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One Project, Six HDDs: The Nacimiento Water Project

John R. Hollenbeck, P.E., Thomas Trott, P.E., Chuck Parker, P.E., and Craig Camp

ABSTRACT

In 2004, the San Luis Obispo County Flood Control and Water Conservation District (District), located in California, adopted the Final Environmental Impact Report for a 45-mile long raw-water conveyance to withdraw water from Lake Nacimiento, for delivery to several Participants (customers) along its route to the City of San Luis Obispo.

Horizontal directional drilling (HDD) under environmentally sensitive streams was selected as the economical and most expeditious means for obtaining environmental permits. Six stream crossings were designed, and construction began in 2008. The six crossings have diameters of 30, 30, 24, 24, 18, and 8 inches, and the respective length of each is 1,800, 1,300, 3,300, 1,900, 1,050, and 988 feet. The carrier pipe is welded steel having wall thicknesses of 0.50 inches for pipes larger than 18 inches, and 0.25 inches for pipes 18 inches and smaller.

Five of the crossings will be within a geologic unit known as the Paso Robles Formation, a weakly indurated alluvial conglomerate consisting of dense mixtures of pebble gravel, sand, silt, and clay. The other crossing is through two geologic units: the Monterey Formation, consisting of moderately-lithified deep marine rocks of late to middle Miocene age, and the Santa Margarita Formation, consisting of semi-lithified, semi-friable massive white sandstone of late Miocene age that was deposited in shallow marine environments.

This paper describes the pre-qualification process used to identify eligible HDD subcontractors, the project's environmental permit requirements, the physical designs unique to the project's construction, and construction performance case history for those HDDs completed prior to final submittal of this paper.

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PROJECT BACKGROUND

The San Luis Obispo County Flood Control and Water Conservation District (District) received annual rights to 17,500 acre-feet of water from the Lake Nacimiento impoundment in October 1959, when it executed an agreement with the Nacimiento dam and reservoir owner, Monterey County Flood Control and Water Conservation District, now known as Monterey County Water Resources Agency (Monterey Agency). The District conducted several feasibility studies over the next four decades, assessing the cost and benefit of building the infrastructure to distribute the water to various areas within the County. The studies indicated groundwater pumping as the most feasible water supply. In the 1990's, demands on the County's groundwater basins were nearing their safe yield; thus, an alternative water source was needed to meet demands and protect the basins. The next feasible water source identified was the Nacimiento Water Project (Project).

The District's water entitlement is divided into two parts. The lakeside usage of the water equates to 1,750 acre-feet annually, and that water resides in the lake for users around the lake. The

remaining volume, 15,750 acre-feet per year, will be conveyed by the Project via pumps and pipeline.

Overall, Lake Nacimiento holds 377,900 acre-feet when at normal maximum pool elevation of 803.07 feet (NAVD88 Datum used herein).

THE "FINAL ENVIRONMENTAL IMPACT REPORT RECOMMENDED" PROJECT

The District's Board of Supervisors adopted the recommendations contained in the Final Environmental Impact Report on January 6, 2004, and directed the County's Public Works Staff to implement the recommended project consisting of a multi-port lake intake, three pump stations (one at the lake, and two booster stations), three water storage tanks, and 45 miles of pipeline. The initial phase of the Project will serve the communities of Paso Robles, Templeton, Atascadero, Cayucos, and San Luis Obispo. These communities are contracted with the District to receive 9,655 acre-feet per year. The remaining 6,095 acre-feet per year is the reserve water that is available to the existing participants, or can be contracted by other communities or water agencies anywhere within the boundaries

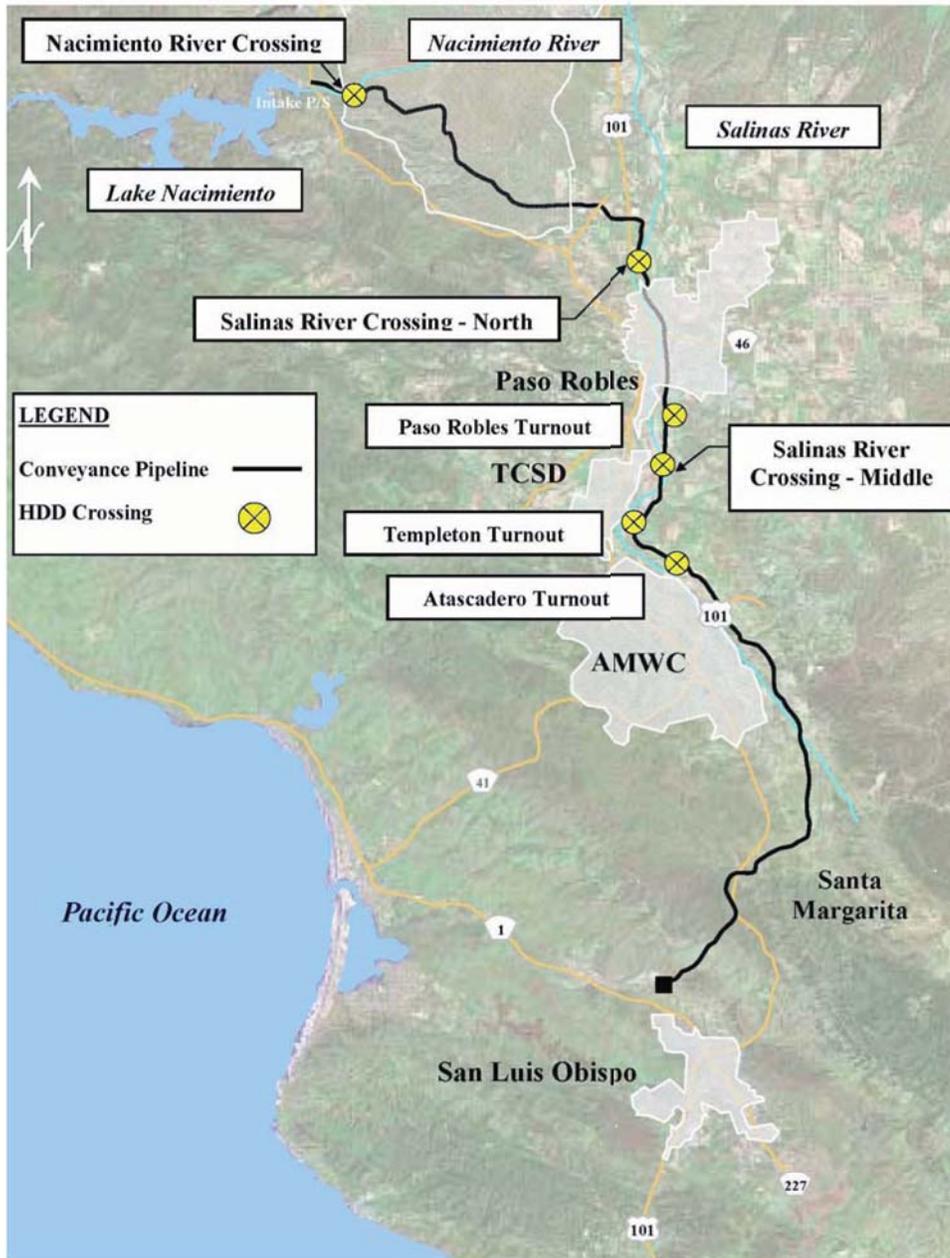


Figure 1. Nacimiento Water Project HDD Crossing Locations.

of the County.

CONCEPTUAL DESIGN

The Project's 45-mile length traverses challenging obstacles where trenchless construction needed to be considered, including: rivers, streams, railroads, roads, and highways. The conceptual design completed in 2001 (Carollo, 2001) identified two river crossings utilizing horizontal directional drilling (HDD). Other trenchless methods were judged more effective for incidental railroad, streams, and road crossings.

HDD was judged to be both economically and environmentally superior during conceptual design for the two crossings summarized in Table 1 and depicted in Figure 1. The most important reason for selecting HDD was the elimination of potential environmental damage caused by open-cutting across the Nacimiento and Salinas Rivers. Open-cut crossings were judged technically feasible, but environmentally challenging. The District judged such environmental risk as cost prohibitive and, thus, HDD was judged the best trenchless method given the geometry of these two crossings. The Project's turnouts that cross the Salinas

River Crossing	Length (feet)
Nacimiento River	800
Salinas River – North	1,100

Table 1. HDD River Crossing Descriptions – Conceptual Design.

River were not defined during conceptual design, although it was determined that river crossings, where required and viable, would be constructed using HDD.

PRELIMINARY DESIGN

Engineering of the Project began with the development of the Preliminary Design Report (PDR) (Black & Veatch, 2006) by the District's design team. The PDR described the engineering criteria for all aspects of the Project, including all trenchless crossings. The trenchless portion discussed the HDD method and the unique features of HDD that could affect pipeline design, alignment, soils, pipe materials, environment, cost, and schedule. HDD features included both positive features, such as improved hydraulic performance when compared to a pipe jacked crossing, and negative features, such as long set back distances required to achieve the crossing depth.

All of the crossings were arranged using preliminary pipe sizes and topography within the proposed alignment. River scour depth was assumed to be 20 feet under the active river channel for the basis of design. Based upon this information, a drill path was laid out and the alignment was adjusted to accommodate the proposed drill path, as permitted by the allowable pipe materials and size. These alignments provided the basis for determining the depth and locations

for the geotechnical boreholes, which produced data that was developed and presented in the Geotechnical Data Report for pipelines (Geomatrix, 2007a) and the Geotechnical Interpretive Report for pipelines (Geomatrix, 2007b). They also helped determine where additional land survey data was required for final design. Once the preliminary pipeline designs were completed, the hydraulic design team reviewed pipe dimensions to ensure the hydraulic performance requirements had been met.

The PDR also presented suggested modifications to pipeline alignment. This alignment study affected the quantity of the HDD's needed for the Project. Near the middle of the alignment that parallels the Salinas River, the river has a tight meander and the pipeline was originally planned to parallel the outside of the river's curve. The design team proposed a single HDD crossing of the river through the inner part of the meander (the pipe would cross under the river twice). The crossing was estimated to be 24-inch pipe diameter with a final drill path of approximately 3,000 feet. This crossing was accepted by the District and identified as the Middle Salinas River (MSR) Crossing. This HDD alternative provided advantages by straightening the pipeline alignment and avoiding the length around the meander. Additionally, the extremely challenging topography along the outer-meander route was not suitable for open cut trenching and would require trenchless methods, such as bore and jack or microtunneling. The straighter, yet long HDD became an

obvious choice to pursue.

FINAL DESIGN

The Final Design began knowing there were three known river crossings and three undetermined river crossings to deliver the water to the Participants. The latter three crossings are the Project's turnouts. The final number of HDD crossings designed and constructed is six: one on Nacimiento River and five on Salinas River (see Figure 1 for location). The six river crossings are summarized in Table 2.

The carrier pipe was specified to be welded steel in accordance with American Water Works Association (AWWA) specification C200 with a Powercrete™ PW (or equivalent) lining and a Powercrete™ R60 (or equivalent) coating, each having a minimum 80 mil thickness applied over three coats. See the discussion on Construction (below) for contractor-proposed alternatives.

The final design anticipates the five Salinas River crossings to be in a geological formation known as the Paso Robles Formation. The Paso Robles Formation is a weakly indurated alluvial conglomerate consisting of dense mixtures of pebble gravel, sand, silt, and clay. The designers expected that each Salinas River crossing would likely encounter some eroded and re-deposited soils originating as Paso Robles Formation and fill created by human activities such as, infrastructure development and farming. The river

River Crossing Name	Diameter (inches)	Steel Pipe Wall Thickness (inches)	Max Depth (feet) ⁽¹⁾	Drill Path Length (feet) ⁽²⁾	Curve Data		
					Length (feet)	Radius (feet)	Delta (Degrees)
Nacimiento River	30	0.50	102	1,800	1,373	3,576	22.0
North Salinas River	30	0.50	42	1,300	1,007	2801	20.7
Middle Salinas River	24	0.50	167	3,300	2,410	6,276	22.0
Salinas River, Paso Robles Turnout	24	0.50	94	1,900	1,513	4,404	20.0
Salinas River, Templeton Turnout,	8	0.25	45	1,050	463	1,234	22.0
Salinas River, Atascadero Turnout,	18	0.25	52	988	669	1,915	20.0

(1) Maximum depth is measured below existing ground surface to top of pipe.

(2) Drill Path Length includes straight and curved lengths

Table 2. Final HDD Design Description.

scour assessment indicated minimum depths in the range of 30 to 40 feet on the Salinas River, and 20 to 30 feet on the Nacimiento River (Geomatrix 2007b).

The final design also included a requirement to install fiber optic conduits with the Project pipeline for installation of fiber optic communication associated with the Project's SCADA system. The fiber optic conduit design specified that four 1.5-inch diameter galvanized rigid steel conduits be pulled simultaneously with the carrier pipe. The District's goal was that two of the four conduits survive the pullback. The specifications required the general contractor to pull a mandrel through the conduits to first assure they were open before installing the fiber in one conduit and a pull rope in another spare conduit. The conduits were specified to be free-floating with the pull-back, with longitudinal joining by butt welding; no mechanical fittings were allowed.

The details of the final design required the

District to obtain the California Department of Fish and Game Streambed Alteration permits, the US Army Corps of Engineers Section 404 Nationwide Permit, and the California's Division of Occupational Safety and Health's (CalOSHA) tunnel classification. The Section 404 permit required the entire HDD process be completed within the summer low flow season (June 15 through October 15) and called for complete stoppage if any drilling fluid entered any waterway. The CalOSHA permit required for all tunnels with an excavated diameter greater than 30 inches, included requirements for hydrocarbon monitoring to account for the oil wells that exist in the local geologic formations.

Final design specifications required extensive submittals to ensure the contractor understood that any spill entering a waterway would stop the project and could lead to substantial penalties; thus, the specifications required the contractor to actively monitor for

leaks and spills. Some of the submittals required locating and maintaining slurry clean-up resources available throughout construction, and conducting meetings to discuss and approve changes to the HDD operating parameters before resumption of drilling. All surface spills had to be contained and cleaned immediately upon discovery and before the end of that shift. The specifications also required the contractor to develop and submit contingency plans for other potential events or construction related issues that may affect the Project's completion or quality. Examples of potential events included the loss of steering information, the excavation tooling becoming stuck or lost in the hole, or the loss of drilling fluid in a subsurface formation. The contractor was also required to monitor and record slurry fluid pressure, thrust or pullback forces, torque, location and time. These documents were submitted to the construction manager during construction.

The specifications required minimum HDD rig sizes based upon each crossing's specific characteristics including pipe, drill path and soils. Table 3 presents a summary of the torque requirements for

River Crossing Name	Torque (foot-pounds)
Nacimiento River	45,000
North Salinas River	45,000
Middle Salinas River	36,000
Salinas River Paso Robles Turnout	36,000
Salinas River Templeton Turnout	10,000
Salinas River Atascadero Turnout	22,000

Table 3. Specified HDD Rig Size Requirements

reaming. The HDD rig was also required to have the capacity to pull 1.2 times the static weight of the carrier pipe and the fiber optic conduits.

PREQUALIFICATIONS OF HDD CONTRACTORS AND BIDDING

The District conducted a prequalification process for the HDD contractors who would become subcontractors for the construction. The District highly regards the protection of the environmental setting of these river crossings, especially since they are habitat for the Steelhead Trout, a listed endangered species. Prequalification of the HDD specialty contractors was judged an effective management tool to assure success of this complicated work while also being assured that the successful HDD contractor would not be performing his first trenchless crossing on this Project. The prequalification statement, uniform system of rating, and the appeal process were derived from the templates developed by the California Department of Industrial Relations. Six HDD contractors were pre-qualified several months prior to bidding the Project. These six pre-qualified specialty subcontractors were listed in the bidding documents as the only firms which could perform the HDD work.

The Project's 45-mile pipeline work was bid in three segments: North, Central and South. The North and Central contracts contain the

Contract	No. of Bidders	Engineer's Opinion of Cost	Bid Range		Successful Bidder		Total HDD Bid Items
			Low	High	Firm	Bid	
Central	9	\$28.6M	\$22.7M	\$29.3M	Whitaker	\$22.7M	\$7.0M
North	9	\$49.8M	\$38.4M	\$51.3M	Teichert	\$38.4M	\$3.8M

**Table 4.
Project Bidding Results of Pipeline Construction Contracts with HDD Work**

six HDD crossings: the Nacimiento River and the Salinas River North are in the North contract, while the remaining four are in the Central Contract. The work for the Central contract was completed in 2008. The North contract HDD work will be completed in 2009.

The District judged the bidding of these two pipeline construction contracts to be very successful. Table 4 presents a summary of the bidding, along with the bid tabulation for the HDD work. Bidding occurred in July 2007.

CONSTRUCTION

The HDD work performed by the Central contract was completed by the time this paper was authored; thus, most discussion will center on that work effort.

The general contractor submitted a value engineering proposal (value engineering incentives are an element of the construction documents) to modify the carrier pipe material, and both the coating and lining systems. During the Spring of 2008, when steel pipe was being ordered for the HDD work, drastic pipe cost increases were seen on a daily basis. A search of the western states found

that AWWA C200 pipe with “Powercrete” epoxy coating was challenging to locate and expensive. The contractor prepared a Value Engineering Cost Proposal for all HDD pipes based on using steel pipe meeting API 5L standards, which was in stock in a Louisiana yard, and coating it with fusion bonded epoxy. The pipe interior coating was 12 to 14 mils of DuPont NAP-Guard Mark X 7-2500. The pipe exterior corrosion coating was 12 to 14 mils of 3M Scotchkote 6233, followed by an abrasion coating of 30 mils of 3M Scotchkote 6352. The proposal was reviewed by the designer and the construction management team, and judged acceptable by the District. The change resulted in a 50-percent split of \$940,000 in savings between the general contractor and the District.

The contractor also was concerned about the pullback of the four bundled fiber optic conduits. Their concern centered on the very small diameter conduits being wound around the carrier pipe and subsequently damaged during the pullback process. The API pipe approved for the carrier pipe had longitudinal seam welds, and the contractor thought that would greatly reduce the tendency of the carrier pipe to rotate during the pullback operation. The

design specified spiral welded pipe, and the contractor was concerned that the spiral welds would potentially promote rotation during pullback.

All four of the HDD river crossings were completed in a compact environmentally-constrained construction window (June 15- October 15) and inspected by the Project’s construction management team. The general contractor listed Michels Corporation as their HDD subcontractor. Because of the narrow construction window, Michels Corporation elected to subcontract the Templeton and Atascadero HDD work to a second tier subcontractor, K-Comm. That work was done in parallel with the other two crossings. The District judged this subcontracting as acceptable with the mandate that the second tier subcontractor be managed full time by both the general contractor and the HDD subcontractor.

Work began on the Atascadero turnout on June 23, 2008. The HDD work consisted of installing an 18-inch diameter welded steel carrier pipe bundled with four 1.5-inch diameter galvanized steel fiber optic ducts. Drilling the pilot hole took four days, but three additional days were required to contain two “frac-outs” where bentonite slurry found its way to the ground surface. This issue was resolved by lowering the slurry pressure and building containment areas at these two locations. Reaming of the pilot hole followed from July 9 to July 20, 2008. The carrier pipe was pulled on July 22, 2008 starting at 5:00 AM and finishing at 2:00 PM, as shown in Figures 2 and 3. The contractor used a Ditch Witch JT 8020 Mach 1 for this HDD crossing. All four of the fiber optic ducts came through unharmed with the carrier pipe.

The Templeton turnout commenced on

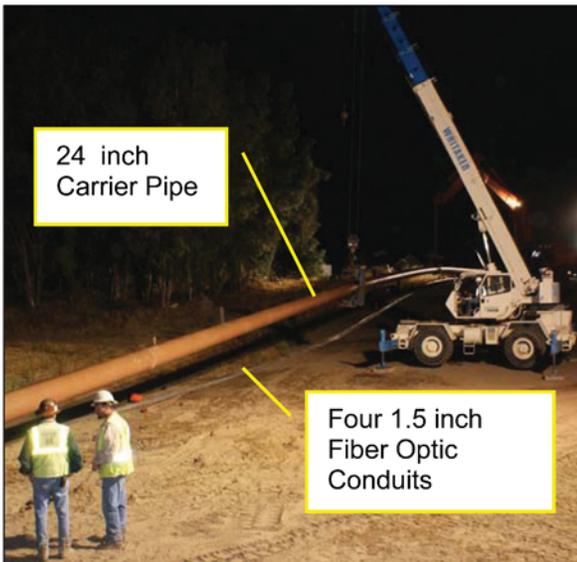


Figure 2. Atascadero Turnout HDD Night Preparation



Figure 3. Atascadero Turnout HDD Pullback

July 25, 2008. This work consisted of installing an 8-inch welded steel carrier pipe bundled with the four galvanized 1.5-inch diameter steel fiber optic conduits. Drilling the pilot hole took one day and reaming was completed in two days. Pulling the carrier pipe and four fiber optic ducts was completed in one day. The contractor used a Ditch Witch JT 8020 Mach 1 for this HDD crossing. All four fiber optic conduits were successfully installed.

Work on the Paso Robles turnout crossing began on July 16, 2008. The work consisted of installing a 24-inch diameter welded steel carrier pipe as well as the four galvanized 1.5-inch diameter steel fiber optic conduits. Drilling the pilot hole took two days and reaming was completed in eight days. Pulling the carrier pipe and four fiber optic ducts was completed in one day starting at 8:30 AM and finishing at 1:45 PM, as shown in Figure 4. All fiber optic conduits were successfully installed.

The MSR crossing work began on July 31, 2008. The MSR work consisted of installing a 24-inch diameter welded steel carrier pipe and four galvanized 1.5-inch diameter steel fiber optic conduits. Drilling the pilot hole took four days and reaming took seven days, see Figure 5. Pulling the carrier pipe was completed in one day, starting at 5:00 AM and finishing at 6:00 PM. The log tracking the thrust/pullback force for the pull revealed a force range between 80,000 and 100,000 pounds and a torque range between 5,000 and 10,000 foot-pounds. The largest pull

force, 100,000 pounds, was encountered roughly two-thirds through the 3,000-foot pull. Unfortunately, only one of the fiber optic conduits made it through with the carrier pipe and the other three stopped 500 feet short of completion due to the cable rigging breaking on the conduit pulling harness. To remedy this problem the contractor performed a second HDD, at a later date, for a single fiber optic conduit so that two usable conduits were available for the Project.

At completion of each of the four HDD crossings, “as-built” surveys, pressure testing of the carrier pipe, and mandrel testing of the fiber optic conduits were performed. The mandrel test ensured that the conduit was intact and had maintained its round shape. The test consisted of pulling a ball or elliptical plug-shaped object, sized no less than 80-percent of the conduit’s inner diameter, through



Figure 4. Paso Robles Turnout HDD Pullback.



Figure 5. Adding drill stem for MSR HDD.

it. The carrier pipe “as-built” surveys showed the alignment met the specified requirements; the pressure tests also met the specified requirements. During the mandrel tests on the fiber optic conduits, it was found that at least two of the four passed the mandrel requirements.

The overall success during construction was due to a high-quality construction team, pre-planned work strategy, and specified submittals. The submittals conveyed what equipment would be

REFERENCES

- Black & Veatch Corporation (2006). Nacimiento Water Project Preliminary Design Report, July 2006.
- Carrollo Engineers (2001). Nacimiento Water Project, EIR Preparation Phase Engineering Report, January 2001.
- Geomatrix (2007a). Nacimiento Water Project Geotechnical Data Report, – Pipelines, March 2007.
- Geomatrix (2007b). Nacimiento Water Project Geotechnical Interpretive Report – Pipelines, April 2007.

used, how required quality would be maintained and documented, how work would be carried out safely, and how the necessary environmental protection measures would be implemented. After the pre-work activities were completed, the contractors worked closely to the schedule to coordinate, inspect, and install the HDD work in accordance to the agreed upon plan. Whenever challenges were encountered, the construction team members worked to arrive at an equitable solution that advanced the overall project completion.

CONCLUSION

Project contractors successfully completed the four Salinas River HDD crossings in a short environmentally-constrained window of time, meeting the specified construction standards. Success resulted from prequalifying eligible HDD subcontractors prior to bidding, adhering to the environmental permit requirements, and establishing the necessary physical designs unique to the Project’s construction. It is anticipated that the two remaining HDD river crossings on the Project will be completed during the allowed environmental construction period in the summer of 2009.

