# Horizontal Directional Drilling a 16-Inch Force Main Under Clearwater Harbor

*Lisa M. Murrin, Kelly J. O'Brien, Dorian Modjeski, Donald R. McCullers, and David O'Connor*

The city of Clearwater is located on the west coast of Florida, with the Gulf of Mexico to the west and Tampa Bay to the east. Clearwater Beach is separated from the Clearwater mainland by Clearwater Harbor, a Class III Outstanding Florida Waterway, located within the Pinellas County Aquatic Preserve. Memorial Causeway connects the beach with the mainland.

When the city retained TBE Group Inc. to evaluate 24 of its aging wastewater pumping stations, the evaluation prompted further analysis of pumping flow alternatives from Clearwater Beach to the Marshall Street Wastewater Treatment Plant (MSWWTP).

Historically, all flow from several wastewater pumping stations on Clearwater Beach have been directed to intermediate stations before being re-pumped to the MSWWTP (see **Figure 1**). The intermediate pump stations, including Pump Station (PS) 16, located adjacent to city hall and recreational facilities, chronically emit offensive odors.

TBE presented the city with several alternatives for improving this wastewater conveyance system, including (1)maintaining the existing configuration, (2)pumping the wastewater directly to the treatment plant with the use of a booster station, and (3)pumping the wastewater directly to the treatment plant without a booster station.

Alternative 3 was selected for implementation, since it was the most cost effective and provided the most benefit to the city. Having each pump station pump directly to the MSWWTP greatly reduces the operational risks of re-pumping.

*Lisa M. Murrin, P.E., is utilities engineering manager for the city of Clearwater. Kelly J. O'Brien is an engineer for the city of Clearwater. Dorian Modjeski, P.E., D.E.E., is director of water & wastewater for TBE Group Inc. Donald R. McCullers is manager of water & wastewater for TBE Group Inc. David O'Connor, P.E., is a project engineer for TBE Group Inc.*

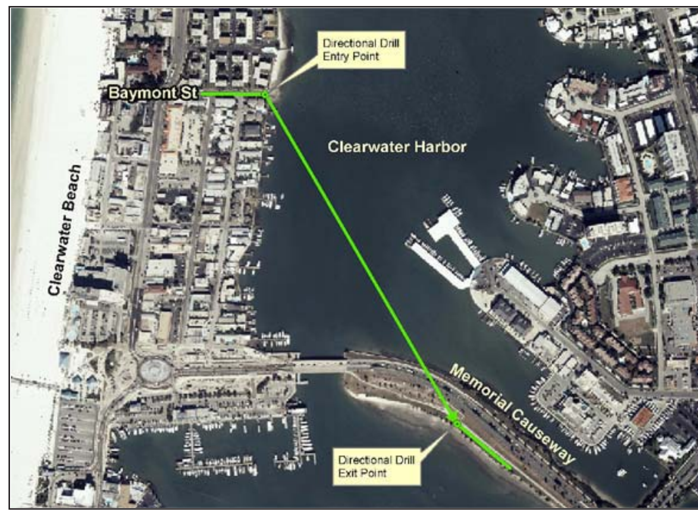


Figure 2

## Project Description

To accomplish the redistribution of the wastewater directly to the treatment plant, the city needed to replace an existing, aging 16-inch sanitary sewer force main from PS 11 to PS 20. This existing force main was constructed approximately 25 years ago by dredging and direct burial and has since been slip lined. The most cost-effective and least disruptive method for constructing the new force main would be to use horizontal directional drilling (HDD) techniques below Clearwater Harbor, connecting Clearwater Beach at Baymont Street to a new force main along Memorial Causeway (see **Figure 2**).

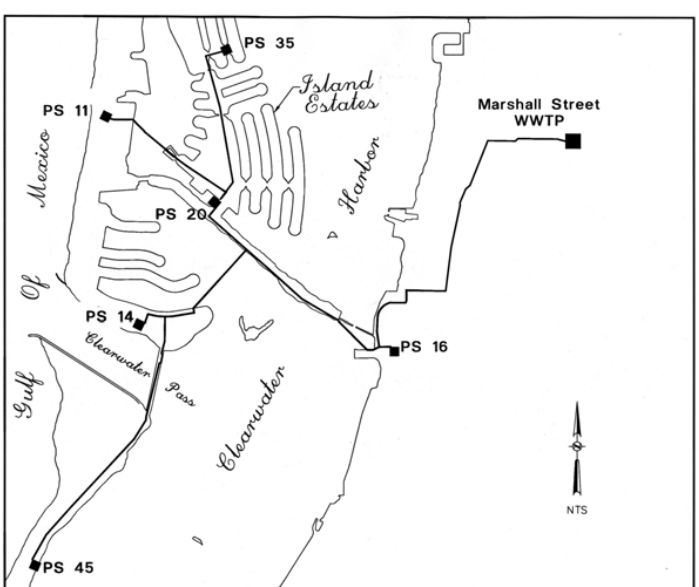


Figure 1

The new force main required horizontal directional drilling beneath the Clearwater Harbor bottom to construct approximately 2,500 feet of 16-inch, high-density polyethylene (HDPE) pipe having a dimension ratio (DR) 9 and an additional 1,200 feet of open-cut construction adjacent to State Road 60 (Memorial Causeway right-of-way). The directional-drill contractor was A&L Underground Inc. of Tallahassee. The project presented several intriguing challenges, most notably logistics associated with drilling operations and obtaining easements through state and privately owned lands.

## Issues and Concerns

Successful horizontal bores are the result of careful planning and skillful execution. The more complex the bore, the more significant the planning stage becomes. During the planning stages of this project, the following issues were addressed:

- Installation method – HDD vs. microtunneling
- Permits
- Easements
- Environmental considerations
- Geotechnical investigation
- HDD operation in a highly populated area
- Tracking devices for accurate installation
- Hydrofracture and mitigation plan

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# Clearwater

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### Installation Methodology

HDD and microtunneling methods were reviewed as alternative installation methods. After careful review and consideration, the city and TBE determined that HDD was the installation method of choice, since this method would be a faster installation, would require no casing pipe and would be least costly.

### Permits & Easements

A Florida Department of Transportation (FDOT) utility permit was required for constructing the pipeline under FDOT right-of-way on State Road 60 (Memorial Causeway). Since no platted public right-of-way existed at the proposed crossing of Clearwater Harbor, a sovereign lands permit was required. A 50-foot-wide easement was requested from the United States Army Corps of Engineers and the Florida Department of Environmental Protection (FDEP) to allow for minor deviations in the pipeline construction.

Initial research of Pinellas County property appraiser plat maps did not indicate private ownership beyond the seawall, but further in-depth research revealed that, in fact, there were five separate, privately owned and submerged plots that intersected the proposed 50-foot easement. After providing legal descriptions and sketches of the plots and following discussions with the private property owners, the city secured these easements to allow for the HDD subaqueous crossing.

On the Memorial Causeway portion of the crossing, the area was open and no problems were encountered. This area provided sufficient work space to fuse the HDPE pipe into one continuous section and perform pressure testing prior to pullback operations, and allowed for the installation of the pipe in one uninterrupted operation during pullback.

On the north beach side at Baymont Street, the existing city-owned right-of-way was not sufficient for the drilling operations. After several meetings with potential contractors to review existing right-of-way and site restrictions, it was determined that a minimum area of 25 feet by 60 feet was required for the drill rig and construction easements from adjacent property owners would be needed. Other components of the drilling operations, such as power generators, slurry mixing tank, and pumps, could be placed at various locations within the right-of-way. Otherwise, the area was generally level, firm, and clear of overhead obstructions, facilitating drilling operations. A temporary construction easement that would accommodate the drill rig was negotiated with the property owner on the north side of Baymont Street.

### Environmental Considerations

Because of the environmentally sensitive location and required permitting, the contract documents required the selected contractor to submit the following documentation for review:

- Noise reduction program
- Solids control and drilling procedures
- Pipe fusion, hydrostatic testing, and pigging procedures
- Contingency plan including contractor's proposed response(s) to the following potential occurrences:
  - o Loss of returns/loss of circulation of drilling fluid
  - o Hydrofracture
  - o Obstruction encountered during drilling
  - o Broken drill pipe
  - o Product pipe collapse

The contingency plan for inadvertent returns and hydrofracture was also reviewed by the FDEP prior to construction, as required by the permit.

### Geotechnical Investigation

A geotechnical investigation was undertaken to examine subsurface soil and groundwater conditions for use in design and construction. Marine test borings were conducted utilizing a drilling rig supported by portable barges, along the general alignment and approximately 50 feet off the proposed centerline of the directional drilling beneath Clearwater Harbor. The test borings were offset from the proposed centerline to prevent the loss of drilling slurry during the crossing installation. The project surveyors provided the position of these borings and also surveyed the mud-line elevation at the time of the test borings.

Test boring logs associated with the directional drill crossing also included drilling rates that were experienced during the advancing of the boring within the underlying limestone formation. Efforts were made to drill the formation with a consistent downward pressure utilizing a 3-7/8-inch tri-cone roller rod bit. In this way, the city could obtain a measure of the relative consistency of the limestone formation throughout its depth of penetration. The borings were conducted utilizing a Failing Model 250 rotary drill rig.

The surface of the limestone formation varied from an approximate elevation of 18.5 feet to an elevation as deep as 36.16 feet (NGVD), based on the test borings conducted along the general alignment of the directional drill crossing. The limestone formation generally varied in consistency, as indicated by Standard Penetration resistance values as well as by drilling rates. The surveyors encountered localized seams that exhibited an extremely hard consistency, as reflected by drilling rates of up to 20.6 minutes for one foot of penetration. These localized seams probably represented very dense and possibly siliceous limestone or chert seams or nodules.

The limestone formation commonly contains crevices, cavities and solution features that can occur on a highly irregular pattern both vertically and horizontally.  Where such zones may be encountered, loss of circulation of drilling fluid may be experienced during the directional drilling process. The contract documents advised the directional-drill contractor to take appropriate precautions in order to protect against a loss of circulation.

### Pipe Design

Alternative alignments were evaluated by TBE Group Inc. during pipe design. The first alignment had a maximum depth of 43 feet and a 1,600-foot bend radius. Also evaluated was an alternative alignment that positioned the pipeline within the limestone before initiating the vertical curve, which provided additional clearance between the pipe

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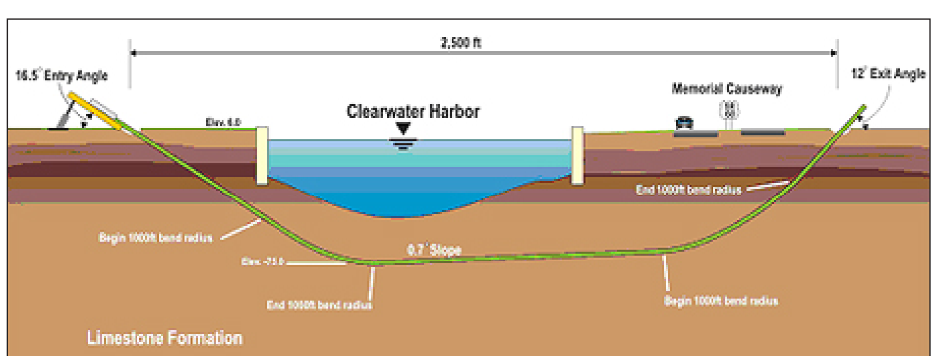


Figure 3

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| PIPE DESIGN | |
|---|---|
| Pipe outer diameter | 17.4 inches |
| Diameter ratio | 9 |
| Pipe inner diameter | 13.53 inches |
| Pipe weight | 40.9 lbs/foot |
| Estimated required pull force | 118,900 lbs |
| Safe pull capacity (S.F. = 2.5) | 120,280 lbs |
| Safety factor against buckling – short term | 25 |
| Safety factor against buckling – long term | 13 |

Table 2

and the seawall foundation. This alternative alignment had steeper entry and exit angles, resulting in a deeper alignment; however, the entry and exit locations were kept the same for both alignments (see **Figure 3**).

The limiting design factor was the pullback strength of the HDPE pipe material. The final alignment was chosen based on the feasible entry and exit angles, establishing the depth to keep the majority of the steering operations in the limestone, and maintaining the original entry and exit points. The final alignment had the characteristics detailed in **Table 1** below.

For the alignment detailed in Table 1, pullback calculations were performed for DR 11 and 9 to determine the minimum pipe wall thickness. In both cases, the evaluations were performed for pulling back the pipe full of water. The calculations were performed using guidelines developed by the American Gas Association (J. D. Hair and Associates, et. al., 1995). TBE compared the estimated pullback forces to safe pull capacity as published by Plexco (40% of yield strength).

**Table 2** above summarizes the pipe design calculations.

## *Tracking System*

To accurately locate and guide the bore, the contractor used a wireline steering system with TruTracker. Basic components of a wireline steering tool include a downhole probe placed inside a nonmagnetic drill collar near the drill bit, wire connecting the probe to an interface unit on the drill rig, readout box, and computer and printer at the driller's station.

The probe's accelerometer measures gravity and resolves the tool's vertical-horizontal inclination. A magnetometer measures the earth's magnetic field and dip angle to resolve the tool's relationship to magnetic north. Information is transmitted to the interface unit that connects to a laptop computer and printer. The readout box provides the driller with constant updates of drill head roll, pitch, and direction.

Wireline systems usually are used with a Tensor TruTracker surface grid system–special software and wire coil placed along the line of the drill path. TruTracker provides a method of verifying that data from the wireline system are not being affected by magnetic forces or other interference and therefore provides an accurate alignment of the drill path.

| CHARACTERISTICS OF THE FINAL ALIGNMENT | |
|---|---|
| Entry angle | 16.5 degrees |
| Depth from ground surface el. 6 to start of 1st vertical curve | 40 feet |
| Length from entry to start of first vertical curve | 141 feet |
| Bend radius | 1000 feet |
| Length of 1st vertical curve | 296 feet |
| Maximum depth | 81 feet |
| Inclination of straight section beneath channel | 0.7 degrees |
| Length of inclined straight section | 1702 feet |
| Depth from ground surface el.6 at beginning of 2nd vertical curve | 60 feet |
| Bend radius of 2nd vertical curve | 1000 feet |
| Length of 2nd vertical curve | 212 feet |
| Depth from ground surface el. 6 at end of 2nd vertical curve | 38 feet |
| Length to exit | 183 feet |
| Exit angle | 12 degrees |
| Total pipe length | 2,534 feet |

Table 1

## *Pipe Installation*

The Tru-Tracker system was set up on the east end of Baymont Street (entry point) and on the causeway (exit point). A wireline tracking system was used to approximately 80 feet out into the harbor on the entry side and from the seawall to the exit point on the causeway.

A pilot hole was made with an 8-inch drill bit. The entry angle was 16.5 degrees and the exit angle was 12 degrees. During the pilot-hole drilling, data were collected at 30-foot intervals from an electronic device giving a magnetic azimuth for left/right of a baseline and the vertical depth. The steering device is located in the head of the pilot bit. Pressurized slurry was used to advance the drill head. The exit point was quite accurate, being within a few feet of the target point.

Once the pilot hole was completed, the hole was enlarged to approximately 24 inches in diameter for the product pipeline. This was accomplished by pre-reaming the hole to successively larger diameters until a 24-inch reamer could be brought from exit point to entrance point. The rule of thumb for the size of reamer required is 1-1/2 times the diameter of the pipe. A hydro-motor (mud motor) was utilized at the cutting-bit location to aid in the cutting of the limestone rock. This limestone rock was located along approximately 90 percent of the entire drill path.

The entire length of HDPE pipe was butt-fused together and laid out along the causeway on rollers. The pipe was pressure tested at 150 psi for 24 hours prior to pullback. Following pressure testing, the pipe was attached to the drill pipe, reamer, and breakaway swivel and pulled back continuously in one segment through the drilling mud along the reamed drill path. The pipe was filled with water prior to pullback to aid in controlling the buoyant forces and to keep the pullback forces below the safe pullback capacity of the HDPE pipe.

A hydrofracture occurred during the pilot-hole drilling near shore, a short distance from the entry point. Containment measures were implemented immediately by the contractor as outlined in the predefined contingency plan to collect the drilling fluids so they could be recycled during the drilling operation (see **Figure 4**). A return pit and settling pit were also used in the recycling operation. Bentonite slurry with additives was used during subsequent drilling activities in an effort to control the hydrofracture.

Once the pipe was installed, a hard pig slightly smaller than the inside diameter of the HDPE pipe was successfully passed through the pipe to check for roundness. Maximum depth of the new force main is approximately 87 feet (65 feet below the harbor bottom). Because of careful planning during the design stages, the city of Clearwater had a successful horizontal directional drill under Clearwater Harbor to replace a 16-inch force main.

## References


- *Bennett/Staheli Engineers, 2001. Technical Memorandum, Pump Station 11 Force Main Relocation for the City of Clearwater HDPE Pipe Design Calculations.*
- *Driggers Engineering Services Incorporated, 2001. Report of the Geotechnical Investigation Directional Drill Crossing, Force Main and Pump Stations LS-11, LS-16 and LS 20, Clearwater, Florida.*
- *Directional Crossing Contractors Association. Guidelines to a Successful Directional Crossing Bid Package.*
- *HDD Consortium, May 2001. Horizontal Directional Drilling, Good Practices Guidelines.*


Figure 4