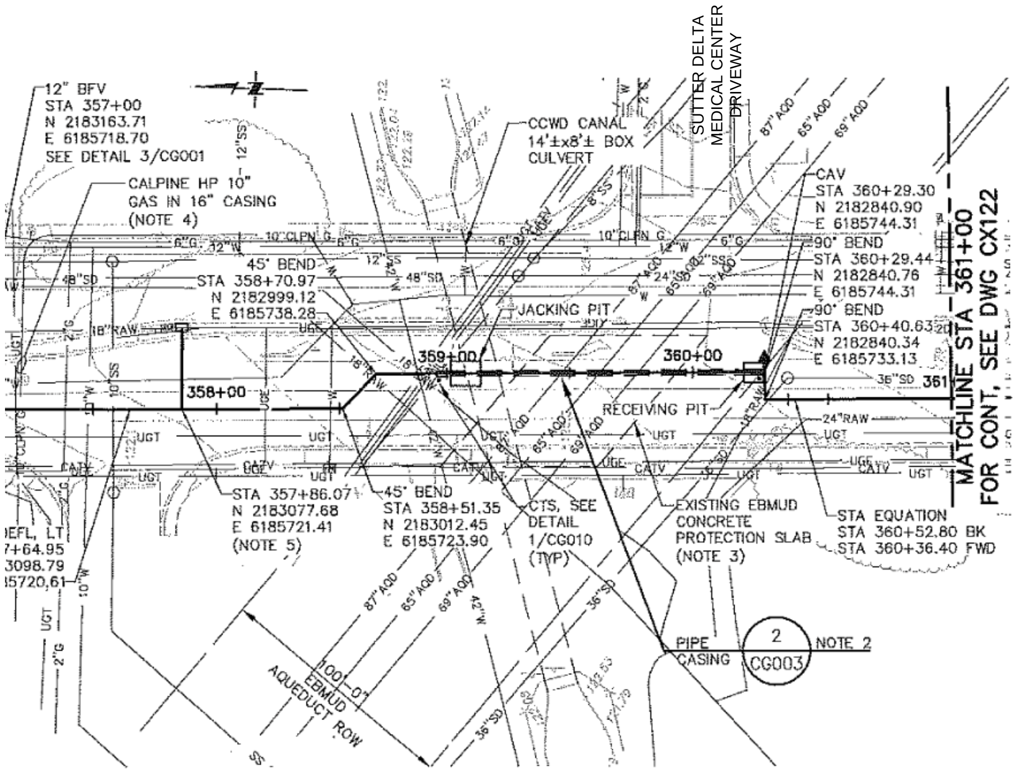
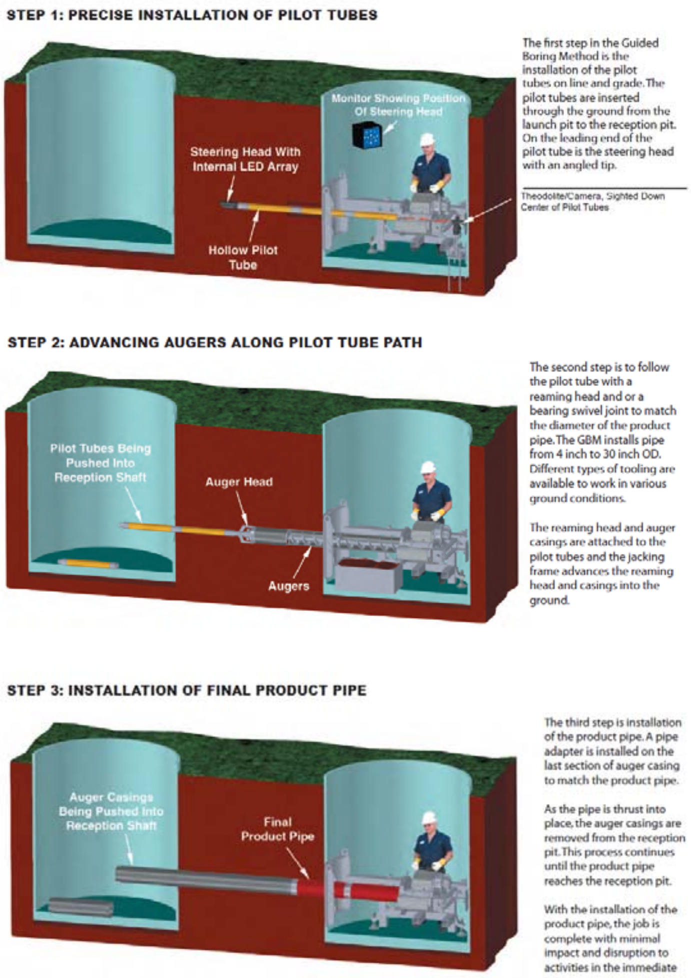


Figure 4. EBMUD aqueducts corridor on Lone Tree Way.

Several design options were evaluated to cross this corridor including jack and bore, directional drilling, open cut, and pilot tube guided boring. DCM | GeoEngineers, our trenchless technologies expert, provided engineering information on these options for evaluation. Jack and bore was removed from consideration because it was not accurate enough to install a pipeline between the protection slab and aqueducts. In addition, installing the pipeline beneath the aqueducts by jack and bore would have required 30 foot (minimum) deep pits and would have resulted in potential future maintenance access problems for DDSD. Directional drilling required a large laydown area. Due to the significant number of utilities in the area, especially high pressure gas lines, directional drilling was considered too risky. Open cut was the easiest option and posed the least amount of risk of hitting the aqueducts and other utilities since they would be exposed. It was assumed that the protection slab could be sawcut and restored to its existing structural integrity based on prior project experience with EBMUD aqueduct crossings. The project design initially proposed open cut construction. However, further discussions with EBMUD indicated that if the slab was to be disturbed, it would either need to be replaced at the construction joint or the entire slab would need to be replaced. No sawcutting through the slab would be allowed. In addition, no traffic would be allowed on the newly poured protection slab until the concrete achieved a strength greater than 3,000 psi. The protection slab covered the entire width of the southbound roadway which was the side of the road on which the recycled water pipeline was proposed to be placed. Unfortunately, no detour route around this major traffic corridor exists. The southbound roadway is four lanes wide and would not be able to be trench plated while the concrete cures. Extensive potholing and coordination with EBMUD was performed but the slab's construction joint could not be located. The City felt that a road shutdown would create significant traffic issues and was not acceptable. Additional potholing was then performed to locate the depth and edge of the slab to determine if the pipeline could be routed around the slab. Potholing showed that the slab extended into the northbound lanes of traffic where additional utilities were already present leaving no room for the new recycled water pipeline. Routing the pipeline outside of the roadway around the west side of the protection slab onto adjacent property was evaluated. The adjacent property is owned by the United States Bureau of Reclamation (USBR). The permit review process by USBR would have been extensive and there was no guarantee that the proposed alignment would be acceptable. Thus, pilot tube guided boring (PTGB) was evaluated to install the new pipeline between the protection slab at grade and the three EBMUD aqueducts below without impacting either.

PTGB is a relatively new trenchless technology. A small steerable hollow pilot tube is pushed from jacking pit to receiving pit to set the grade and alignment of the final pipeline. Once the pilot tube has been installed, it is followed by a cased auger and then the product pipe or casing pipe. This is a highly accurate pipe installation method, on the order of ¼-inch over 300 feet, but the soil properties must meet strict criteria in order for the technology to be implemented. The geotechnical borings must show standard penetration blow counts (N-values) of less than 40 blows per foot which indicates that the soil is not too dense or hard for the pilot tube to penetrate. PTGB can only be used above groundwater or slightly below groundwater with less than 10 feet of head in non-flowing ground conditions. In addition, it is limited to installation lengths on the order of 300 feet due to its optical guidance system. PTGB has the distinct advantage of working in very small pits, on the order of 8 feet in diameter, which can be fit within the congested utilities of this crossing. Figure 5 illustrates the step-by-step process for PTGB. Fortunately, the EBMUD crossing on Lone Tree Way met these criteria.



Images and information obtained from Akkerman, Inc

Figure 5. Step-by-step installation of pipeline via pilot tube guided boring.

This portion of the pipeline work on the project has not been constructed to date. Because this work will be performed in a major thoroughfare, one of the challenges is to determine if the construction is best to be performed during the day or night. If the work is performed during the day, the construction duration (i.e. number of days) in this corridor will be extended due to the limited daytime work hours established for the project within the Contract Document constraints. If the work is performed at night, the City has allowed extended construction hours, thereby reducing the construction duration. Because this corridor is located adjacent to a residential area, noise considerations are crucial. The City and DDSD plan to obtain a quote from the Contractor for both day and night work for evaluation prior to proceeding with the work.

The important lesson learned on this aspect of the project is that what may have worked on a previous project will not necessarily always work. Each project must be taken on a case by case basis. Even though open cut excavation through the EBMUD protection slab was approved on previous projects, it does not mean that it will be approved for a future project.

HIGHWAY 4 WIDENING PROJECT IMPACTS

The Contra Costa Transportation Authority, in cooperation with the Federal Highway Administration and Caltrans, are widening Highway 4, its interchanges and affected local roadways for approximately 6 miles. A portion of the Highway 4 Widening Project lies within the project area. At Lone Tree Way/A Street, the interchange will be reconstructed requiring relocation of all utilities currently located in the adjacent local roadway. DDSD was notified of this work at the start of the Recycled Water Project's construction phase. Initially, coordination to relocate the recycled water line into its post-freeway widening alignment was attempted, but the timing did not work since several properties located adjacent to Highway 4 must be acquired and demolished prior to relocation of the existing utilities. This work could not be completed prior to the Recycled Water Project's Contractor demobilizing from the area. This area is also where sliplining with FPVC pipe occurred. Since relocation of DDSD's pipeline facilities will be required at a future date, DDSD was concerned about having a future Contractor tap into the main distribution pipeline while keeping the pipeline in service. To facilitate the future recycled water pipeline relocation, tie-in connections to the recycled water pipeline were designed and constructed. At the approximate locations where the future pipeline will connect, tees and isolation valves were installed. This will allow the future Contractor to install the new relocated pipeline while keeping the existing pipeline in service. Once the new pipeline is completed, the isolation valves will allow the new pipeline to be placed into service and the old pipeline to be removed from service without disruption of recycled water service. An irrigation connection will also be installed on the south side of Highway 4 to facilitate landscape irrigation for the new freeway shoulders. All of this work was performed by the Contractor as a change order. Through agency cooperation, the needs of all stakeholders were met. The Recycled Water Project construction was able to move forward in a timely manner as well as facilitate future construction activities. By understanding the overall goal, a better project was achieved.

PIPELINE ALIGNMENT SELECTION WITH OVER 200 UTILITY CROSSINGS

This project is located in an urban area and it was anticipated that many utility crossings would be encountered. In all, there were over 200 utility crossings, not including service laterals. Agencies with which coordination for utilities was required included AT&T, PG&E, Contra Costa Water District, East Bay Municipal Utility District, Contra Costa County Flood Control District, Caltrans, Southern Pacific Railroad, Chevron, Calpine, Kinder Morgan, Shell, Venoco, Mirant, City of Pittsburg, City of Antioch, and DDSD. It would have been exorbitantly expensive to pothole every utility during design and so a judgment call had to be made as to which utilities should be potholed. A spreadsheet was created listing every known utility that would be crossed, including its size and type (e.g. primary/secondary electrical, direct bury, conduit, joint trench, etc.) to gain a better understanding of the different categories of utilities and their respective quantities. It was determined that none of the water lines would be potholed since the City indicated that they had depth and location information. Because the surveying work included measuring invert elevations for storm drains and sanitary sewers within manholes and catch basins, depth information for storm drain and sewer crossing locations could be inferred. The following question was then posed to determine which remaining utilities should be potholed, "If this utility is hit by the Contractor, what would be the consequences?". Utilities regarded as having severe consequences if struck by a backhoe were potholed. These utilities included all gas lines 4-inch and larger, all primary electrical lines, high pressure oil and fuel lines, and the EBMUD aqueducts. Responsibility for locating the remaining utilities not potholed during design was placed on the Contractor.

Many assumptions were made regarding location and depth of utilities based on structures found in the field, including water meter boxes, electrical boxes, and manholes. To be conservative, it was assumed that there were utilities that would be in conflict and would need to be crossed either over or under by adjusting the recycled water pipeline's profile from that shown in the Contract Documents. To account for these unknowns, a line item was included in the bid schedule for additional over/under crossings not shown in the Contract Documents. The line item included additional fittings, combination air valve (CAV), restraints and/or thrust blocks, and appurtenances. By setting a price for the work prior to construction, it protects all parties during construction.

In addition to standard public utilities, in the vicinity of Lone Tree Way and Ridgerock Drive/James Donlon Boulevard, Chevron, Kinder Morgan, and Venoco gas/oil lines are present within Lone Tree Way. This made it challenging to determine the best pipeline alignment. Based on the maps obtained from these utilities, an alignment was designed. When potholing was performed to verify the location and depth of the oil and gas lines to ensure adequate pipeline separation, it was determined that the oil and gas lines were in very different locations than earlier assumed which required a complete pipeline realignment. In fact, the recycled water pipeline had to be realigned to the other side of road and utilities potholed again for further verification.

As of the date when this paper was written, only the construction on Pittsburg-Antioch Highway, W. 10th Street, Crestview Drive, and A Street has been completed. Many of the utilities shown in the documents provided by other utilities and included in the Contract Documents on Pittsburg-Antioch Highway that needed to be crossed under were in fact not encountered. This was due in part to water meter boxes that were installed but their service laterals were never connected to the main line due to a lack of development. The Contractor also submitted an RFI and proposed to rope under utilities instead of using fittings. For utilities that were located adjacent to each other, roping enabled the Contractor to cross under multiple utilities at the same time thus eliminating fittings, CAVs, and restraints, saving both time and money. DDSD was able to obtain a credit for the CAVs not installed. Approximately two-thirds of the CAV locations on Pittsburg-Antioch Highway that were shown were eliminated due to roping and utilities not being present.

At the intersection of W. 10th Street and D Street, a telephone box is located on the northwest corner of the intersection. During design, AT&T was contacted to obtain information on the box, including size and depth of the utility, and to schedule a site visit to open the box. AT&T was not available for a site visit but provided dimensions for the vault. On the design plans, the telephone box was oriented with its long side in the east-west direction, parallel to the pipeline alignment. However, the Contractor discovered in the field that the long side of the telephone box was in fact oriented north-south. Figure 6 shows a photo of the telephone box and pipeline trench. Since only the manhole cover was exposed and the AT&T utility map indicated conduits entering/exiting all four sides of the vault, it was impossible to determine the box's orientation without looking inside. To adjust for field conditions, the Contractor originally planned to angle

Figure 6. Telephone vault at the intersection of W. 10th Street and D Street.

the recycled water pipeline around the box, but was concerned about damaging the integrity of a nearby sanitary sewer manhole constructed of brick. In the end, the Contractor maintained the design alignment by routing the pipeline beneath the AT&T vault, approximately 12 feet deep.

At the intersection of W. 10th Street and H Street, the Contract Documents indicated a pothole was performed during design showing two 4-inch pipelines, one crossing the recycled water pipeline and one running parallel along W. 10th Street. It was unknown where the parallel pipeline went and what it contained. None of the utility maps obtained showed the pipeline. During construction, it was determined that the 4-inch pipeline running parallel down W. 10th Street was a 4-inch gas line which based on PG&E utility maps was shown turning onto G Street, further downstream, rather than onto H Street. This required an alignment adjustment during construction. The option to relocate the recycled water pipeline to the westbound lanes was evaluated. However, the westbound lanes included buried telephone conduits and a telephone box, none of which had been potholed. The concern for shifting the alignment within the eastbound lanes was avoidance of the existing sewer lines. However, because of the existence of sanitary sewer manholes in the vicinity, the sewer line was easily located and the decision was made to shift the recycled water pipeline's alignment approximately one foot to the north to avoid the 4-inch gas line.

The important lesson learned on this aspect of the project is what is actually constructed may differ from what was designed. Unless the changes are documented in as-built drawings, what is buried in the ground is anyone's guess. Even with due diligence by the design engineer, one must still rely on the accuracy of other agencies' data. Additional verification through potholing and other means can only be performed to the extent that project budgets allow. Field conditions may vary, but with a solid Contractor on board and open communication between the Owners, construction manager, design engineer, and Contractor, obstacles may be overcome.

CONCLUSION

Designing and constructing a system expansion through an established community is challenging, but many lessons can be learned from this project so decisions, approaches, and improvements can be implemented on future projects to gain increased success.

Utilizing Fusible PVC, an innovative technology, to slipline and reuse an existing pipeline reduced project construction costs, traffic and business impacts, and permitting issues. Performing as much potholing as the budget allows to locate existing utilities and verify existing conditions will ensure a smooth and successful construction. Selecting a construction method to cross the EBMUD's aqueduct corridors required evaluating options and understanding what may have worked on a previous project will not necessarily always work. Each project must be taken on a case by case basis. The Highway 4 Widening Project impacts on the Recycled Water Project were minimized through agency cooperation and by understanding the overall goal. The needs of all stakeholders were met and the Recycled Water Project construction was able to move forward in a timely manner as well as facilitate future construction activities. Pipeline alignment selection with over 200 utility crossings required an understanding that what is actually constructed may differ from what was designed. Unless the changes are documented in as-built drawings, what is buried in the ground is anyone's guess. Even with due diligence by the design engineer, one must still rely on the accuracy of other agencies' data. Additional verification through potholing and other means can only be performed to the extent that project budgets allow.