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Calleguas Municipal Water District Continues to Overcome Trenchless Challenges on the Salinity Management Pipeline

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ABSTRACT: Calleguas Municipal Water District (Calleguas) has completed constructing portions of the Calleguas Regional Salinity Management Pipeline (SMP) in Ventura County, California. The SMP is a regional pipeline that will collect and convey salty water generated by groundwater desalting facilities and excess recycled water for reuse or discharge into the ocean when there is no demand for reuse. The pipeline is being constructed in multiple phases over the course of many years.

SMP, Phase 1E ultimately included seven trenchless crossings under waterways, railroads, and intersections. The trenchless construction methods used included slide rail and sheet pile shafts, pilot tube auger boring (30-inch and 66-inch diameter steel casings) and open shield pipe jacking (66-inch diameter steel casings). The geotechnical conditions encountered on the trenchless crossings included sands, silts, and clay all below the tidally influenced water table.

This paper will highlight key events and responses during construction of the trenchless crossings. Of particular challenge on all crossings were the high groundwater levels and very soft soils. The focus of the paper will be overcoming the obstacles on the last trenchless drive of the project where the open shield tunnel boring machine (TBM) became stuck beneath the concrete-lined channel of the Oxnard Industrial Drain. The paper will detail the difficult rescue of the TBM and the eventual completion of the 66-inch diameter steel casing tunnel beneath the active drain.

1. INTRODUCTION

Phase 1E is part of the Calleguas Regional Salinity Management Pipeline (SMP) currently being constructed by the Calleguas Municipal Water District (Calleguas). The purpose of the pipeline is to collect concentrate from the demineralization of brackish groundwater and excess recycled water generated by inland water reclamation/wastewater treatment plants. When there is insufficient demand for re-use, the excess flow will be conveyed via outfall pipeline to a diffuser located 3,900 feet offshore where it can be safely discharged into the ocean. By removing salt from groundwater and surface waters in the region, Calleguas will improve water quality in an area where drought and regulatory restrictions are increasing threats to the agricultural, municipal, and industrial water supply.

2. PROJECT CONDITIONS

The Cities of Port Hueneme and Oxnard are located in Ventura County on the southern coast of California (Figure 1). The project area is located near the coast, approximately 60 miles northwest of Los Angeles, in a geologic region known as the Oxnard Plain. The plain was formed through fluvial deposition of sediments transported to the coast by the Ventura and Santa Clara Rivers during the late Pleistocene and early Holocene. As a result, subsurface conditions in the project area consist primarily of silty fine sand to sandy silt with some silt and clay, soils which were confirmed by the geotechnical investigation. While the sediments are primarily fine-grained, trace gravel and cobbles are also common.

Figure 1. Location map of Port Hueneme/ Oxnard, CA

3. PROJECT SCOPE

This phase of the pipeline included 7,473 LF of 48-inch welded steel pipe to be installed primarily by open cut. However, there were several obstacles that required installation of casings by a trenchless method so that the 48-inch carrier pipe could be installed within. The contract documents prescribed that the casings be installed by either pilot tube (guided) pipe ramming or pilot tube (guided) auger boring, although Calleguas was open to accepting other methods. The original contract document called for six casings to be installed via trenchless methods although ultimately seven were completed. Five of these crossings are detailed in Section 4 below. The crossings are generally discussed in the order they were completed, except for Casing No. 2, the most challenging crossing, which is discussed last.

Two other casings were installed that are not discussed in detail within this paper:

- Casing No. 5 – Ventura County Railroad Crossing - This casing was 97 LF of 0.5-inch wall, 66-inch diameter welded steel casing at depth of 12 feet. This casing was installed via open cut methods.
- Casing No. 6 – Ventura County Railroad Crossing - This casing was 84 LF of 0.5-inch wall, 30-inch diameter welded steel casing at a depth of 10 feet. This casing is needed for a future water line that will be installed at a later date by the City of Oxnard.

The construction contract was awarded to Whitaker Construction Group, Inc. (WCGI) of Paso Robles, CA at a bid price of $15.9 million in July 2009. WCGI named Pacific Boring (PB) of Caruthers, CA as their tunneling subcontractor.

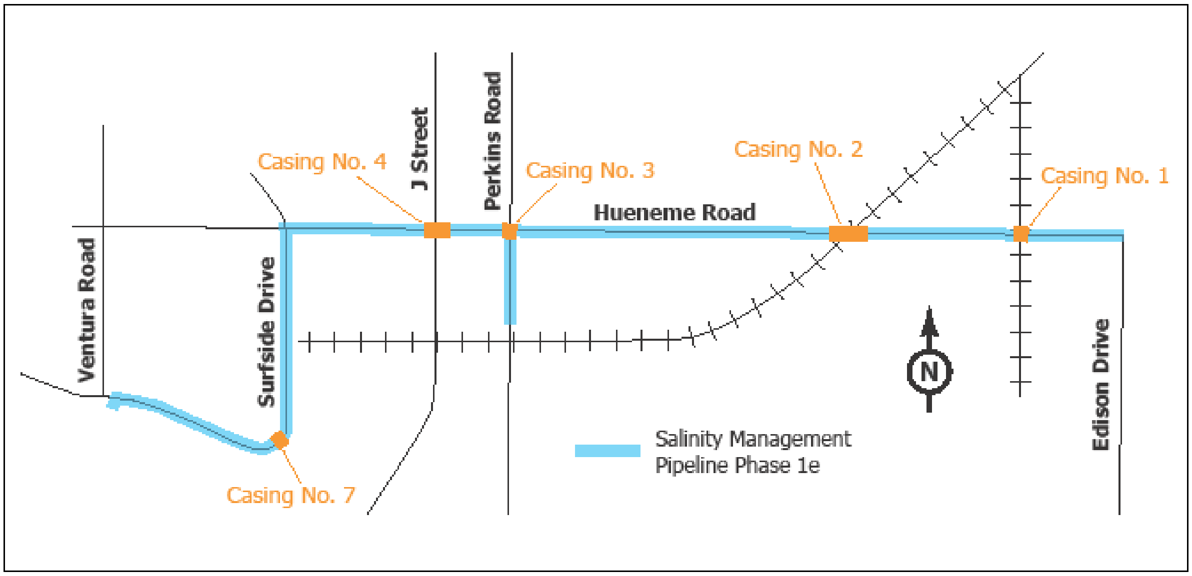

Figure 2. Map of Project Elements

4. CONSTRUCTION OF TRENCHLESS CROSSINGS

4.1 CASING NO. 1 – VENTURA COUNTY RR CROSSING

The first casing to be installed on the project was Casing No. 1 – Ventura County Railroad Crossing. The crossing consisted of 100 LF of 0.75-inch wall, 66-inch diameter welded steel casing at a depth of 15 feet. The launch shaft was a slide rail shaft and the reception shaft was comprised of conventional shoring boxes. Both shafts had deep wells installed to control groundwater around the shafts.

PB mobilized an Akkerman GBM 240A pilot tube machine and American Augers 48/54-900 G2 auger boring machine to the site to install the 20-foot lengths of casing. They also used a set of 30-inch and 66-inch sand augers produced by Michael Byrne Manufacturing (Figure 3). These augers have a heavy duty vertical face with “pie shape” doors that can be opened and close by rotating the auger to the left or right.

The boring was completed in three passes. For the first pass, the pilot tubes were advanced at the required line and grade. Once the pilot tubes reached the reception shaft, the Akkerman GBM 240A was removed from the shaft and a 30-inch pilot tube adapter and 30-inch reaming head were placed in the shaft. The sections of casing were then bored into place, thus pushing the pilot tubes out into the reception shaft. Once the 30-inch casing was installed the full length of the drive, a 30-inch to 66-inch reaming head was welded to the end of the 30-inch casing and the 66-inch steel casing was bored into place. This process took a total of six days of single shifts. PB grouted the annular space outside the casing then demobilized from the site.

Figure 3. Sand Auger Flights

4.2 CASING NO. 4 – "J" STREET DRAIN CROSSING

The second casing to be installed was Casing No. 4 – "J" Street Drain Crossing, consisting of 235 feet of 0.75-inch wall, 66-inch diameter welded steel casing at a depth of 30 feet. The "J" Street Drain is a concrete-lined flood control channel. The casing also had to cross under the Redwood Trunk Sewer, which is a 60-inch diameter sewer located under the "J" Street Drain. Several other small water lines and sewers were also crossed by the tunnel.

The method used to construct both of the shafts was slide rail shoring with deep wells for dewatering. No dewatering was done along the alignment due to the fact that the "J" Street Drain is typically full of water. When PB mobilized to the site, they elected to first advance their pilot tubes the length of the drive at the center of the tunnel horizon to "probe for obstructions" with their Akkerman GBM 204A machine. The pilot tubes were advanced the length of the drive without encountering any obstructions, so they removed the tubes before setting up the Akkerman TBM with 5000 Jacking System. The machine was equipped with a cutter wheel with closable hydraulic doors (Figure 4) and a screw conveyor for spoils removal to the electric locomotive mounted muck bin.

Prior to beginning any bored tunnel greater than 30 inches in diameter, the California OSHA Mining and Tunneling (M&T) Division requires that a pre-tunneling inspection be conducted with the tunneling contractor by an inspector from the division. During the inspection for Casing No. 4, the CAL/OSHA M&T inspector raised concerns about the need to positively locate the Redwood Trunk Sewer prior to the tunneling. In accordance with the contract, WCGI (the prime contractor, who was responsible for the potholing in advance of the tunneling) had surveyed the depths of the upstream and downstream manholes and estimated the slope of the pipe to determine the depth of the existing trunk sewer at the location where the new casing was to be tunneled underneath with a clearance of 4 feet. It was not feasible to pothole the trunk sewer due to the fact that the "J" Street Drain is almost always full of water. However, CAL/OSHA M&T would not let the tunneling commence until the trunk sewer was "positively" located. At Calleguas' request, the City of Oxnard Wastewater Operations and Maintenance staff made several attempts to locate the sewer via non-destructive methods using a sonde and electric locating device. All of these attempts were unsuccessful. Eventually the CAL/OSHA M&T Inspector agreed to let the tunneling proceed after Calleguas' Project Manager sent a letter documenting the method that was used to locate the trunk sewer and expressing confidence in the accuracy of the information provided.

Once the tunneling began, the only real issue on this drive was the amount of groundwater encountered. Once the tunnel was advanced past the zone of influence of the dewatering wells around the launch shaft, the amount of groundwater greatly increased. The rotation of the cutter wheel on the TBM caused the material to basically liquefy as the machine advanced (Figure 5). However, the tunneling continued and the TBM reached the shaft after 13 days of tunneling with only one sinkhole occurring at the western/near side edge of the "J" Street Drain.

Figure 4. Akkerman TBM and cutter wheel

Figure 5. Saturated spoils in the muck bucket

4.3 CASING NO. 7 – BUBBLING SPRINGS CROSSING

The next crossing to be completed was under Bubbling Springs/Hueneme Drain (Figure 6), a box culvert. This crossing was not originally planned to be a trenchless crossing. The contract drawings depicted the crossing to be constructed by supporting the 28-foot wide by 5.5-foot high concrete channel by placing wide flange beams underneath and on top and connecting the beams with chains, thereby supporting the channel while the soil underneath was removed and the 48-inch pipe was installed. However, WGCI had concerns about this design and requested that they be allowed to have PB install an additional auger bore crossing. The 45-foot long crossing was completed successfully in three days by conventional auger boring in a single pass.

Figure 6. Bubbling Springs Crossing

4.4 CASING NO. 3 – PERKINS RD. CROSSING

This casing consisted of 116 LF of 0.75-inch wall, 66-inch diameter welded steel casing at a depth of 20 feet. This tunnel was included as part of the work to cross underneath a busy intersection with a number of utilities which would make for difficult open cut construction. The launch shaft was constructed using slide rail with deep wells. The reception shaft was constructed of beams and steel sheets, also with deep wells to control groundwater. The material was damp sand which made for good tunneling on this drive. The work was completed over the course of four days of single ten hour shifts (Figure 7).

Figure 7. TBM entering the Reception Shaft

4.5 CASING NO. 2 – OXNARD INDUSTRIAL DRAIN CROSSING

This casing was designed as 320 LF of 0.75-inch wall, 66-inch diameter welded steel casing at a depth of 20 feet. The main feature of this drive was the crossing of the 100-foot wide concrete-lined Oxnard Industrial Drain (OID) at the end of the drive, with a clearance of only 4 feet. The launch shaft was constructed with slide rail shoring with deep wells and the receiving shaft was comprised of conventional shoring boxes, steel sheet and deep wells. No dewatering of the tunnel alignment was performed due to the fact that the OID is tidally influenced and generally full of water. In addition to crossing underneath the OID, the tunnel also crossed beneath railroad tracks, a 36-inch clay pipe sanitary sewer and several asbestos concrete water lines.

From the onset, groundwater was a significant issue on this drive. Almost immediately, PB voiced concerns about the amount of groundwater that was being encountered. The soil would liquefy when the TBM advanced and even though the machine operator was rotating the cutter wheel with the doors closed to control the inflow of material the risk of over excavation remained high.

The tunneling occurred with minor subsidence occurring in very limited areas, but otherwise without incident, passing underneath two water lines and a single railroad track in the first 100 feet. The tunneling crew was able to continue advancing the TBM and deal with the saturated soil conditions as they advanced. That was until a Friday morning in December as the TBM began to advance beneath the OID at a distance of about 200 feet from the shaft. At that point the TBM operator inside the machine came out of the tunnel and notified the inspector that the TBM had struck an obstruction near the 12 o'clock position of the machine and that he believed they could no longer advance without doing something about the obstruction.

The obstruction that the TBM had come in contact with appeared to be part of the concrete for the drain. Whether or not it was actually part of the drain could never be definitively confirmed, but the concrete appeared to be part of a footing for the first of three stem walls that supported the roadway above the drain (Figure 8). The obstruction was difficult to investigate further given the safety risks posed by having an active drainage way directly overhead, the unstable soil conditions, and the amount of water that was flowing into the TBM. Tunneling operations were stopped until the situation could be assessed and a new approach developed.

In consultation with Staheli Trenchless Consultants (the trenchless inspector), WGCI, PB, and the design engineer, Calleguas decided to suspend the tunneling and have the approximately 200 linear feet of casing grouted in place while a plan was developed for how to complete the tunnel drive. Ultimately, it was decided that a new shaft would be installed as close as possible to the edge of the OID and that an attempt would be made to pull the TBM out of the ground and into the shaft. Once the TBM was rescued, the shaft would be deepened an additional 10 feet and the TBM crossing would be completed.

Figure 8. Concrete Obstruction beneath the OID and a view of the wall supporting the roadway above the drain

It took nearly six months to complete the new tunnel design, obtain permission from permitting agencies and procure the materials to complete the new, deeper tunnel. Due to the proximity of the new intermediate pit in relation to a very fragile 36-inch VCP sewer line and the OID, it was determined that a sheet pile system would be the best approach to install the new pit. Using the sheet pile system instead of slide rail shoring reduced vibration and therefore lowered the risk of damaging the nearby facilities. The intermediate pit location and nearby facilities are shown in Figure 9. As previously mentioned, groundwater was a major concern and a number of dewatering wells were installed and were online for over a year in order to facilitate installation of the new intermediate pit.

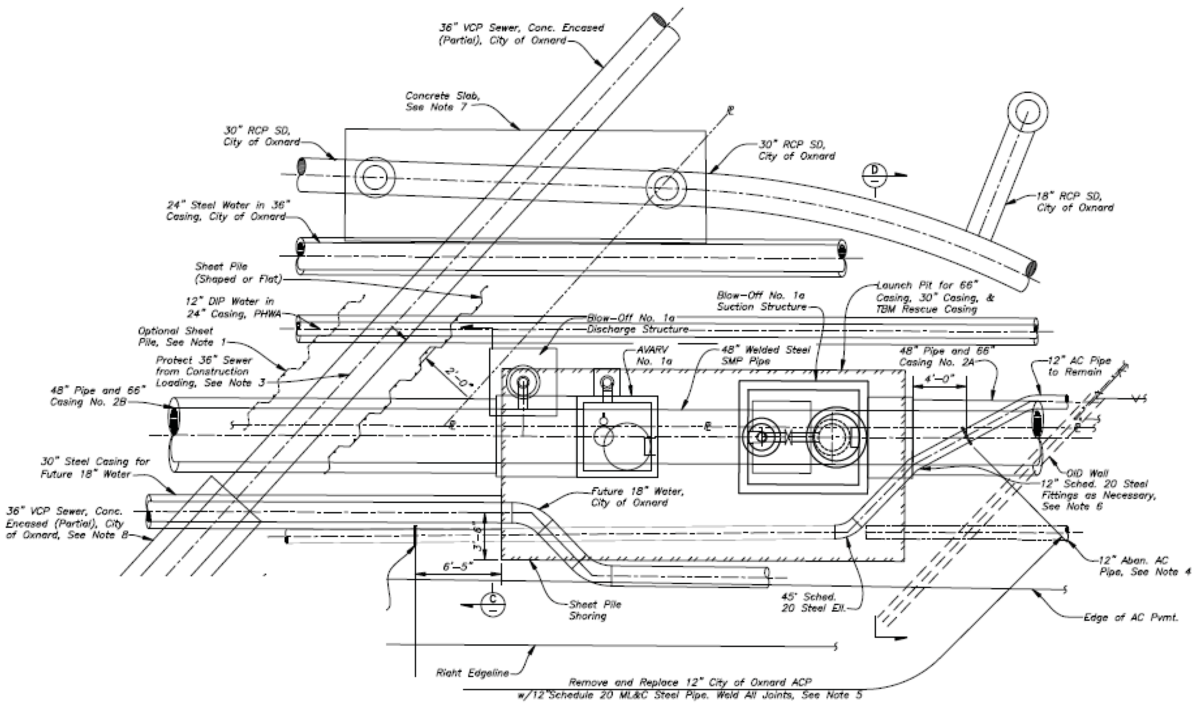

Figure 9. New facilities due to TBM getting stuck under OID

Once the rescue shaft was completed PB mobilized to the site, bringing with them an 800-ton jacking frame and a 20-foot long section of 84-inch casing. They then used the jacking frame to advance the 84-inch casing over the TBM, thereby fully engulfing the TBM. By doing this, PB was able to ensure that the concrete-lined channel above the tunnel would be fully supported before the TBM was pulled back in to the rescue shaft. After the 84-inch casing was advanced approximately 12 inches beyond the face of the TBM, PB repositioned their jacking frame so that the frame could be operated in reverse and used to pull the TBM in to the rescue shaft. The frame was disassembled and reinstalled in the shaft, after which 1-1/2-inch Dwidag bars were used to connect the back ring of the TBM to the front of the jacking frame. PB then pulled the TBM back in the shaft approximately 4 feet before pumping grout between the 84-inch casing and the 68-inch OD TBM in order to fill the void in front of the TBM and support the face of the excavation. This proved to be difficult since groundwater continued to flow in to the casing during the entire procedure.

On the following day PB was concerned about the grout curing to the point that would make the TBM difficult to pull out, so they elected to attempt to finish pulling the TBM all the way back in to the rescue shaft. PB was able to do this with relative ease, only needing about 200 tons of thrust to pull the TBM into the shaft (Figure 10).

Once the TBM had been pulled back and lifted out of the shaft and the jacking frame removed, the remainder of the casing was filled with a flowable grout.

Figure 10. TBM Pulled into the Shaft with an 800-ton jacking frame operating in reverse

Once the TBM rescue was completed the prime contractor (WCGI) commenced with deepening the rescue shaft an additional 10 feet so that the risk of hitting another bridge pier would be more or less eliminated. Once the shaft was deepened, PB would use the rescue shaft as a launch shaft so that the original tunnel drive could be completed beneath the OID.

The tunneling of the 115 feet beneath the OID started off with some difficulty. PB had elected on their own to advance their 4-inch pilot tubes just above the proposed new top of casing before commencing with the open shield pipe jacking. This was performed on a Friday without incident until PB returned to the site the following Monday to discover a large amount of groundwater flowing into the shaft from the 4-inch hole once they removed the cap from the hole. The effect of this discovery was that PB had to spend several days making attempts to control the groundwater before eventually installing a shaft seal to launch the TBM through.

The TBM was finally launched through the seal and almost immediately encountered a dense dark gray clay layer that was absent of free-flowing water. The tunneling proceeded without incident all the way to the reception shaft located just east of the OID. Unfortunately the outside of the shaft was not being effectively dewatered and PB had to spend some additional time cutting holes in the shaft wall and recovering the TBM than they would have had the reception shaft been adequately dewatered. The day after the tunneling was completed, the TBM was lifted out of the shaft and the PB crew grouted the annular space outside the casing (Figure 11). The product pipe was then installed and sand was blown in between the casing and the 48-inch product pipe.

Figure 11. TBM being hoisted out of the Reception Shaft

5. CONCLUSION

The seven tunnel crossings on the already complicated construction of the Salinity Management Pipeline, Phase 1E project resulted in challenges and obstacles that were unforeseen at the beginning of construction. Groundwater, concrete obstructions, and difficult soil conditions made the tunnels on this project extremely challenging, but with the efforts of the Owner, their Consultants, the other impacted agencies, and the Contractor, the project was successfully completed in the spring of 2012.

6. REFERENCES

Calleguas Municipal Water District, (2008) - Construction Drawings, Salinity Management Pipeline, Phase 1e, Specification Number 486

Fugro West, Inc., (2008) - Geotechnical Investigation Report, Proposed Boring and Jacking for Salinity Management Pipeline Phase 1e. Calleguas Municipal Water District, Oxnard and Port Hueneme, CA