North American Society for Trenchless Technology (NASTT)
No-Dig Show 2010

Chicago, Illinois
May 2-7, 2010

Paper A-1-04

OCEAN OUTFALL PRESENTS CHALLENGES TO HDD CONSTRUCTION

Laura Wetter, G.I.T.[1], Matt Pease, P.E.[1], Kristine McCaffrey, P.E.[2], and Donald R. Kendall, Ph.D., P.E.[2]

[1] Staheli Trenchless Consultants, Bothell, WA
[2] Calleguas Municipal Water District, Thousand Oaks, CA

ABSTRACT: The Calleguas Municipal Water District has completed the horizontal directionally drilled (HDD) segment of construction of an ocean outfall located in Port Hueneme, California. The new outfall is the termination of a salinity management system developed by the Calleguas Creek Watershed Management Plan, and connects onshore pipeline facilities at Port Hueneme to a diffuser located 3,900 feet offshore. The outfall consists of approximately 2,300 feet of 36-inch high density polyethylene (HDPE) installed via HDD connecting to 2,700 feet of 30-inch steel seafloor pipe. The HDD segment exited about 1,300 feet offshore, and involved reaming, pipe layout and pullback using the assistance of divers, barges and tug boats. Highlights of the project included a 60-foot elevation difference between entry and exit points and an exit location below 30 feet of water.

This paper details events and responses as they occurred during HDD construction. Particular challenges were expected during the sequencing and execution of drilling near the exit location, especially with regards to drilling fluid escape and borehole stability. The solutions to these challenges will be explored and discussed for future HDD and ocean outfall work.

1. INTRODUCTION

The Hueneme Outfall Project is a key element of the Calleguas Regional Salinity Management Pipeline currently being constructed by the Calleguas Municipal Water District (CMWD). 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 the outfall 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, CMWD will improve water quality in an area where drought and regulatory restrictions are increasing threats to the agricultural, municipal, and industrial water supply.

The initial project goal was to rehabilitate the existing Port Hueneme sewage outfall which had been abandoned since the mid 1970s. However, concerns about capacity and structural integrity of the 30-inch pipeline led to the selection of a new outfall as the preferred alternative.

2. PROJECT CONDITIONS

The City of Port Hueneme is located in Ventura County on the southern coast of California (Figure 1). The project area is located on 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, CA

The outfall is made up of two segments: approximately 2,300 feet of 36-inch high density polyethylene (HDPE) installed via horizontal directional drilling, and approximately 2,700 feet of 30-inch steel pipe laid out on the seafloor. The design bore alignment for the HDD segment is shown in Figure 2.

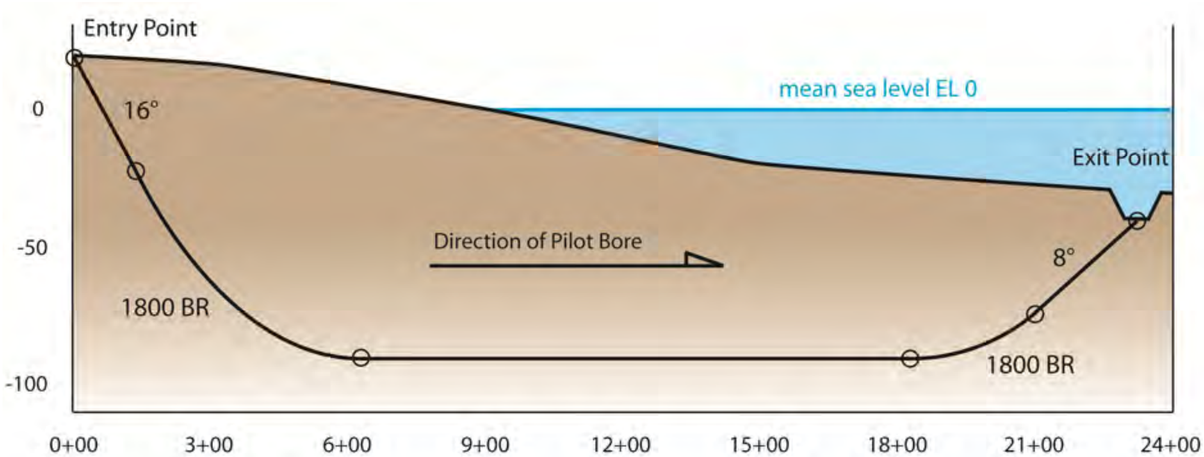

Figure 2. Design bore alignment for the HDD portion of the outfall

The bore begins in the parking lot of the Port Hueneme Beach Park, with a straight, tangent section inclined at 16 degrees for the first 140 linear feet. Curving downward with a bend radius of 1800 feet, the bore reaches a maximum depth of 91 feet below sea level (bsl). After completing a straight section of approximately 1200 feet, the bore bends up to a tangent section of 8 degrees, exiting at 40 feet bsl. Ground elevation at the exit location is approximately 30 feet bsl, requiring excavation of an exit pit via sea floor dredging.

3. PREPARATION FOR DRILLING

The contract was awarded to Manson Construction Company, with The HDD Company as the HDD sub-contractor. Construction began in September of 2009 with the preparation of the entry site. Due to the project location within a highly developed residential area, stringent noise restrictions were imposed on the project, including the limitation of working hours and the installation of sound attenuation barriers over 20 feet high surrounding the construction work area. Additionally, a sound monitor was required by CMWD to monitor noise generated during drilling activities.

HDD work began in early October with the installation of approximately 90 feet of 54-inch steel conductor casing along the 16 degree tangent section of the bore alignment. The design had not originally required conductor casing, leaving the use of casing to the Contractor's discretion. However, the Contractor chose to utilize a casing due to his concern over gravel lenses present in the first 120 feet of the alignment. Additionally, review of the design suggested that use of conductor casing at the entry could help alleviate the large pressure differential resulting from the elevation difference of 56 feet between the entry and exit locations.

Figure 3. 18-inch centralizer casing installed in larger 54-inch casing

After installation and clean out of the 54-inch conductor casing, an 18-inch steel casing with centralizer pads welded on was inserted the entire length of the 54-inch casing plus an additional 17 feet in preparation for the pilot bore (Figure 3). TruTracker coil was laid out along the onshore portion of the alignment in a shallow hand dug trench above the centerline of the bore. A second TruTracker coil was placed on the ocean floor from the exit point extending 500 feet toward the shore, held in place by concrete ecology blocks set 50 feet apart.

4. DRILLING THE PILOT BORE

The pilot bore began on October 10th, using a $9^{7/8}$-inch tri-cone spud bit (Figure 4). A tensor steering tool located behind the bent sub in the borehole assembly was used to track the progress of the pilot hole. Changes in azimuth and inclination were monitored as drilling progressed, allowing the drill rig operator to make directional changes as needed. After the third drill pipe, groundwater was observed coming up out of the 54-inch casing along with the drilling mud, which had slowed noticeably in circulation. No signs of hydrofracture appeared however, and drilling progressed smoothly after an increase in mud speed. Drilling continued until drill pipe (DP) #32 with consistent slurry returns.

Figure 4. Tri-cone spud bit

Slurry circulation began to slow significantly at the start of DP #33. At this point the drill bit was at approximate STA 11+00, within the straight horizontal section of the alignment (Figure 2). After tripping three pipes and drilling with little to no returns, the Contractor decided to run a second drill pipe (a "washover" pipe) in along the pilot bore pipe inside the 18-inch centralizer casing. The theory was that a blockage at the end of the casing was preventing the circulation. After inserting the washover pipe down bore approximately 150 feet and retracting, re-drilling began with DP #29. Slurry returns continued to be intermittent, and while the beach was closely monitored for hydrofracture, no signs were found. After drilling up to DP #34 – at which point mud circulation had completely stopped – the Contractor elected to trip out to DP #18 and re-drill. Circulation was re-established and drilling continued smoothly until DP #33 at which time returns slowed noticeably. The Contractor continued drilling with intermittent returns all the way through DP #68.

Upon reaching DP #68 the drill rig operator began to have problems with upward steering while continuing to see no mud circulation. Steering was problematic until the end of DP #75, at which point the drill bit was approximately 100 horizontal feet beyond and 12 vertical feet below the designed exit location. Exiting beyond the design location could have presented permitting difficulties for the Owner, but the driving force in deciding to redrill was that the Contractor did not have enough drill string on site to ream and perform pullback through a borehole more than 100 feet longer than anticipated. The Contractor decided to trip back to DP #63 (approximate STA 20+50) and re-drill the pilot bore to the left of the first bore in an attempt to achieve better steering capabilities. This plan was successful, and the pilot bore was completed on October 14th, 12 feet to the left (south) of the design exit.

5. FIRST REAMING PASS AND BOREHOLE EXIT

Figure 5. 27-inch fly cutter

The first reaming pass began on October 16th with a 27-inch fly cutter. Prior to starting, the entire drill string was tripped back to the entry point and the borehole assembly and 18-inch centralizer casing removed from the 54-inch casing. The face of the fly cutter is shown in Figure 5. Forward reaming progressed with consistent slurry returns which grew in size and cohesion as distance increased. At this point in time the borehole had not yet exited onto the ocean floor in an attempt to keep slurry returns and cuttings flowing back to the entry point where they could be cleaned and re-circulated instead of discharging into the ocean. Forward reaming was intended to promote this process and keep all mud processing and containment facilities onshore.

The first reaming pass was stopped after DP #60 (approximate STA 18+60) as the Contractor did not want to inadvertently ream the abandoned section of borehole which began at STA 20+50. After tripping back to the entry point, the original borehole assembly and drill bit was placed on the rig to re-drill the section of pilot bore out to the ocean floor and into the exit pit which had just been excavated via dredging. Drilling progressed without incident and a derrick barge was moved into position offshore to secure the borehole assembly upon the exit of the drill string (Figure 6). Sixty feet away from the exit the driller began pumping water to clear out the drill string of mud. Once clean, the driller pumped compressed air through the drill string in order to force air bubbles out the end which could be seen by the divers waiting on the barge.

Figure 6. Derrick barge and supporting tugboat from shore

The drill string exited into the dredged trench and was maneuvered by divers up out of the water and onto a pontoon boat anchored alongside the barge. The pontoon was used to support the midsection of the span as the drill string was pulled toward the barge. The driller began advancing the drill string a little bit at a time while the derrick crane slowly pulled up on the drill bit and the winch on the deck pulled the pipe toward the barge (Figure 7). Initially the drill bit was exiting the water at about a 30 degree angle, which was too steep to secure to the deck without damage to the pipe. The crew was able to reposition the rigging supporting the drill string farther back down the pipe to improve the exit angle, and managed to get the borehole assembly secured to the deck of the barge where it was removed from the drill string.

Figure 7. Drill string suspended between derrick barge and pontoon

6. REAMING

A 45-inch fly cutter with 2.5-inch hydraulically expanding cutting teeth (shown in Figure 8) was used for the second reaming pass which began on October 27th. With teeth fully extended the 50-inch reamer (size with teeth expanded) was installed at the drill rig and forward reamed using the barge winch to pull on the drill string while the rig applied torque to rotate the reamer. However, the expanded teeth were damaged upon reaching the end of the 54-inch conductor casing. While pumping mud at low pressure and carefully monitoring for signs of settlement, the Contractor began rotating the reamer in an attempt to mill out the end of the 54-inch casing. The drill string had some problems with rotation but managed to get past the casing. No signs of settlement were observed.

Figure 8. 45-inch reamer with expanding teeth

After 300 feet of drill string had been advanced, reaming was stopped to break a section of drill pipe off on the barge and reinstall the swivel and cable. Reaming continued smoothly until DP #15 when viscosity of the mud began to noticeably decrease and spoils coming off the mud tank separators turned from larger cohesive pieces to clays and ultrafine-grained material. Reaming continued, but the mud was not viscous enough to hold suspended spoils and had too much fine content to separate out at the tank. New mud was mixed and reaming continued slowly, with new mud being constantly made to keep the velocity up. Additionally, the derrick barge was having difficulties developing enough tension on the drill string and the rotary torque was slowly increasing. By DP #37 the rotary torque had increased beyond the capacity of the drill rig and the Contractor had decided to trip the reamer back to the entry point.

After removal of the 50-inch reamer, the Contractor advanced the drill pipe on to the deck of the derrick barge to serve as a tail string for a new 17-inch back reamer. The plan was to back ream the bore approximately 500 feet from the exit pit towards the shore, up until the 27-inch diameter hole generated by the first reaming pass. This pass was quickly and successfully performed and the 17-inch reamer tripped back to the derrick barge. The 50-inch reamer was reinstated back on the drill rig with modifications including four additional front jets and some new bullet bits to the barrel portion of the reamer in hopes of making a second attempt at forward reaming. This time the 50-inch reamer made it all the way to DP #49 before the rig maxed out its torque and was forced to trip back. The reaming pass experienced the same problems as the earlier attempt at the 50-inch diameter, with the addition of multiple breaks of the drill string between the pontoon and derrick barge.

Figure 9. 48-inch reaming assembly exiting to the derrick barge

After the multiple failed attempts at the larger diameter, the Contractor elected to try forward reaming a 32-inch fly cutter, this time successfully completing the ream to the exit pit with adequate slurry returns and low rotary torque throughout. After removal onto the deck of the derrick barge, the 32-inch reamer was broken off the drill string and replaced with a new reaming assembly consisting of a 48-inch fly cutter, 29-inch centralizer and 36-inch barrel reamer. The back ream began at the exit pit with DP #75 and advanced all the way to DP #31 with no slurry returns observed at the entry. At this point reaming was considered complete and the reamer was tripped back to the barge (Figure 9).

7. SWAB AND PIPE PULLBACK

Swabbing began on November 14th from the entry point. Although slight delays were experienced pushing the 43-inch barrel reamer in and out of the 54-inch conductor casing, three swab passes were completed in two days. Mud was pumped at a moderate pressure throughout but little to no returns were observed at the entry point.

Figure 10. HDPE pipe heading out to sea from Pt. Mugu

Concurrent with the beach site work, the 2,300-foot HDPE pipe string had been laid out, fused and tested at the Navy Base Ventura County at Pt. Mugu a few miles to the south of Port Hueneme. Once preparations had been completed at the beach site, a pipe pulling head was bolted onto the offshore end of the HDPE pipe and towed out to the derrick barge (Figure 10). Upon the pipe reaching the barge, a swivel was attached to the end of the drill string behind the swab barrel and the pull head attached to the swivel. There was concern about the lack of water within the pipe but as the derrick barge lowered the pipe down to the sea floor the pipe went down without difficulty. As pullback started however, the pipe began to rise up in front of the exit hole due to buoyancy. Meanwhile, pull loads were approaching 75% of the capacity of the pipe. The Contractor began pumping water into the offshore end of the pipe and pushing down with the 24 ton dredge bucket to sink the pipe in front of the exit pit. Pullback pressure began to drop substantially and was at 25% of capacity by DP #55. Intermittent returns were noted at the entry point starting around DP #44.

Pullback proceeded smoothly up until DP #4 at the end of the 54-inch conductor casing. The drill string was pushed forward and backward in an attempt to work the swab barrel through the end of the casing but was met without success for over two hours. Pull forces were so high that the supports between the rig and the casing sheared off and the rig moved several feet toward the entry pit. The Contractor tried inserting 100 feet of 18-inch centralizer casing in an attempt to centralize the barrel within the 54-inch casing, but with no effect. Pullback was halted on November 18th with the pull head within 90 feet of the entry pit.

Figure 11. Excavation to expose pull head

After considerable discussion with the Owner, the Contractor exposed the pull head and swivel inside a slide rail shoring excavation at the end of the conductor casing (Figure 11). However, once the pull head was exposed it was discovered that the pipe was too far out of alignment to be connected within the excavation at the end of the conductor casing. The last 90 feet of 36-inch diameter HDPE product pipe was eventually installed via open cut in February of 2010.

8. LESSONS LEARNED

Several valuable lessons were learned throughout the HDD portion of this project. Firstly, the different strategies developed for dealing with an exit pit under more than 30 feet of water will be useful for future outfall construction. Although the Contractor had planned to forward ream in an attempt to limit mud discharge into the ocean, the tension provided by the derrick barge was not sufficient and the drill rig could not achieve the necessary rotary torque to complete the large diameter reaming passes. Back reaming at smaller diameters was a successful solution, combined with careful monitoring of the exit pit for excess mud discharge and of the beach for any signs of inadvertent returns.

Secondly, the effect on the pullback forces of pulling an empty pipe will be of interest to HDD designers. It was assumed that seawater would fill the pipe prior to pullback with no outside help, but filling the pipe actually required considerable pumping and the assistance of the dredge bucket on the barge. The significant increase in pullback forces as the pull was attempted with an empty pipe indicates the importance of accounting for water weight during both design and construction.

Thirdly, problems with low mud viscosity through the later sections of the drill were likely the result of sea water interaction with the bentonite clay particles of the drilling fluid. It is important for all HDD work that the proper fluid additives are on hand to counteract any negative reactions with the anticipated geologic and/or hydrogeologic conditions.

Lastly, as with any construction job, unexpected issues arose at multiple occasions. The close working relationship between the Contractor and Owner allowed for the speedy resolution to problems while maintaining a safe and efficient work environment.

9. REFERENCES

Calleguas Municipal Water District. (2008). Construction Drawings, Hueneme Outfall Replacement Project, Specification Number 484.

Fugro West, Inc. (2006). Geosciences Desktop Study, Calleguas Municipal Water District, Hueneme Outfall Replacement Project, Port Hueneme Area, California.

Fugro West, Inc. (2007). Geotechnical Study, Calleguas Municipal Water District, Hueneme Outfall Replacement Project, Port Hueneme Area, California.

Fugro West, Inc. (2007). Site Characterization Study, Calleguas Municipal Water District, Hueneme Outfall Replacement Project, Port Hueneme Area, California.

Fugro West, Inc. (2007). Supplemental Geosciences Study, Calleguas Municipal Water District, Hueneme Outfall Replacement Project, Port Hueneme Area, California.