TUNNELING 2,500 FEET OF PIPE UNDER BISCAYNE BAY

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ABSTRACT

Watson Island and Biscayne Island are pristine islands located in Biscayne Bay between the mainland City of Miami and Miami Beach (Figure 1). The City of Miami is actively developing the islands for commercial and residential purposes. Of importance is the construction of the new Parrot Jungle facility in Watson Island; the old facility in the mainland will be relocated to the new facility when construction is completed in 2003. Providing water and wastewater services to Watson Island has been the primary concern of the City of Miami Public Works Department. Under an agreement with the Miami-Dade Water and Sewer Department (MDWASD), the City would construct a pipeline from Watson Island via Biscayne Island into mainland Miami and MDWASD would own and operate the completed pipeline. The pipeline would cross Biscayne Bay parallel to a historic existing bridge between Biscayne Island and the mainland. The Biscayne Bay's fragile environment and marine traffic precluded "open cut" technology to install the 12-inch pipeline. Trench-less technology was the selected construction method.

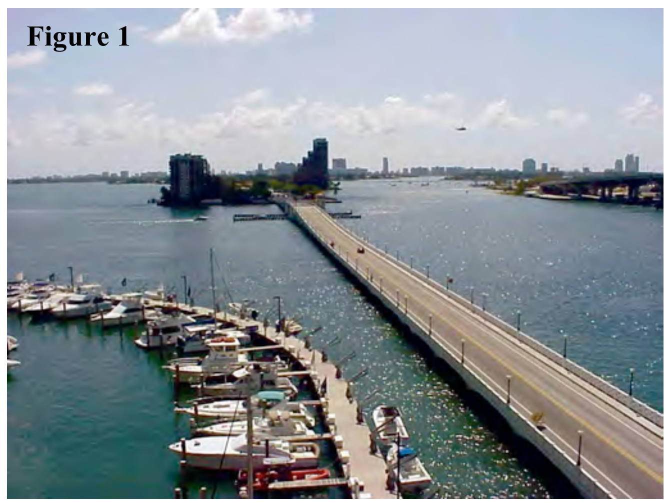


Figure 1

TECHNOLOGY REVIEW

The following technologies were available for the tunneling project:

- Auger Boring
- Horizontal Directional Drilling
- Micro Tunneling
- Pipe Jacking
- Pipe Ramming

The 2,500-foot tunnel was to be constructed along the McArthur Causeway bridge alignment in the hard limestone strata of the South Florida coastline. Among the available trenchless technologies, Horizontal Directional Drilling (HDD) was the selected method to construct the tunnel because of its limited impact on the entry and exit areas and the suitability of HDD for the installation of small diameter pipelines via the drilling method. Moreover, HDD would offer the best possible depth of alignment in order to avoid interferences with the adjacent bridge piles.

HORIZONTAL DIRECTIONAL DRILLING (HDD)

In the horizontal directional drilling method, a pilot hole is drilled using a cutting tool (Figure 2) beginning at the entry point at an alignment suited to avoid interferences and following a selected pipe profile. A typical profile of the pilot hole is shown in Figure 3. Directional control is provided by a small bend in the drill string just behind the cutting head. The drill path is monitored by an electronic package housed in the pilot drill string along the cutting head. The electronic package detects the relation of the drill string to the earth's magnetic field and its inclination. The data is transmitted back to the surface where calculations are made as to the location of the cutting head.


Figure 2

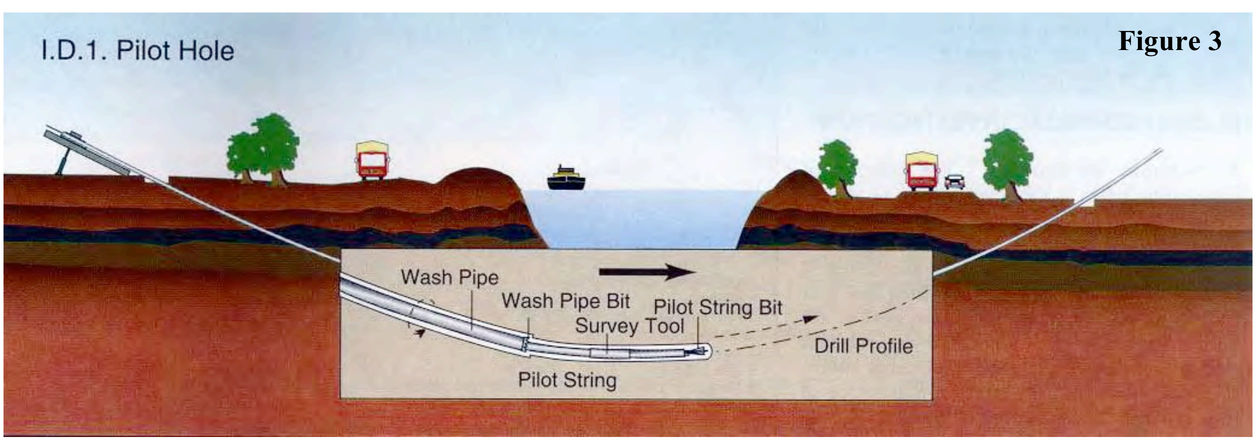


Figure 3

Once the pilot hole is completed, the hole is enlarged to a diameter suitable for passing the 12-inch pipeline. This is achieved by "pre-reaming" the hole to successively larger diameters (Figure 4). Large quantities of slurry are pumped into the hole to maintain the integrity of the hole and to flush out cuttings.

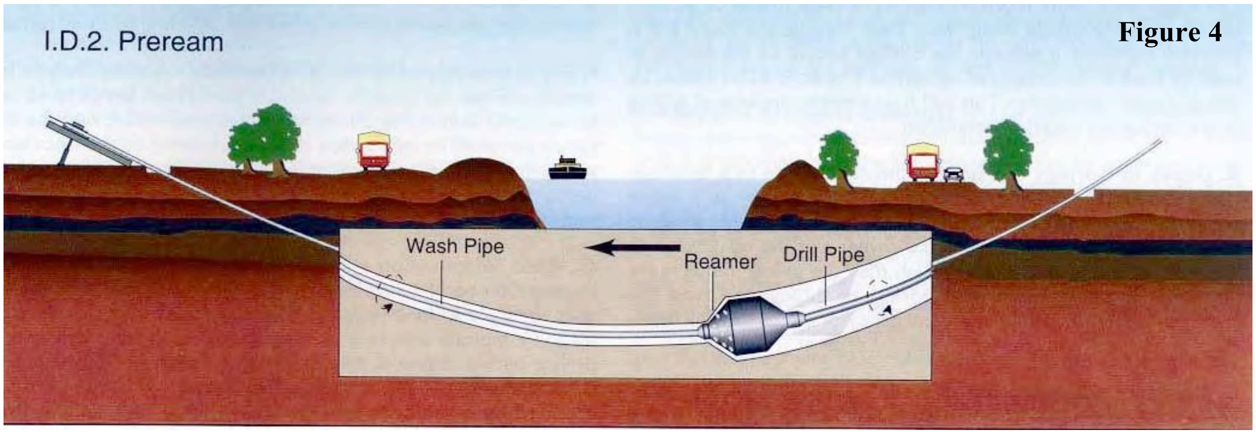


Figure 4

Once the drilled hole is enlarged to the suitable diameter, the 12-inch pipeline is pulled through the hole (Figure 5).

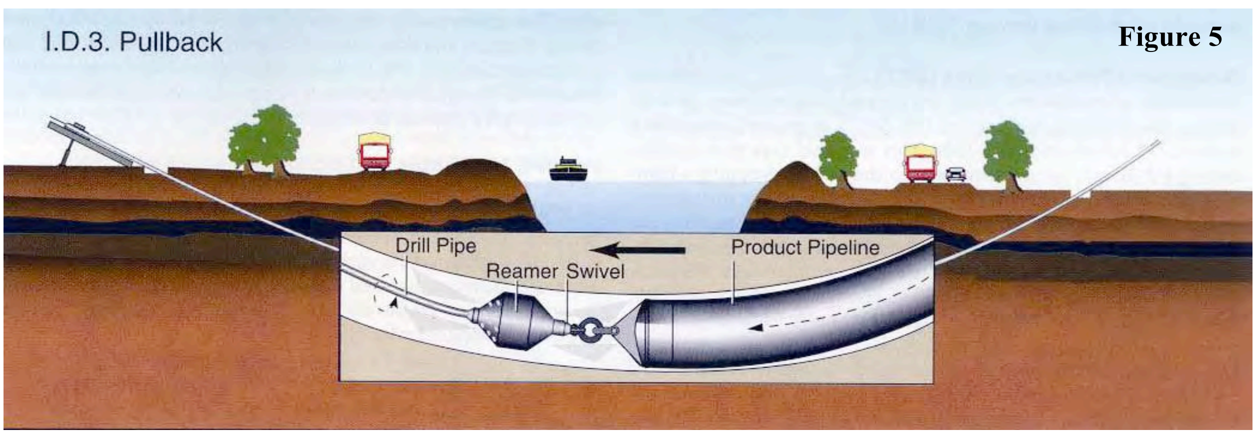


Figure 5

The rig side represents the drilling side and the exit-side represents the exit point of the cutting tool and the entry point for the pipeline. For this project, the mainland was used as entry point and Biscayne Island was used as the exit side for the HDD.

GEOTECHNICAL CONSIDERATIONS

Selection of an appropriate alignment for the pipeline was the key factor in the success of the HDD program. In many portions of Miami-Dade County, the sub-surface soils consist of varying mixtures of sand and limestone. In order for HDD to be used successfully on this project, a layer of uniform material was required to control the drilling operation. The goal was to avoid lenses of material with significant variations in cutting qualities and select a profile that was conducive to drilling without major changes in cutting effort or changes in drilling direction.

An accurate representation of the sub-surface profile was required to select cutting equipment and planning the drilling process.

Geotechnical studies conducted for the HDD program consisted of the following:

- Sub-bottom Profiling
- Marine Soil Borings

Underwater imaging technology utilizing a sub-bottom profiler was used to plot the sub-surface characteristics of the soil profile to a depth of 100 feet. The Edge-Tech X-Star Chirp full spectrum digital sub-bottom profiler was chartered using small craft along the alignment to collect the sonic data into a computer. The sonic data was then interpreted based upon sound speeds in the media to classify the soil. Initially, assumptions were made on soil sound transmission coefficients to estimate soil profiles. Based on the preliminary profiles, locations were selected to perform field soil borings. A geologist analyzed the materials collected from the borings in order to estimate sound transmission coefficients. These coefficients were then correlated with the sound data to accurately classify the soils expected in the path of the HDD.

Three 110-foot deep soil borings were conducted at locations selected after the sub-bottom profiling data was analyzed (Figure 6). The borings used the Standard Penetration Test (SPT) and Rock Coring as the method of investigation (Figure 7). The soil/rock samples recovered from the soil borings were classified and stratified as follows:

Layer A:

Description:	Sand
Top Elevation:	-8 feet NGVD
Thickness:	3 feet
Average SPT N-Value:	2 Blows/Foot

Layer B:

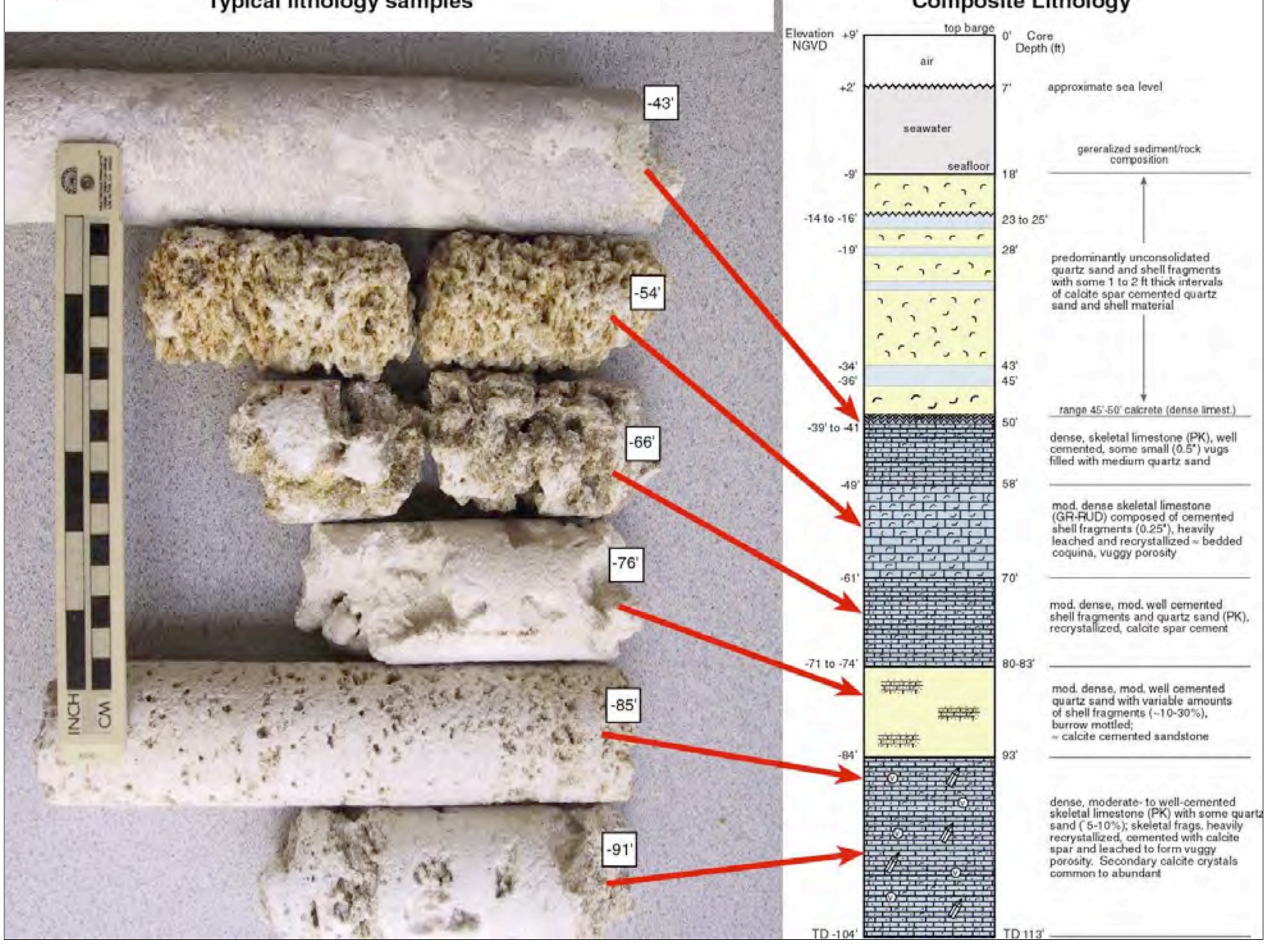
Description:	Limestone
Top Elevation:	-11 feet NGVD
Thickness:	7 feet
Average SPT N-Value:	16 Blows/Foot

Layer C:

Description:	Sand
Top Elevation:	-18 feet NGVD
Thickness:	16 feet
Average SPT N-Value:	12 Blows/Foot


Figure 6

Figure 7



Layer D:

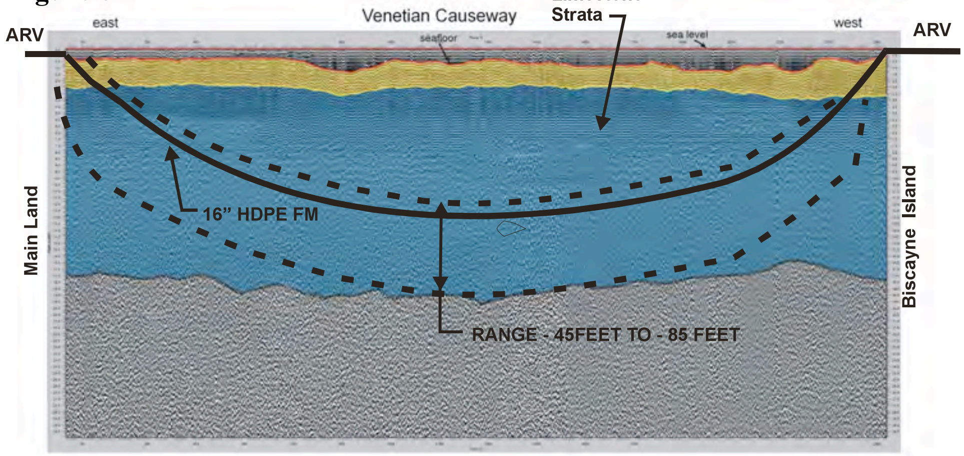
Description:	Limestone
Top Elevation:	-34 feet NGVD
Thickness:	28 feet
Average SPT N-Value:	100 Blows/Foot

Layer E:

Description:	Limestone/Sandstone/Sand
Top Elevation:	-62 feet NGVD
Thickness:	41+ feet
Average SPT N-Value:	43 Blows/Foot

The above classification of soils, along with samples collected from the rock coring program were analyzed under laboratory conditions to estimate sound transmission coefficients. These coefficients were then added into the sound data collected by the sub-bottom profilers to classify the soils in three dimensions. The three dimensional classifications were then used to finalize the HDD profile (Figure 8).

Figure 8



Layer D, the dense limestone strata was the densest of all the layers and was considered difficult to drill.

Layer B and C had fragments of both lime-rock and sand which would impact the alignment of the cutting tool because of the uneven densities that could be expected.

After review of the soil conditions and the available cutting tools, an alignment below Layer E was chosen to provide a consistent stratum for the drilling process.

ENVIRONMENTAL CONSIDERATIONS

An environmental survey of the pipe corridor was conducted as part of the environmental permitting phase for the project. Biscayne Bay is identified as Class III waters and required an Environmental Resource Permit for construction. Since ownership of the Bay along the pipe corridor was titled to the City of Miami by the State, property ownership issues were not part of the permit procurement process.

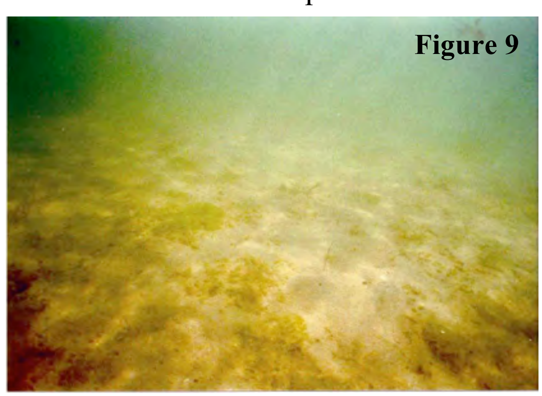


Figure 9

Typical conditions in the Bay along the pipe corridor are illustrated in Figure 9. The alignment had virtually no sea grass growth or other sensitive vegetation that would concern the Florida Department of Environmental Protection (FDEP). However, FDEP imposed the following major conditions on the project:

- Best Management Practices (BMP) for erosion control of drilling fluid at the entry and exit points.
- Use of bentonite-based drilling fluid to minimize environmental impacts.
- Close monitoring during construction.

One of the major concerns with HDD in South Florida coastal waters is the potential for the formation of “frac-outs”. Frac-outs occur when the drilling fluid under pressure follows weak planes in the geology of the surrounding soils and escapes into the environment causing damage to benthic communities and wildlife. The depth of the alignment (approximately EL. -80 at center of bay) and the drilling methods minimized the concerns with frac-outs. Close visual monitoring was required to detect leaks into the Bay bottom.

The FDEP, The US Army Corps of Engineers and the Miami-Dade County Department of Environmental Resource Management (DERM) approved the permit application for construction under strict monitoring requirements.

PIPE SELECTION

The pipe used for the project had to have an inside diameter of 12-inches, be flexible enough for pulling through the HDD hole and provide long term life span for the expected service.

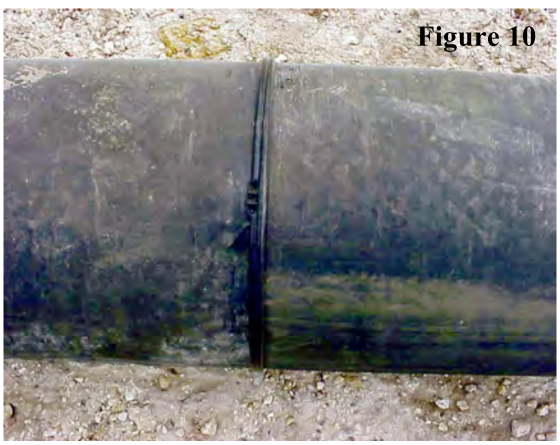


Figure 10

High Density Polyethylene (HDPE) was the selected material. The properties of the HDPE pipe is as follows (Figure 10):

Inside Diameter (I.D.):	12.915”
Outside Diameter (O.D.):	16.000”
SDR:	11

Figure 11

Elastic properties of the pipeline were critical for the installation program. The 2,500-foot HDD profile would impose significant tensile loads on the pipe during the installation process (centenary action). The tensile loads would be influenced by pipeline temperature, empty versus full pipe and other frictional effects. “Drillpath” software was used to calculate stresses in the pipeline during the pull back procedure in order to ensure that the pipe would not be overstressed. In order to control pipe temperature increases due to exposure to the sun during pullback, exposed portions of the pipe were immersed in the Bay to reduce the pipe temperature (Figure 11). The temperature reduction would in turn reduce axial tensile stresses during pull back.

In addition to installation stresses, the pipeline would also experience earth loads and hydraulic loads during operation. These stresses were calculated and found to be within acceptable limits of the HDPE material properties.

THE HDD PROGRAM

The installation began by the setup of the drilling equipment, drill shafts, cutting tools, reamers, slurry pumps, recycling equipment, slurry pit, generators for power and other ancillary equipment on the entry side at the mainland (Figure 12).

The pilot hole was drilled in substantial accordance with the selected pipe profile. The pilot hole drilling procedure had to be a slow procedure with shaft sections being reversed and pushed in small increments.
Returns on the slurry were excellent in the initial sections and slowed considerably as the drill shaft exited into Biscayne Island.


Figure 12

A steel casing was considered in order to protect the hole should the shaft require removal. After review of the soil conditions, however, a casing was not used in order to maximize the available construction schedule and minimize other drilling constraints.

After the pilot hole was completed, reams of increasing diameters were used to progressively increase the hole diameter to approximately 24 inches in order to pull the 16-inch HDPE home.

After the final ream was completed, the pipe was pulled through the hole to its final position. The line was then cleaned and connected to the tie-in points.

SUMMARY

The HDD method is an excellent trenchless technology available in the small pipe diameter market. The attractiveness of HDD is the minimum environmental impact on the pipeline route and the minimum staging areas required for construction at the entry and exit points. A significant pipeline was installed under Biscayne Bay without any impact to the environment or operations in the mainland and Biscayne Island. Issues to be considered in an HDD program are as follows:

- Pipe Selection
- Alignment
- Length of HDD
- Pipe Profile
- Geotechnical Characteristics
- Installation Methodology and Constraints

The City of Miami experience can be utilized in other utility applications where environmental protection becomes a driving force in the selection of construction technologies in the trenchless technology market.