1. ABSTRACT

In an attempt to address aging cast iron infrastructure throughout San Diego, California, the City of San Diego initiated the replacement of a 30-inch potable water transmission main with a 24-inch PVC pipeline along Upas Street in historic Balboa Park, crossing under California State Route 163 (CSR 163). Horizontal directional drilling (HDD) installation methods were selected to minimize disturbance to the park and the critical highway. The California Department of Transportation (Caltrans) only required a casing for the segment crossing the highway. Therefore, a unique design for the HDD crossing was implemented, using a 30-inch, 700-foot-long, partial casing and a full 24-inch, 1,725-foot-long carrier pipe installed simultaneously. The casing length satisfied the Caltrans requirements by providing a casing under CSR 163, but limited the length of casing required for the entire installation. The installation included a specially designed pull-head, which allowed for simultaneous attachment to both the casing and carrier pipe ends and also allowed drilling slurry to flow between the two pipes. This provided an alternate form of ballasting for the casing while the carrier pipe was ballasted using a standard fill line arrangement.

A previous paper reviewed the design process for this project in detail. This paper will review the construction considerations, including the drill rig arrangement, material selection, pipe laydown concerns, and neighborhood sensitivities as they related to the original design. The successful results of the construction process reveal what happens when a unique design meets the real world and ever-changing parameters of the actual construction site.

2. INTRODUCTION

Balboa Park has been a focal point within the City of San Diego, CA since the early 1900s. Originally reserved in 1868, beautification projects on this 1,200-acre area began in 1892 with the planting of several donated trees and plants. This continued into the start of the 20th century with a park improvements plan implemented from 1903 to 1910 to install water lines and roads, and continue planting. With its large open spaces located within two miles of the Port of San Diego, the park was the ideal location for the Panama-California Exposition in 1915-1916. The exposition was held to celebrate the opening of the Panama Canal and San Diego’s significance as the first port to the north for those travelling west through the canal. A large portion of the buildings and landscape currently in the park were constructed in preparation for this fair. The San Diego Zoo was founded at this exposition in 1916, now celebrating its centennial with over 4,000 animals.
Over its history, the park continued to develop and provide an idyllic location for fairs and events in San Diego, stimulating both the economy and the community. Preparations for the California Pacific International Exposition in 1935-1936, an effort to counteract the depression, created more landscaping, structures, and theatres still in use today including the Starlight Theatre and the Old Globe. With the majority of the original structures still intact and in use, housing some of the 17 museums, 19 gardens, theaters, and the famous San Diego Zoo, Balboa Park is a unique tourist attraction and a historic piece of the City of San Diego.

The construction of California State Route 163 (CSR 163) from 1942 to 1947 followed the park’s intent to maintain the extensively landscaped area. CSR 163 cuts along the west side of Balboa Park, connecting Interstate 15 to Downtown San Diego. Originally called U.S. 395, it was the first freeway built in San Diego. The northern section of the freeway has the typical eight lanes but, after crossing Interstate 8 just north of the park, the freeway reduces to four lanes and is engulfed by the greenery of Balboa Park, earning it the designation of a California State Scenic Highway and Historic Parkway.

CSR 163 is now heavily trafficked as it provides direct freeway access to the park and downtown area. Balboa Park itself is situated in less than two square miles that are densely populated by historical landmarks and attractions, often playing host to various marathons, walks for cures, and festivals. Access to these facilities is critical to the community, presenting a difficult situation when construction is needed in the area.

3. PROJECT BACKGROUND

Many of the existing water lines in Balboa Park were installed during the initial development of the area, some as early as 1902. The lines of most concern and in need of replacement ran under Park Boulevard, 5th Avenue, and Upas Street. The 16-inch line under Park Boulevard was installed in 1913 and the 16-inch to 20-inch cast iron pipes under 5th Avenue were installed over the years from 1902 to 1958. The 24-inch to 30-inch pipeline under Upas Street had been in service since 1939, supplying water as a main transmission line into Balboa Park. Now reaching from 60 to over 100 years in age, the cast iron lines have deteriorated and experienced multiple leaks and failures (see Figure 1).

Figure 1. Existing cast iron water line.

Development of the area and its natural topography put these lines at greater risk of failure with several sections that could not feasibly be reached to perform point repairs. Approximately 28,500 feet of water mains were replaced in total over all phases of this replacement project. The mains along Park Boulevard and 5th Avenue were replaced as part of Phase 1. The Upas Street pipeline replacement was designed and installed as Phase 2. The most technically challenging aspect of the pipeline was located along the Upas Street alignment where the existing 30-inch cast iron line crossed under CSR 163 at the northern border of Balboa Park (see Figure 2). The freeway did not exist at the time of the utility’s initial installation, which cuts through a small canyon with an approximately 100-foot drop from Upas Street on either side. Standard installation methods would not be practical. The City of San Diego tasked Infrastructure Engineering Corporation (IEC) to design a solution for the overall pipeline replacements and this complex freeway crossing.
4. PROJECT DESIGN

IEC began design in early 2012 and enlisted the expertise of several consultants. Helix Environmental Planning completed field surveys of vegetation and wildlife to determine any conflicts in the project area that could disturb a habitat or interfere with cycles such as nesting seasons. Allied Geotechnical Engineers conducted a geotechnical investigation along the CSR 163 alignment as well as other areas of the pipe replacement. IEC subcontracted the analysis and design of the CSR 163 trenchless crossing to Bennett Trenchless Engineers (BTE). The City of San Diego and IEC determined areas of potential impact to the community and environment and BTE provided options to cross beneath the freeway within those parameters.

The water line crossing started at the intersection of Upas Street and 7th Avenue on the west side of CSR 163 and ended near the intersection of Upas Street and Vermont Street on the east side of CSR 163 (see Figure 3). The project area itself was the largest constraint on the design of the crossing. To the west was a condominium complex right on the corner of Upas Street and 7th Avenue with an HOA that was known to be quite vocal when any construction took place in the area. The west side also had a cobblestone retaining wall and several trees that were part of historical Balboa Park and could not be damaged or removed to facilitate construction. To the east were several suburban homes, Boy Scouts and Girl Scouts facilities, and the Theodore Roosevelt Middle School, all with driveway access directly off of Upas Street. A path that followed very closely to the intended water line alignment allowed pedestrian access from one side of CSR 163 to the other.
IEC’s initial consideration of installing the crossing by open trench methods was quickly eliminated as an option due to the traffic control measures required to shut down CSR 163. BTE analyzed the site to determine the most feasible installation method. Although pipe jacking methods using a steel casing are typically considered in road crossings, this crossing was approximately 1,700 feet in length and had a 100-foot elevation drop from the potential shaft locations to the freeway. Neither this length nor the excessively deep jacking and receiving shafts needed to accommodate such a bore were considered practical. Horizontal directional drilling (HDD) was the only practical method to cross the freeway with minimal disturbance to the surrounding area. BTE designed the bore path to have a 1,000-foot bending radius and a low point elevation of 158 feet set to ensure that the bore would be above known gravels and cobbles. This design allowed for a minimum cover of 32 feet under CSR 163 and a maximum cover of 107 feet under the ridge to the east of the freeway (see Figure 4). The bore began near the corner of Upas Street and 7th Avenue on the west with an entry angle of 16°, and continued to just past the driveway into the Boy Scouts facility on the east end, with an exit angle of 14°. Because driveway access to the Boy Scouts had to be maintained during construction, a 150-foot conductor casing was included in the design for the eastern end of the bore to prevent bore collapse as the area just above the exit point would experience regular traffic loading during construction.

Caltrans requires any pressurized lines crossing within their right-of-way (ROW) to be installed within a redundant casing as a precautionary measure to prevent potential sink holes in the freeway if the line beneath were to leak or burst and erode the surrounding soil. Because the casing requirement only applied to the line within the ROW, a partial casing was proposed by IEC for the 1,700-foot crossing. This would only require approximately 700 feet of casing pipe, eliminating 1,000 feet of casing material from the project cost. The design planned for the carrier pipe to be pre-loaded into this partial casing such that pullback from the HDD exit point would bring the casing to the western side of the bore, ultimately extending from the HDD entry point to the eastern extent of the Caltrans ROW. BTE recommended a pull-head that would allow for connection to both the carrier and casing pipe and allow drilling fluid to flow between the casing and carrier to mitigate the risk of the casing buckling during pullback.

The west side of the crossing was designated as the bore entry point and, therefore, the location of the drill rig due to traffic control limitations on the east end of the bore. There was only about 300 feet of layout space along Upas Street back from the west end of the HDD to its intersection with 6th Avenue. Past 6th Avenue, there were several blocks of homes and businesses with a cross street every 250 feet, so the east side was not an ideal location for the 1,700-foot plus assembled pipe length. However, the area was capable of housing the necessary 20,000 to 30,000 square foot drill entry staging area. This square footage could be manipulated as needed to fit the necessary equipment within the constraints of Balboa Park. The staging area required at least 75 feet of space behind the entry point to fit the drill rig but needed to protect the historic wall and trees in the vicinity. The entry pit obstructed the current pedestrian path across CSR 163, requiring an alternate walkway to be created to provide access to the bridge.

The east side of the crossing had a longer layout space that would allow the entire 1,725 feet of pipe (longer than 1,700 feet when accounting for the curve of the bore) to be laid out from Vermont Street to Park Boulevard prior to pipe pullback (see Figure 5). However, this stretch would cross the only driveway to the Boy Scouts, one of two driveways into the Girl Scouts, Richmond Street, and Upas Street access to the Roosevelt Middle School. Assembly of the entire length would not be possible until absolutely necessary for pipe pullback. The Girl Scouts facility had a second driveway accessed off of Richmond Street and the middle school had an alternate access point from Park Boulevard, but neither Richmond Street nor the driveway to the Boy Scouts facility could be blocked other than for a short time during installation. Richmond Street was one of the few off-ramps from CSR 163 and not only provided alternate access to facilities on Upas Street but was the only delivery access point for feed and supplies to the San
Diego Zoo. The design only allowed closure of the Boy Scouts’ driveway during pullback and closure of Richmond Street for a two-hour period during which the pipe would be elevated over Richmond Street to allow traffic access during pullback.

The CSR 163 water line crossing would replace an existing 30-inch cast iron line. The original request for design proposals stated that the 30-inch cast iron would be replaced with another 30-inch line. However, after reviewing the City’s hydraulic model calculations, IEC determined that a 30-inch diameter pipe would be oversized with flow at velocities less than two feet per second. IEC suggested that the City downsize to save money both in material costs and borehole drilling costs. Upon completion of further hydraulic models, the City approved a reduction in size to 24-inch.

Both fusible polyvinyl chloride pipe (FPVCP) and high density polyethylene pipe (HDPE) were considered as carrier and casing pipe materials in the HDD crossing design. FPVCP was not at that point included on the City of San Diego Approved Materials List (AML), but IEC, having designed other successful FPVCP installations, recommended that it be considered and had BTE include FPVCP as part of the design calculations. BTE performed pullback load analysis and pipe stress and buckling analysis for two material options: (1) 24-inch DR 18 FPVCP carrier pipe with a 30-inch DR 21 FPVCP casing and (2) 30-inch DR 9 IPS HDPE carrier pipe with a 42-inch DR 13.5 IPS HDPE casing. The casing sizes were chosen to provide a standard minimum two to three inches of clearance between the carrier pipe outside diameter (OD) and the casing pipe inside diameter (ID). The larger HDPE carrier pipe size was specified to match the design flow area required (see Figure 6). The DR chosen for the HDPE casing did not meet the desired pressure capacity but was the thickest DR available in that size. Carrier pipes were assumed to be filled with water during installation and, to determine stresses in the worst-case scenario, each pipe was evaluated as if it were installed without a casing. Calculations confirmed that both HDPE and FPVCP options could be installed within safe limits of pull loads and buckling stresses recommended by the manufacturer. Analysis actually determined that there was a risk of buckling in the HDPE casing, but ballasting the casing with drill fluid would mitigate this risk.
The HDPE option would require the additional design of thrust restraints at the connections from HDD to open cut water line to restrain against the shrinking and elongation of the carrier pipe with temperature and pressure changes in the line. FPVCP does not have this issue and, therefore, did not have this requirement. Greater detail on the analysis and considerations by Bennett Trenchless Engineers in developing the design for this CSR 163 crossing can be found in a paper previously published by NASTT as part of the 2014 No-Dig Show, Paper No. TM1-T2-03. The rest of the water line to be replaced along Upas Street was to be installed by open trench methods except for a small 200-foot slipline section.

5. PROJECT BIDDING

The Upas Street pipeline replacement was set up as a “Construction Manager at Risk”, or CMAR, project delivery method where a single contractor is brought in during the design phase of the project to provide value engineering. The contractor then obtains subcontractors through a bidding process, and manages them during the construction phase of the project for a guaranteed maximum price. The City of San Diego retained J.R. Filanc Construction Company, Inc. (Filanc) for CMAR services at 90% design. When close to 100% design, Filanc revised the list of bid items provided by IEC. Filanc opted to divide the project into 16 parts or “bid packages” in order to comply with the City’s small and local businesses contracting requirements. Each bid package was bid independently and was awarded as a subcontract under Filanc’s supervision. One package was purely electrical, one was landscaping, two were paving, and the other 12 involved water line replacement. The HDD under CSR 163 was bid as part of Phase 2, Bid Package 6.

Even though design had included both FPVCP and HDPE pipe material options, the final bid form and technical specifications for the HDD only allowed HDPE. The City had pulled the FPVCP option from the bid documents at 90% design because it was not included on the AML. FPVCP was used in a couple of pilot projects in San Diego, but the Public Utilities Department did not give permission to use it in any other project until testing was complete. The FPVCP supplier submitted to the City to be officially added to the AML and, due to the success of these pilot projects and satisfaction with testing performed, FPVCP was added to the list. After notice of approval, but prior to the bid date, an RFI was submitted to add FPVCP back as a material option, at which point FPVCP was allowed as an equal to HDPE for the water line and casing via an addendum. Revising the Caltrans permit to account for this new pipe material was relatively simple as Caltrans had already approved FPVCP on their AML.

Package 6 bid on February 26, 2015 and, after only receiving one bid, was awarded to TC Construction who chose to use FPVCP for the CSR 163 crossing and subcontracted the bore to The HDD Company.

6. CONSTRUCTION

The original 30-inch cast iron line was taken out of service by the City prior to drilling operations due to the main’s close proximity to the HDD entry and exit pits. This required close coordination with the University Pipeline Replacement Project that was also in construction; the University Pipeline is a parallel back-up transmission main to the Upas Street Pipeline. However, before the main could be taken out of service, Caltrans irrigation lines along the sides of CSR 163 needed to be re-plumbed. Caltrans had originally tapped the irrigation lines that fed the greenery along the side of CSR 163 into the 30-inch transmission main below the freeway. The City of San Diego does not allow direct connections to transmission mains. In order to be in compliance with current design requirements, 1,000 lineal feet of new 8-inch irrigation supply line was constructed from CSR 163 to connect back to Vermont Street as part of Bid Package 8.

Prior to drilling operations, the City of San Diego surveyors staked the centerline of the alignment on both sides of the freeway. After that, HDD surveyors used this staking to set a grid pattern on both sides of the centerline. These offsets were used for steering information during the drilling process. Before drilling began, Caltrans set a survey grid pattern along the freeway and performed ‘surface settlement monument’ surveys periodically during construction to ensure the freeway was not damaged by the drilling operations. This same grid was checked post-construction.

TC Construction began site preparation in January 2016 just before their subcontractor, The HDD Company, began drilling the pilot bore under CSR 163. The HDD Company started the pilot bore in mid-January, following the bore alignment designed by BTE. The actual location of the entry pit had to be moved slightly to the southeast to avoid
the root zone of historic Marston House Canary Island Pines in the vicinity of the designed staging area (see Figure 7). The proximity to the two high-rise condominium complexes north of the staging area kept the construction in strict compliance with noise and work hour policies. Crews were only allowed onsite for eight hours per day, Monday through Friday, with work not permitted to start until 8 AM. Extreme caution was taken during boring operations starting with the 11-inch pilot hole. To lower the potential for frac-outs or loss of circulation, an 18-inch ream was completed in multiple phases during the pilot hole process in order to relieve the annular space. The pilot bore was drilled to the highway, at which point the 11-inch bit was pulled out of the hole and an 18-inch reamer was drilled through the pilot bore to the same point. The reamer was then pulled out and the 11-inch pilot bit was again used to drill to within 60 feet of the exit point. The pilot bit was pulled out, then followed by an 18-inch ream of the full alignment to the HDD exit point. The alignment was reamed three more times with increasing diameters to a final borehole diameter of 42 inches using mud motors and rock reamers on the entire bore. Even though only a partial casing was to be installed in this crossing, the entire length of the crossing needed to be reamed to 42 inches to appropriately accommodate the 32-inch OD casing pipe that would be pulled from the east side of CSR 163 to its final location on the west side of the bore. The hole was swabbed twice with a 36-inch barrel reamer prior to attachment of the barrel reamer to the pipeline for pullback. In total, the bore itself took 10 weeks to complete.

![Figure 7. HDD entry side staging area.](image)

FPVCP was delivered to the project site starting in mid-February 2016. In the original design, the driveway into the Boy Scouts facilities was to remain open at all times except during pipe pullback. However, to simplify pipe layout, Filanc approached the Boy Scouts during construction to suggest construction of a driveway between the Girl Scouts’ and the Boy Scouts’ facilities that would allow access to the Boy Scouts via the Girl Scouts’ secondary driveway off of Richmond Street. The Boy Scouts approved and TC Construction built a connecting driveway between the two facilities. This allowed pipe layout to run in front of the Boy Scouts’ primary driveway without creating a traffic circulation issue (see Figure 8). The new access gate benefitted the Girl Scouts and Boy Scouts after construction as they tend to use each other’s parking facilities as overflow lots but, when previously separated, were forced to walk out to the street and around to access the correct facility. Because the primary driveway would no longer need to support vehicular traffic, the designed conductor casing on the east end of the bore was not installed.
The 700 feet of 30-inch casing pipe was fused first in one length in the last week of February. The length of 24-inch carrier pipe to be pulled concurrently with the casing was then fused and pre-loaded into the casing pipe to a length that allowed 20 feet of the carrier pipe to extend past the casing and permit an intermediate fusion to the remaining non-cased 24-inch carrier pipe (see Figure 9). This pre-loaded pipe segment was laid out from Richmond Street, past the Boy Scouts’ driveway, and approximately 120 feet down the pedestrian walkway near the HDD exit point (see Figure 9).

The remainder of the 24-inch carrier pipe (outside of the casing) was fused in three pieces on the sidewalk in front of the Roosevelt Middle School, between Richmond Street and Park Boulevard (see Figure 10). Pipe fusion and pullback was initially planned to occur during winter break of 2015 so the middle school would not be in session during construction; however, delays due to phasing coordination with University Pipeline did not allow construction to begin until the following year. Luckily, the middle school was very cooperative with the City regarding construction of the water line replacement. The principal allowed fusion of the carrier pipe to take place in front of the school while it was in session. An alternate bus pick-up and drop-off location was set up at the school’s south driveway from Park Boulevard instead of the main driveway off of Upas Street. Fusion of the 24-inch carrier pipe sections was completed in early March with only intermediate fusion remaining. Assembling this pipe into multiple lengths instead of one long length ensured Richmond Street, Park Boulevard, and the Roosevelt Middle School drive were not blocked. Intermediate fusion was completed the day of the pipe pullback.
Among the benefits of installing only a partial casing was the simplification of pipe layout. Had a casing been required for the full length with the carrier pipe pre-loaded within it, Richmond Street would have to be blocked for a much longer period of time to fit the entire casing length along the laydown area. The partial casing option, which fit the required 700-foot casing and its pre-loaded carrier pipe between Richmond Street and the pedestrian walkway, left Richmond Street open to the public until pullback into the borehole. This also saved on project costs by eliminating 1,000 feet of 30-inch casing material. However, this unusual casing concept exhibited additional risk in an already lengthy and high-risk bore under the freeway. In a typical cased HDD, if there were an issue during installation that caused the assembly to become stuck, the carrier pipe could be pulled out and salvaged as it did not have direct contact with the soil in the borehole. In this partial casing option, should the assembly become stuck, both pipes would be trapped down hole instead of only the casing. Also, because the borehole along the entire length needed to be large enough to accommodate the casing pipe, this left an unusually large annular space for the non-cased 24-inch carrier pipe, increasing the likelihood of soil settlement. Therefore, construction crews needed to exercise great caution during the installation of this unique crossing and contact grouting was specified for both ends of the bore to address the settlement risks.

To ballast the casing pipe to alleviate buckling pressures on that pipe, a custom pull-head configuration was created. The pull-head consisted of a pull-head within a pull-head to pull the casing and carrier pipe into the borehole simultaneously. A standard 24-inch pull-head was installed on the 24-inch carrier pipe. A modified 30-inch pull-head without the pull eye fit over the 30-inch casing and 24-inch pull-head allowing for a single connection to the 24-inch pull eye during pullback. The drill slurry could flow through the opening between the 30-inch pull-head and 24-inch pull eye as well as the coupons cut out on the side of the 30-inch pull-head configuration (see Figure 11). The 24-inch carrier pipe was ballasted with water using a standard fill line arrangement from the back end.

Pullback into the borehole was initiated on April 8, 2016. The original design had called for elevation of the pipe string over Richmond Street to allow traffic during pull-in. But during construction the contractor was actually able to shut down Richmond Street for the duration of the pipe pullback (two days in total). Prior to completing intermediate fusion joints, the 700-foot pre-loaded casing was backed out of the pedestrian pathway and aligned with the HDD exit pit. The full assembled pipe string would not be able to fit between this HDD exit point and Park Boulevard without crossing Park Boulevard. The 700-foot cased segment was pulled approximately 200 feet into the bore (see Figure 12) to allow the full length of carrier pipe to be fused together without stopping halfway through
the bore to perform an intermediate fusion joint. Once started into the borehole, the three pipe lengths in front of the middle school were fused together, then fused to the cased carrier pipe segment. The entire pipe string was successfully pulled into place on Saturday, April 9, 2016 (see Figure 12).

![Figure 12. HDD pipe installation](image)

One minor issue occurred during pull-in at the point where the partial casing ended and the non-cased carrier pipe began. When most of the 30-inch casing was down the borehole, the casing above ground began to straighten out. This created a pinch point for the 24-inch carrier pipe within it at the point where the carrier pipe came out of the casing. An elevated roller was used to support and prevent over-bending of the carrier pipe until the casing was pulled further into the borehole.

Upon completion of the pipe pullback, The HDD Company installed grout to approximately 50 to 60 feet on each end of the bore. This is standard practice for this type of installation to fill any voids between the pipe and soil at the shallowest points of the alignment. Grouting was especially important on the east side of the bore where a non-cased 24-inch carrier pipe was pulled into a 42-inch borehole. The HDD water line crossing was connected to the existing 30-inch main and successfully pressure tested on June 8, 2016, holding 150 psi for four hours. TC Construction is currently working on the open trench water line replacements along Upas Street that were bid as part of Packages 6 and 7.

7. CONCLUSION

The overall success of the CSR 163 crossing can be attributed to detailed planning and design by the City of San Diego, Bennett Trenchless Engineers, and IEC and their consultants, as well as coordination between the City and contractors with the facilities surrounding the project area. Overall, the installation followed the designed alignment and material specifications, differing mainly in project timing and construction layout constraints.

The original design had included a conductor casing on the east end of the bore with the intent to keep the driveway to the Boy Scouts open at all times other than during pullback. In actual execution, the CMAR approached the Boy Scouts and received approval to build a driveway from the Girl Scouts to the Boy Scouts, allowing pipe laydown across their primary driveway and eliminating the need for a conductor casing. During pullback, the initial plan was to only close down Richmond Street for a two-hour period in order to elevate the pipe over the street and allow traffic access during pullback. Instead, the contractor applied for and received permitting to close Richmond Street for the two days that pipe pullback took place. The HDD entry staging area was also moved slightly southeast from that shown in design to reduce potential damage to the root zones of the historic trees. The schedule initially intended to have the drill start on October 15, 2015 and be completed by December 31, 2015 when the Caltrans
permit expired. Due to delays from project phasing coordination and preparation, the Caltrans permit was extended and construction did not begin until January the following year. Once started, the HDD installation, from mobilization to successful pipe pullback, was completed in three months at a cost of $2,863,500.

Those involved in the design and construction were ecstatic at the success of the HDD crossing. Residents had a general interest in the project with passersby stopping to ask questions. The City was pleased that the pull went smoothly and was completed faster than they had anticipated. Great efforts were taken to minimize disruption and impact to the community.

8. ACKNOWLEDGEMENTS

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