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American Canyon Rehabilitates Aging Steel Transmission Line by Pipe Bursting

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1. ABSTRACT

In 2015 the California drought continued into its fourth year prompting the state of California and utilities to search for ways to preserve valuable potable water while finding alternative sources for agricultural water. On April 1, 2015, Executive Order B-29-15 was implemented to reduce potable water usage by 25%, remaining in effect until February 28, 2016.

The City of American Canyon had an aging 14-inch steel transmission line from the 1940s that had become increasingly susceptible to leaks. As one of only two transmission lines, the line was critical to meeting the city's daily water demands for both residential and commercial use. The rehabilitation of this line would aid in providing the city the mandated 25% reduction in potable water usage.

While certain parts of the line could be patched, there was an approximately 7,400-foot segment that required complete replacement. The city explored options of line replacement and rehabilitation, keeping in mind the increased summer water demands and water use reduction goals. In the spring of 2015 the city decided that the most cost effective way to address the failing 14-inch steel transmission main was to rehabilitate the line using pipe bursting technology and 12-inch PVC pipe as the replacement pipe. Construction began in fall 2015 and was successfully completed in mid-February 2016.

Details of the design development, pipe material selection, and construction methods attributing to the successful installation of this new transmission main asset for the City of American Canyon will be reviewed within the context of the project.

2. INTRODUCTION

Initial development of the City of American Canyon began in the 1800s with small remote farms and ranches on a patch of land in northern California. Extensions to the Northwest Pacific Railroad and Southern Pacific Railroad in the 1880s brought potential residents and overall growth to an otherwise stagnant economy. The area was originally known as Napa Junction, joining the railroads as they extended west to Santa Rosa, south to the City of Vallejo, and north into Napa Valley.

The Napa River makes up the western boundary of the city with the San Pablo and San Francisco Bay to the southwest. The proximity to these large bodies of water and tributary streams yield highly saturated soils and create marshlands throughout the region. In the 1930s trenches were dug to drain these marshlands, allowing for farming and ranching and turning the terrain into a largely agricultural area. In the 1940s a 14-inch steel water line was installed by a private water company through American Canyon to connect the wells under Napa Pipe (an industrial site on the eastern edge of Napa River in the north) to the C&H Sugar Factory to the south. This in turn provided American Canyon with its first major transmission line. Development continued into the 1950s when 85% of the wetlands were functioning not only as farmland but being used for hunting, fishing, waste management, and salt production as the Cargill Salt Company established commercial salt ponds off the Napa River. A secondary water line was installed in the late 1980s to support the growing population and the increased water demand.

The 6.6 square miles between the Sulphur Springs Mountains in the east, the Napa River in the west, the Napa vineyards to the north, and Vallejo to the south (see Figure 1) was officially incorporated in 1992, changing its name from Napa Junction to American Canyon as its now known. As a city, the residents in the region could make their own decisions for the land instead of relying on Napa County. Upon incorporation, the city began improvement projects in the wetlands, restoring 178 acres of a 300-acre landfill back to tidal wetlands and converting the land into one of the city's several recreation sites with trails for biking and hiking. The low-lying floodplains were reinstated to wetlands in 2006, creating habitats for birds, fish, and other wildlife to prosper.

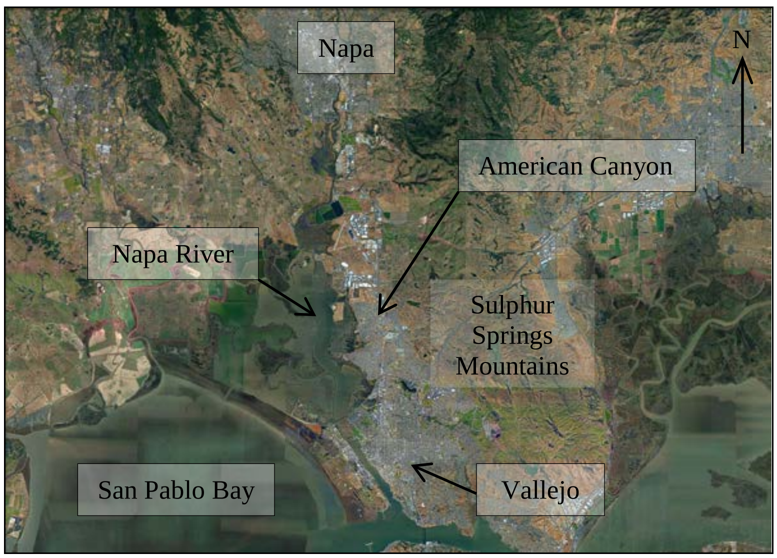

Figure 1. Location map.

American Canyon is now the second largest city in Napa Valley with a population of over 20,000. Even with the growing community, the city maintains a 'small town' feel with its emphasis on outdoor recreation, home to several parks and hiking trails and host to a weekly farmers market every Sunday. Its residents take great pride in preserving the open spaces, wetlands, and trails throughout the city. These preservation efforts could be quickly thwarted by construction; extreme sensitivity would need to be taken to ensure the safety of habitats in the vicinity of repairs to a leaking water line installed long before the city's founding.

3. PROJECT BACKGROUND

The water system in American Canyon consists of two transmission mains; one 14-inch steel water line installed along the western edge of California State Route 29 (CSR 29) in the 1940s and one 18-inch ductile iron water line installed along the eastern edge of CSR 29 in the 1980s. The city does not have its own water supply; it imports 100% of its potable water from the California State Water Project, a water storage and distribution system that reaches and supports both northern and southern California. More specifically, American Canyon's supply comes from the North Bay Aqueduct. Each year, approximately 980 million gallons of potable water leave the city's holding tank to serve 5,400 homes and businesses in American Canyon.

In the past few decades, a 7,400-foot segment of the 14-inch steel line had formed numerous leaks. Over 200 spot repairs had been performed along the main as leaks arose, yet it was still hemorrhaging between 100 to 200 gallons of potable water per minute (gpm), resulting in 200 to 300 acre-feet per year (AFY) of unaccounted water. One AFY equates to 325,900 gallons per year so, at its worst, approximately 98 million gallons of water were lost each year, or 10% of the city's total water demand. The 70-year-old transmission main was located along a roadside ditch with a few swales that detoured into vacant fields. The leaks along the line would fill these ditches with potable water that would then migrate through the swales to open fields, resulting in bright patches of green grass scattered along the alignment in the midst of the drought (see Figure 2).

Figure 2. Wet patch in a typically dry cattle field, a result of run-off from the leaking water main.

On April 1, 2015, the governor of California issued a drought declaration, Executive Order B-29-15. Under this order, the State's Water Resource Control Board was to lead a statewide initiative to achieve a 25% reduction in potable water usage, to remain in effect until February 28, 2016. American Canyon rightfully interpreted this mandate as a message that leaking pipelines were unacceptable. In recent years, the frequency of leaks on the city's 14-inch steel main had increased exponentially. A total of 32 leaks were plugged in all of 2014. Upon receipt of the governor's mandate, the city immediately checked the water line with portable sounding devices to identify potential leaks. A total of 28 leaks were located and repaired in the month of April alone. These April repairs and the replacement of a small pipe section in front of City Hall saved an estimated 20 to 30 AFY. However, this was only a fraction of the estimated water loss from the 7,400-foot water main segment along the highway. At this point it became clear that spot repairs were not enough to stop the outflow from the pipe's walls. The steel pipe was old, brittle, and falling apart (see Figure 3) to the point where the equipment and operations to complete subsequent repairs would actually damage the pipe further. A complete replacement was required.

Figure 3. Existing 14-inch steel transmission main installed in the 1940s.

It was not news to the City of American Canyon that this aging line was the source of extreme water loss in their potable water system, as seen from the hundreds of spot repairs spanning the past few decades. Two main factors discouraged water main replacement in the years previous: a lack of funds to support such a large project and a lack of ideas on how to tackle the replacement. American Canyon was not familiar with trenchless technologies; the standard method of utility installation was open trench. Open trench methods would have required at least one lane of CSR 29 to be closed which would in turn require night work. Moreover, much of the alignment was in highly saturated soils (due to water escaping from the pipe below) that had formed their own habitats, rendering these standard installation methods even more tedious. With these obstacles in mind along with costs to hire a design engineer, provide supporting surveying and analysis, and assemble a traditional bid package, the city envisioned the pipe replacement project costing anywhere between four million to five million dollars. With limited options, the line remained in place and was spot repaired as needed. The governor's mandate was the turning point, serving as a catalyst to begin planning the steel transmission main's replacement. The city did not yet have a definitive strategy on how to handle the replacement but not having any options was no longer an option.

4. PROJECT DESIGN

The existing 14-inch steel pipe laid at the bottom of the roadside ditch along CSR 29 with a minimum cover of three feet. There was only 5 to 10 feet from the ditch to the southbound lane of the highway, without any barriers between them. CSR 29 consists of two southbound and two northbound lanes with a posted speed limit of 65 miles per hour and approximately 50,000 vehicles travelling the route daily (see Figure 4). Other traits of the alignment included a creek crossing and ditch "habitats" that had formed in the over-saturated land above the leaking water line (see Figure 4). A mixture of potable chlorinated water from the steel line and storm water run-off into the ditch developed into a habitat with green vegetation, tulles (typically found in marshlands), and a potential for red-legged frogs. The design needed to consider the impact of construction on highway traffic and the environment. A single lane closure would severely hinder residents' daily commute and damage to these habitats and their wildlife would go against the city's preservation efforts.

Figure 4. Environment near existing 14-inch steel pipe [southbound lanes of CSR 29 (left); ditch "habitat" (right)].

Design of the water line replacement was initiated in spring 2015, shortly after the governor's executive order was released. Prior to hiring a design engineer, American Canyon researched possible solutions for installing the new pipeline with minimal impact to the environment and residents. The city had little exposure to trenchless technology, however, one of their few previous projects utilizing trenchless technologies involved a sewer force main pipe with a segment installed using directional boring. The fusible polyvinyl chloride pipe (FPVCP) supplier for that project, Underground Solutions (UGS), worked with the contractor to provide pipe and design guidance. The city's positive experience with this past project and familiarity with FPVCP led American Canyon to reach out to UGS for advice on the current problematic water line. Pipe bursting methods were suggested in order to install a new line along the same alignment without intensive open trench construction.

FPVCP had been installed by pipe bursting in several other locations through varied existing pipe materials including steel, assuring the city that bursting of steel was a feasible rehabilitation option. Trenchless methods provided the least invasive approach for the project site. If installed using open cut methods, one of the highway's southbound lanes would need to be closed to allow for the necessary trench excavation and setup, forcing all work to be completed at night to minimize the impact to traffic. It would also prove difficult to keep the trench stable while installing the new water line as much of the soils in the project area were like that of a wetland. Over 7,000 feet of trenching would inflict extensive damage to the habitats along the drainage ditches. Alternatively, pipe bursting allowed all lanes of the highway to remain open and imposed far less on the habitats that had developed along this segment, only requiring excavation at entrance and exit pits.

Rehabilitation of the steel line was viewed as an emergency project as the frequency of breaks increased and there was no means of patching them without causing further damage. Any measures to save time needed to be taken. Because the city was responsible for paying for the project, an obstacle that prevented them from fixing the line in the first place, any options that cut down on project costs were chosen. The project was designed in-house by the Engineering Division of the American Canyon Public Works, lowering the overall cost of design. The city assembled relatively minimal drawings only including the plan view of the alignment. Another cost and time saving measure was to not complete a detailed survey of the project site, only a basic review. Profile drawings were not available because of this, but it removed a series of tasks from the city's already long list. More detail was put into the project specifications to present a clear scope to bidding contractors.

Now that pipe bursting had been decided as the best installation method, the type of pipe bursting to be used in the project had to be specified. Because steel is a ductile material, pneumatic equipment cannot burst it. Pneumatic pipe bursting uses percussive movement to burst the existing line which is only effective on fracturable pipe materials such as clay or concrete. Only static equipment can pipe burst steel. The static system attaches roller cutters in front of an expander to 'slice' the steel open before the expander pulls through to burst it open, allowing the new pipe to be pulled in at the same time (see Figure 5). The city specifically required static systems to ensure that the steel line was properly expanded.

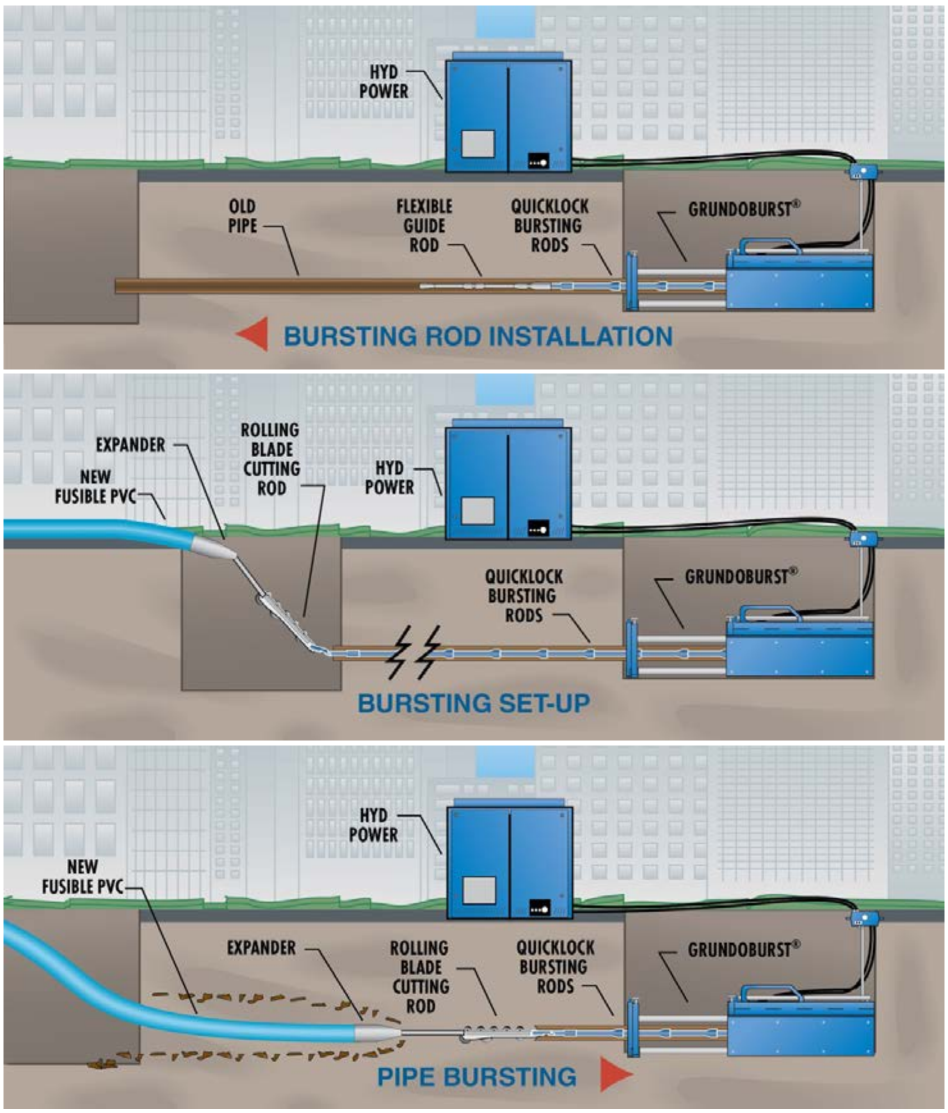

Figure 5. Step-by-step diagram of typical static pipe burst installation.

FPVCP was chosen as the new pipe material due to American Canyon's previous successful work with the material, their familiarity with PVC in their systems, and the supplier's installation success in similar rehabilitation projects. Typically, because pipe bursting equipment can burst the existing line to a diameter greater than its original size, a larger pipe size is installed in place of the existing pipe. In this case however, additional capacity was not needed in the city's potable water system. Flow analysis calculations determined that the same flow characteristics could be achieved using 12-inch DR 18 PVC pipe due to PVC pipe's higher Hazen-Williams coefficient (C-factor) over steel, decreasing the transmission main size from that of the 14-inch steel to an outside diameter of 13.2 inches.

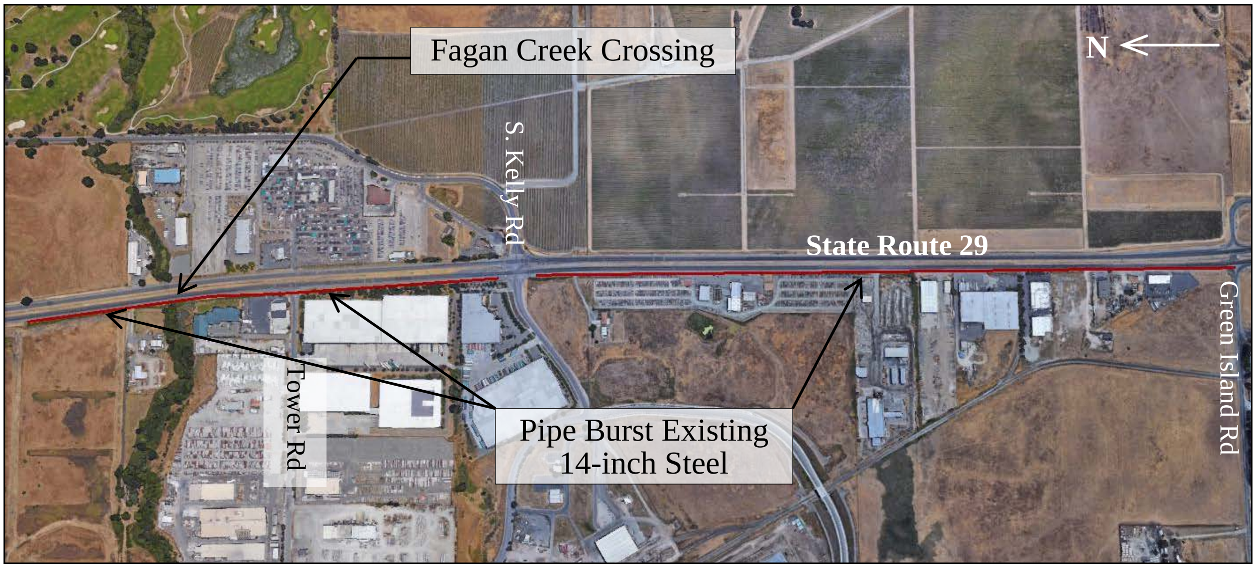

Figure 6. Extent of steel pipe alignment to be rehabilitated.

The extent of the rehabilitation was based on the extent of the pipe lengths with the greatest water loss and most frequent leaks. These lengths consisted of approximately 7,400 feet of steel pipe starting just north of Fagan Creek and ending at the intersection of Green Island Road and CSR 29 to the south (see Figure 6). Of this length, there was about 6,000 feet that was in desperate need of repair and required replacement as soon as possible. The lengths outside of these 6,000 feet were not exhibiting as many leaks as the rest of the line but were the same age and material. These sections were in the middle of the pipe alignment to be rehabilitated, between Tower Road and South Kelly Road, and would eventually need replacement. Because they weren't directly attributing to the lost 10% of American Canyon's water supply, the city set these as a second priority, to be replaced only if funds allowed. The total 7,400 feet of pipe bursting were split into 11 "locations" each with an entrance and exit pit and ranging from 278 to 900 feet in length based on the city's estimate of where bursting equipment could be set up. The 6,000 feet of pipe that took priority were labeled as locations #1 through #9. The less critical water main lengths were labeled as locations #10 and #11. One other aspect considered during the design was the Fagan Creek crossing. Due to the shallow bury depth of the existing steel line, the pipe to be burst comes out above the creek, not beneath it. The city decided to span the 40-foot creek crossing using ductile iron pipe installed above ground.

5. PROJECT BIDDING

Once the city completed their in-house design, the 14-inch Water Line Pipe Bursting project advertised to bid on July 16, 2015. The bid form consisted of a Base Bid and two Bid Alternates. The Base Bid covered the 6,029 feet of critical water main to be pipe burst. Separate line items were broken out for the FPVCP, the fusion services, the pipe bursting installation, and the entrance, exit, and reconnection pits required to complete pipe burst operations. The two bid alternates covered the lower priority pipe length. Bid Alternate #1 included 650 feet of pipe bursting for "Location #10" noted in the plans, running south from Tower Road. Bid Alternate #2 included 658 feet of pipe bursting for "Location #11" running from the end of Location #10 to South Kelly Road. Other items in the Base Bid schedule included the reconnection of service lines, fire hydrants, air release valves, and backflow prevention devices, valve connections, and the Fagan Creek crossing. The lowest bidder was based only on the Base Bid price, not accounting for the two additive alternate pipe burst lengths. The project bid on August 11, 2015 and received four bids. JMB Construction (JMB) was determined to be the lowest responsible bidder and was awarded the project. JMB planned to self-perform the pipe bursting installations with equipment and support from TT Technologies, Inc. – Trenchless Solutions. TT Technologies provided static pipe bursting equipment and specialty tooling, along with technical training and support as needed.

6. PERMITS, EASEMENTS, AND FUNDING

Due to the emergent nature of the project, standard slow-moving permitting procedures were not an option. American Canyon approached the United States Army Corps of Engineers (USACE) to explain how the typical two-year permitting process was not feasible for this pipe replacement. The city committed to completing a full biological workup of the project site with a biologist on standby and any other items typically required in the two-year permitting process as far as mitigation measures, oversight, and so on. They were willing to fulfill the conditions of a standard permit, but they did not have the time to go through the two-year process. Given the governor's mandate and the state of the water line, the USACE issued an emergency permit. The permit was initially for 60 days but the city asked for an extension that allowed a total of 90 days to complete major construction.

Because the 14-inch steel line was located along the edge of CSR 29, construction fell within a California Department of Transportation (Caltrans) right-of-way. State laws allow a city to replace or fix a pipe in cases of emergency without an encroachment permit. American Canyon notified Caltrans that they would take advantage of that law in order to begin construction immediately. Construction did not require closure of the highway and would be performed during the day for the most part so there was little risk. Caltrans understood the issue and, not wishing to hinder any efforts to meet the governor's mandate, issued a permit without delay.

Another partner that became involved with the water line rehabilitation was the Coca-Cola Company. Coca-Cola has a facility on Commerce Boulevard in American Canyon, near the south end of the water line to be replaced. This facility is American Canyon's biggest customer in terms of water usage, using approximately 300 AFY, about the amount of water that was lost through the steel line. As part of a corporate sustainability program, Coca-Cola had set a goal to replenish every drop of water they use throughout all of their facilities by 2020. The company has made efforts around the world to give water back through conservation efforts or water line rehabilitations such as this. American Canyon approached Coca-Cola regarding this program after the project had advertised to see if they would be interested in having a part in this rehabilitation. The facility was very willing to be part of the solution since this line was their water supply. Coca-Cola agreed to pay for the entire project, asking the city to do the project and just send them the bill once it was completed. This meant that all of the additive alternate pipe burst lengths could be completed.

7. CONSTRUCTION

Construction could not start until the water demands typical of the summer and early fall months had subsided. The only other transmission main in American Canyon was the 18-inch line on the east side of CSR 29 and it could not handle the summer water demands alone. For this reason, construction did not start until November 2015 when JMB crews arrived on-site to start preparation of the steel line for pipe bursting.

Site preparation involved set up of an above ground bypass system, taking video of the existing steel line, and potholing. JMB shut off valves at each end of the steel pipe segment and installed a 2-inch bypass line above ground to supply each commercial and residential meter along the alignment. JMB performed a video inspection of the 14-inch pipe to check for any bends, obstructions, repair couplings, or variations in the alignment from that shown in the plans. A few bends were located but no major patches or couplings were found that would impact the pipe bursting process. The bends in the alignment were cut out prior to the pipe burst installation to allow the new 12-inch water line to pull through the deflection. Potholing was completed over each planned pipe burst run to verify the depth of the line prior to installation.

Fusion of 12-inch FPVCP began on November 4, 2015 for the first pipe burst run of the project. Fusion equipment was set up along the western shoulder of CSR 29 where fused pipe could be strung out to the total length needed for each pipe burst run (see Figure 7). Traffic control was minimal since all lanes of the highway were kept open for the duration of the project. However, several side streets and businesses were accessed off CSR 29. Access to the side streets had to be maintained at all times and driveways needed to be open to the public at least during business hours. The long pipe strings would occasionally cross one of these paths and, instead of attempting a tricky aerial layout or blocking access entirely, shallow trenches were excavated across the road and then covered with steel plates to maintain vehicular access and allow constant access for the pipe to cross (see Figure 7). At some crossings, the contractor was able to use existing drainage culverts to pull a fused pipe length under a road (see Figure 7). Both crossing methods allowed the pipe to be fused to the full length required for each run without need of intermediate fusion joints.

Figure 7. Pipe fusion and layout [fusion (left); layout under road (center); layout through culvert (right)].

The pipe bursting equipment and pits were set up away from any driveways or intersections to avoid conflict. JMB used a static pipe burst unit from TT Technologies to install each of the pipe burst runs (see Figure 8). The unit used “Quickloc” bursting rods that allowed the contractor to add or remove rods much faster than standard threaded rods and a rolling blade cutting rod (see Figure 8) to slice the steel before it met the expander head.

Figure 8. Static pipe burst equipment [static pipe burst unit in exit pit (left); roller cutters (right)].

Initially in design, 11 pipe burst runs or “locations” were anticipated; however, once on-site, JMB determined that much longer runs could be completed at lengths up to 1,200 feet. This revised plan increased productivity and minimized the number of entrance and exit pits and the associated excavation and assembly time, lessening the impact to traffic and businesses on the alignment. Fewer pits also reduced the risk of disrupting the environment along the pipeline; several lengths of the alignment were considered to have a habitat with potential for special status species (the red-legged frog) and required a biologist to be on-site to monitor construction.

The number of pipe burst lengths was reduced to six. For each run, JMB set up the bursting unit in the exit pit and then fed the bursting rods through the existing steel line to the entrance pit. On the entrance pit side, a roller cutter and expander head were attached to the new 12-inch pipe and connected to the bursting rods (see Figure 9). At that point the assembly was pulled back through the existing line (see Figure 9), cutting and bursting open the 14-inch steel and pulling the 12-inch FPVCP into place behind it all the way to the exit pit (see Figure 10). Because the existing pipe alignment was under the drainage ditch, the pipe strings laid out through the drainage culverts and along the shoulder of the freeway could be pulled into the entrance pit with little to no adjustments. For four of the six runs, pulling the new pipe string into place did not obstruct access to any facilities, which allowed them to be installed during the day. The other two runs, however, would cross and block off several driveways during installation. These could not be installed during business hours, requiring night work. The pipe was strung elsewhere prior to installation and then pulled into place when the run was ready for pull back.

Figure 9. Installation from entrance pit [cutter and expander assembly (left); initial pull into existing steel (right)].

Figure 10. Installation from exit pit [roller cutter pulled through (left); pipe pulled completely through (right)].

One issue encountered in this project was the shallow alignment of the existing steel pipe. JMB potholed prior to pipe bursting to confirm the line was deep enough to properly burst the steel. This was a concern because if there is not enough soil around the existing pipe to hold it in place, the pipe can shift during the bursting process. The steel was deep enough to allow pipe bursting for most of the alignment except for one approximately 500-foot segment at the southernmost end of the project. Not only was it too shallow to pipe burst, but the city requested that the new line be installed deeper than the existing alignment, ruling out pipe bursting altogether. The length was to be installed using standard open trench methods instead. FPVCP was used for this open cut section as it was already on-site for the intended pipe burst run. The contractor could only excavate 100 feet of trench per day so two 45-foot lengths of FPVCP were fused together to make multiple 90-foot pipe lengths that would fit into the allotted open trench and connect with couplings. This segment did not have the same saturated soil content as some other parts of the alignment so disturbing a habitat with open trench excavation was not a concern.

With the 14-inch steel completely rehabilitated, JMB reconnected over 25 appurtenances to the new line, including water meters, air release valves, tees, and the existing 14-inch steel line on the extremities of the project. Most construction was completed by the end of January 2016 with only minor excavation and testing completed in February. The new line successfully passed pressure testing on February 19, 2016 after holding a pressure of 200 psi for two hours.

8. CONCLUSION

The governor's drought declaration in April 2015 served as the stimulus to fix the long leaking 70-year-old steel transmission main along CSR 29 in the City of American Canyon. The city immediately started planning to replace the line in the hopes of saving up to 300 AFY of potable water. Voluntary restrictions were also imposed on residents of American Canyon to cut back 20% over the previous year's consumption levels. Both of these efforts brought the city close to the desired 25% reduction in potable water usage.

The cooperation between American Canyon, UGS, USACE, Caltrans, and the Coca-Cola Company allowed for a successful rehabilitation project. By designing the project in-house and utilizing the emergency permits and procedures, the city was able to drastically cut the duration and cost of the project. Coca-Cola's funding through their sustainability program allowed American Canyon to rehabilitate the full extent of the problematic 14-inch steel line without bearing the weight of the project cost. In turn, Coca-Cola replenished every drop of water that they use annually. Within a month of the project's completion, Coca-Cola paid the city for the project's entirety, totaling nearly $1.5 million.

All the major construction items were successfully completed by the end of January 2016, within the 90 days allowed by the emergency permit granted by USACE. The choice to use trenchless installation methods over the typical open trench methods the city was familiar with directly attributed to the success of the project and the ability to meet such a tight deadline. The impact to the environment, traffic, and the surrounding homes and businesses was greatly reduced due to pipe burst technologies, opening doors to options the City of American Canyon may never have considered previously.

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