Project Management Institute. Kingdom of Saudi Arabia

A new benchmark in the Offshore construction industry

# Long reach Offshore to Offshore HDD

## ABSTRACT:

Horizontal Directional Drilling has a long history in civil and industrial applications. This paper addresses the technical and project management aspects associated with the utilization of HDD - methodology to execute one of the longest offshore-to-offshore subsurface sections for oil field development. In 2017, the assessments began for the development of options to execute 12 inches pipeline by around 7.5 Km for subsea and subsurface section opposite to the shores of Jubail Industrial City in Eastern Province in Saudi Arabia. The operation is intended to take place within the premises of one of the largest industrial seaports in the world, which has imposed additional complexities in the design, planning and execution of the project. While HDD is widely used for onshore applications, the HDD applications where both entry and the exit points are located offshore, referred to as offshore-to- offshore sections, are rare in the industry. Therefore, this paper to document the necessary concepts as well as creating benchmarking with similar application in the industry.

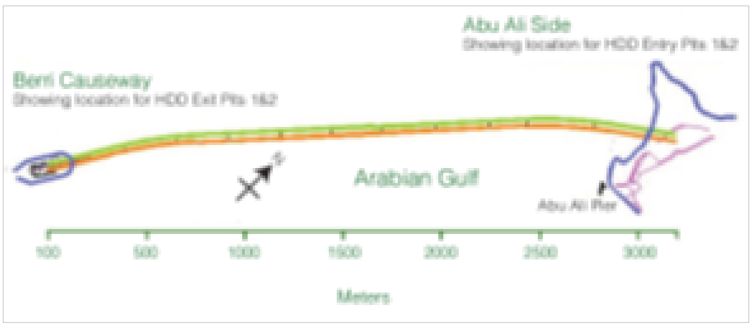
## HDD HISTORICAL BACKGROUND

Horizontal Directional Drilling (HDD) is a method used to create underground crossing path for pipelines or cables beneath existing assets, difficult topographic zones such as mountains or rivers, and natural or manmade obstacles. This is achieved by drilling the ground to create a properly sized path for the asset.

HDD allows pipes to be installed without the need for trenching or dredging, significant environmental advantage that drives most applications. The first stage of the process involves drilling a pilot hole between two ground entry points, using electronic positioning/steering instruments to guide the drill head along the required path and then pulling the asset through the drilled corridor.

In the region, Saudi Arabian oil field Shaybah development had also mandated the use of HDD technologies for the crossing of the crude pipelines over several sand dunes. Among the recent applications over there was the section to support a 24" pipeline for a crossing section of 2100 m approximately, connecting Shaybah oil field to Abqaiq plant. The deployment of HDD method in the application has saved a significant civil work to overcome the widely spread sand dunes in the field.
The process of deploying submarine power cables involves multiple phases that are critical to the success of the project. Given the harsh and dynamic marine environment in which these cables operate, there are important considerations

Saudi Arabian Oil Company has completed a key onshore - onshore HDD section regionally, despite its crossing the Arabian Gulf waters, in Berri oil field of the kingdom. In early 2009, the HDD section for two pipelines, a 24" crude pipeline and a 30" water pipeline from Drill site Causeway to Abu Ali Island, was constructed opposite the shores of Jubail Industrial City in Saudi Arabia. The section that carried both pipelines was a 3100 m section, drilled at a maximum depth of 32m below the seabed. Due to the proximity of this special experience to the subject of this paper, more information is considered hereunder for benchmarking purposes.




https://primehorizontal.com/wp-content/uploads/06/2017/Saudi-Intersect-Preprint-609.pdf

Project Management Institute.
Kingdom of Saudi Arabia

# PROJECT BACKGROUND

| PROJECT DETAILS | |
|---|---|
| SCOPE OF WORK | EPCI Contract: Onshore, Shore Approach and offshore subsea works |
| LOCATION | BRRI Field, Jubail, KSA |
| TOTAL LENGTH | 7,583m, 6 HDD's sections |
| CROSSINGS | HDD#1 – Onshore to offshore- 840m<br>HDD#2- Offshore to offshore- 1574m<br>HDD#3 - Offshore to offshore- 1001m<br>HDD#4- Onshore to offshore- 660m<br>HDD#6&5- Onshore to onshore – 1754m |
| DIAMETER | 24 & "12 ,"8" Steel with internal CLAD liner |
| GEOLOGY | Calcarenite, cemented sand, clay |
| EQUIPMENT | 1 HDD RIG<br>Pushing/Pulling force: 250tons, 400tons |

Saudi Aramco intends to install several pipelines with the support of Horizontal Directional Drilling (HDD) in an area with severe restrictions due to very busy ports and geotechnical challenges. Several options were considered; However, HDD has been the final methodology chosen to comply with environmental, financial and execution area constraints. To facilitate the installation of new pipelines, Saudi Aramco has built two artificial islands, of different dimensions, which will be used for drilling and other developments to support future Saudi Aramco plans.


From the artificial South Island A, crossing the future expanding area of the port and then crossing the south breakwater structure to reach the platform from the southern side proved to be the most effective from technical, environmental, and economic aspect. Drilling is being made in one of the largest petrochemical shipping ports in the world, executed between King Fahad Industrial Port (KFIP) at the North side and Jubail Commercial Port (JCP) at the South side. The Project is designed not to interfere with port operations or navigational routes from either one.

For the pipeline route from Island A to the platform, three HDD operations have been executed, installing a 12-inch steel water injection pipeline from the artificial island to offshore platform, each posing different challenges:

I. HDD#1 – Offshore crossing – 840m

II. HDD#2 –Offshore-to-Offshore – 1574m

III. HDD#3 –Offshore-to-Offshore – 1001m

Project Management Institute. Kingdom of Saudi Arabia

HDD#1 was drilled from artificial island towards offshore, with the main challenges being the limited space available at entry point and subsurface revetment crossings, as well as the exit point which was in 1.5m LAT (Lowest Astronomical Tide). The water depth required the mobilization of specific marine equipment for this crossing. Further to above challenges, again due to water depth and other HDD's strings, the 1.3km string was laid at 500m away from the exit location which further required dedicated arrangements for safe installation. During pullback the HDD#1 string have been floated and cross over the HDD#2 string, this approach been carefully planned due to minimum water levels and the arrangements specifically designed for this crossing.

HDD#2, one of the longest offshore-to-offshore HDD crossing, was drilled from 6.5m WD to 3.5m WD. The pipe string length was almost 2.0km crossing two navigational channels with different elevation per each from 7m to 10m which further giving technical and operational constraints. The pipe string was laid parallel to other pipe string, 8.5m away, and in proximity of the HDD#1 string end, providing limited space and leaving no room of error during pullback operations.

HDD#3, which is the second Offshore-to-Offshore crossing, has its own criticalities, starting with the need of not impacting KFIP & JCP main navigational routes and addressing the significant water column drop from 6.5m at entry point to 12m at exit point. Furthermore, the pipe string of 1.6km was laid outside the port, in a water depth of 22m and exposed to strong currents, therefore was left flooded with chemically treated water and partially designed with concrete weight coating for stability reasons.

Figure below summarizes the result:

In addition to mentioned pipeline of 12-inch water injection, Saudi Aramco intends to install three more pipelines which will be executed with support of HDD in same stringent execution area.

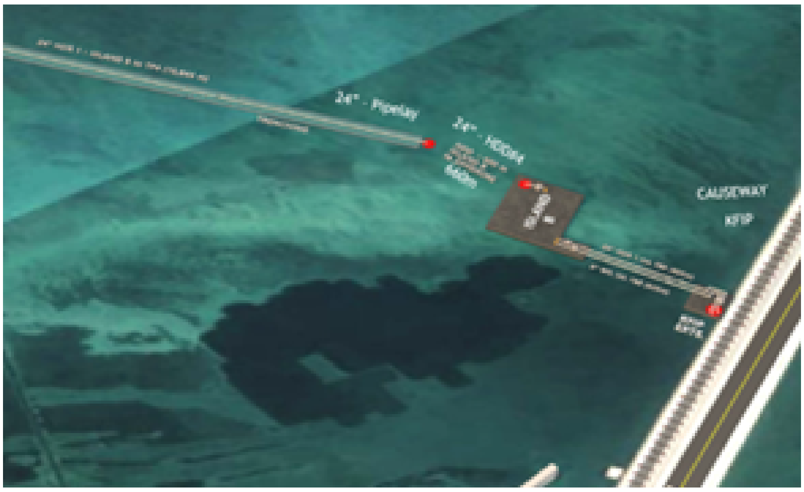
I. HDD#4 – Onshore-to-Offshore – 660m

II. HDD#5 – Onshore crossing – 1754m

III. HDD#6 – Onshore crossing – 1754m

HDD#4 was drilled similar to HDD#1 from an artificial island, called Island B, which is under KFIP jurisdiction but also under Saudi Aramco BRRI field, therefore both areas shall be accounted for permitting and execution constraints. A 720m long 24inch steel pipeline has been laid on seabed and pulled through HDD borehole upon drilling completion.

Project Management Institute. Kingdom of Saudi Arabia




HDD#5 and HDD#6 were drilled from the third artificial island, KFIP Extension, towards Island A. The pipe strings were pre-welded on Island A and placed on carrying rollers for entire length. As all pipelines are internally protected by CLAD liner, the weld was made from a stationary welding area and pulled until HDD entry location by a linear winch, in preparation for final HDD pullback. The HDD crossing was made under the KFIP access causeway.

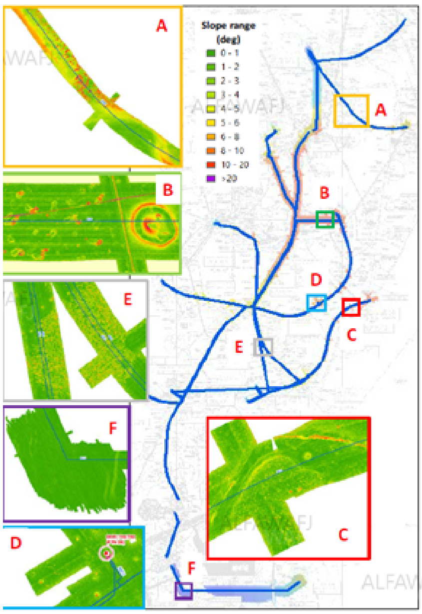
Project Management Institute. Kingdom of Saudi Arabia

## SITE SURVEYS AND CONDITIONS

The Arabian Gulf is a Late Pliocene to Early Pleistocene shallow elongated basin, which represents a low-lying region adjacent to a mountain chain formed as a result of plates collision that affected the area during the Late Pleistocene–Holocene epoch.

Known thicknesses of Late Pleistocene-Holocene sediments are highly variable. In the shallow water areas, such as the project's, sediment thickness varies up to a maximum of about 10 m, although large areas have less than 2 m.

The seafloor in the pipeline corridor of the HDD area often appears where the rock at surface is unfractured, flat and uniform.




For a thorough geotechnical analysis of the project, several soil sample boreholes have been executed in the HDD corridor.

From the survey results, it has been concluded that the soil appears to be dominated by dense to very dense SAND, either calcareous or silica, but also highly consistent COHESIVE layers, and variably CEMENTED HORIZONS, even fine-grained materials are encountered at increasing depth. Stronger fine horizons, higher than 50 kPa and up to more than 250 kPa, are very stiff to hard SILT and CLAY, with PI largely varying from a few tens to more than 100, are present as interbedded layers. A certain degree of cementation is sometimes observed in sandy levels throughout the sequence.

Project Management Institute. Kingdom of Saudi Arabia

## DESIGN PARAMETERS

Due to hard seabed surface, channel crossings and recent trenching executed for transitions in & out at different elevations for pipe strings a composite ARO fabricated from Glass Fiber / Epoxy Composite and polyester composite sleeve wraps, applied on several layers, was found suitable for purpose. Furthermore, where necessary CWC is used for stability or mechanical support.

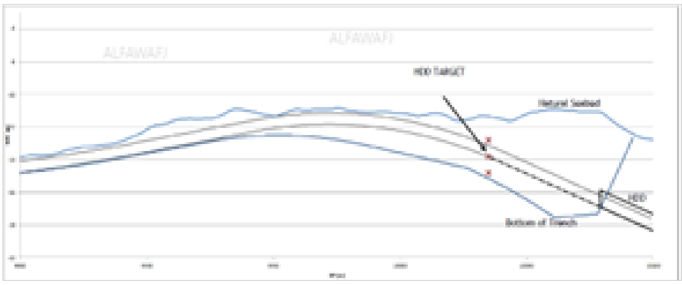
The design, specifically the length, of the HDD section must take into consideration the maximum length of prefabricated pipeline. It is noteworthy that it's always recommended to perform the pipe pull in a single stage, or a minimum number of stages if not possible, to minimize the probability of pipe getting stuck, which is a major risk in such operation. Therefore, it is recommended that the pipeline be completely fabricated prior to the pulling operation

Maintaining pipelines within the HDD section is significantly more difficult than surface pipelines. Therefore, Corrosion protection measures for the pipeline have been thoroughly assessed as part of the HDD design. Pipes will be having external Fusion Bond Epoxy (FBE) coating, that is applied on a greater number of layers compared to surface flowlines. It is noteworthy that the design and application of Cathodic Protection systems in HDD section are considered as a promising research venue, as suggested under research direction section of this paper. For this project been utilized temporary cathodic protection and upon completion of HDD's and connection of the sections described a permanent ICCP been implemented. However, ICCP design and implementation proves to be challenging and one of a kind in world considering the length of 7km to be protected and multiple strings connected.

# EXECUTION METHODOLOGY

## TRENCHING OPERATION AND STRING PRE-LAY

Initially the seabed was trenched to prepare it for HDD entry and exit drilling. The bottom of the trench reached around 7m below the seabed. This arrangement was almost symmetric for both entry and exits points. Furthermore, two backhoe dredger vessels assisted in the operation due to the hard and rocky soil. The diagram below demonstrates the trenched seabed profile:




After the completion of the trenching operation the pipe string was welded and laid at the seabed in line with the HDD exit point, to be pulled at the final stage of the operation. The pipe-lay works were conducted in shallow water area, with a state-of-the-art ultra-shallow water pipe-lay vessel “namely SAIPEM® Castoro12” which can operate in a draught ranging from 1.4m to 2.65m. The pipe string welding criteria will not be covered in this paper, as it is deemed beyond its scope.

## HORIZONTAL DIRECTIONAL DRILLING (HDD)

Multiple passes or stages are to be considered for HDD executions, starting from pilot hole and completing with pullback and completion of the works.

This article will focus on HDD#2 which been drilled Offshore-to-Offshore for a total length of 1574m, thereby providing details about challenges and insights for future projects.

The Pilot hole was drilled from HDD equipment to a designated “exit” point offshore as previously highlighted. HDD equipment is placed on a drilling barge specifically geared with anchor line and SPUDs.

Generally, in HDD, a Jack-up is preferred for drilling, avoiding the weather challenges and tide changes. However, the Jack-up has not been utilized due to soil conditions in the area and seabed profile.

At the entry point a 16” steel conduit pipe was installed for approximately 100m providing rigidity to the pilot hole drill string and prevents breakouts near the entry point.

Project Management Institute. Kingdom of Saudi Arabia

The table below reflects the main parameters of this operation:.

| | PARAMETER | MAGNITUDE | UNIT |
|---|---|---|---|
| 1 | Initial size of pilot hole drill bit | 8/5 9 | Inch |
| 2 | Initial pilot hole size | 11 | Inch |
| 3 | Drilling duration of pilot hole | 3.5 | Weeks |
| 4 | Entry point angle | 6 | Degrees |
| 5 | Exit point angle | 5 | Degrees |

Reaming, or in enlarging runs are later conducted to expand the drilled pilot hole to the desired diameter. In this operation, a total of two (2) reaming passes were conducted, with the first using 18” reamer and the second used a 24”. Every run of reaming was followed by at least one run of cleaning. The entire reaming and cleaning operations for this project consumed around 3 weeks of continues work. .

Once the reaming and cleaning process is completed, the pipeline string can be pulled back via a pullback assembly that includes a specially made swivel, a shackle and a pulling head. The rig was sized for maximum 400 MT, however approximate 70 MT was needed for the operation, in line with the designed forces. Before the pulling operation, the pipeline was floated to further mitigate the coating damages even though ARO was utilized due to the hard soil at the surface, considering the pipe string length of almost 2km. Multiple vessels were used to keep the pipeline on trajectory and careful pullback weather window was chosen to minimize extensive waiting time between last cleaning pass and pullback. Around 24 hours were needed to complete the pipe pulling operations, and consequently the HDD operation.

## RESEARCH DIRECTIONS & FUTURE IMPROVEMENT

As Horizontal Directional Drilling (HDD) technology applications are still relatively new, there are several research areas to be explored. The topics approached are briefly underlined below:

## ABRASIVE RESISTANT COATING

The design and the selection criteria of the Abrasive Resistant Coating, or shortly (ARO), which is wrapped around the other body of the pipeline is among the most significant research directions. The identified parameters that can affect the design of the coating include the formation frictional forces and geomechanically interaction with the ground.

Moreover, the environmental footprint of the Drilling fluid is also an important research area, with a greater emphasis on the application of offshore-offshore HDD projects. This is because the logistical requirements for environmentally friendly disposal of the drilling fluid one more challenging in offshore environment.

Nevertheless, this field is not new at all, as there has been a long-standing research effort in the oil and gas industry associated with the drilling of oil & gas development and exploration wells, which can provide significant insights in this area.

Specifically for this project, the ARO utilized proved to be adequate, however in future projects a thorough investigation for fusion bonded to pipe ARO systems and possibly additional layers are recommended due to the geology in the area. The Onshore systems shall not be utilized or shall be avoided.

## INJECTED CURRENT CATHODIC PROTECTION

The design of the optimum corrosion protection system can be affected by the pipe being several meters below the mudline. The right balance between the number of the sacrificial anodes and the current injection point which is part of the Injected Current Cathodic Protection System also warrants further research.

## CHALLENGES

Each project has its own complexity and faces challenges during preparation and execution; however, this project is starting with one of main challenge - its magnitude. Having each type of crossing, and the inherent difficulty of maintaining the same spread and arrangements for each crossing, made the project highly risky and time-consuming in both preparation and execution.

This project was faced with few of challenges some of which are listed below:

- **COVID** – planning of the HDD started before 2020, however been severely impacted due to COVID, however it continued and adapted as moved towards execution
- **Location** – area of execution in between two of the busiest ports, KFIP & JCP, limited allocated area on artificial islands complicated logistic and arrangements required to drill
- **Permits** – as per above point the location presumed to obtain permits from different entities in the area as KFIP, Coast Guard, JCP, Marafiq, Ministry of Defense and others. However, Saudi Aramco facilitated their release in due time.

- **Logistics** – apart of the permits to enter different premises. The logistics to carry the equipment and consumables from and to onshore & offshore impose the need dedicated logistics team and equipment per each drilling location, onshore or offshore as each had its own complexity.

- **Geotechnical** – even if multiple geotechnical investigations been conducted, during drilling works each HDD borehole path faced changes in layers strengths of different compositions. Even if is expected to encounter changes the magnitude of the impact necessitated changed in the execution methodology, specialized tooling, increase in consumable consumption and arrangements to ensure safe execution.

- **SIMOPS:** During HDD execution, multiple drilling RIG's were present at each artificial island increasingly the risk of H2S and further complicating work environment requirements.

- **HDD#1** – shallow water (1.5m), limited drilling space allocated, drilling crossing in proximity of revetment, main string at 500m away from the HDD exit, pullback of string over the HDD#2 string in the shallow water are only few of the challenges that HDD#1 been faced with, however a specific marine and drilling spread only for this crossing been employed to execute in due time.

- **HDD#2** – being one of the longest offshore to offshore HDD crossing have been carefully treated and dedicated offshore spread been provided. The 2000m string with ARO coated, multiple channels crossings-imposed pipe string floating which further complicated the offshore arrangements and spread requirements. However, with meticulous planning the works been successfully executed.

- **HDD#3** – The offshore crossing length might not be longest, however due to the port breakwater crossing, deeper drilling has been made, due to the navigational channel a no-go zone been imposed by port authorities, due to the currents outside breakwater the pipe string has been kept flooded and only before pullback have been dewatered and pulled. The 1600m string length have additional challenges due to weather constraints.

- **HDD#4** – The most challenging for aspect of this crossing, apart from the geotechnical conditions which differed from all other crossings, was the logistics due to KFIP and Coast Guard which has specific rules and permits for crossing into their premises. The exit location was located in a shallow water of around 1.7m WD which same as HDD#1 made difficult access to the area and tide table been used in accessing.

- **HDD#6# & 5** – Drilling from a slightly confined area, KFIP Extension, with similar constraints as HDD#4 and crossing the KFIP causeway with utilities above and underground, busy highway to/from KFIP made these two crossings highly supervised by KFIP and multiple other entities with utilities which were crossed.

## CONCLUSION

Following the above description of the project, it can be considered one of the most difficult HDD Offshore-to-Offshore crossings attempted and successfully executed. In addition to the challenges explained, the length of the crossing was one of the most critical points to consider. The unique length of approximately 1.6km for drilled section and the string to be pulled of 2.0km, makes this project a benchmark in Saudi Arabia and worldwide.