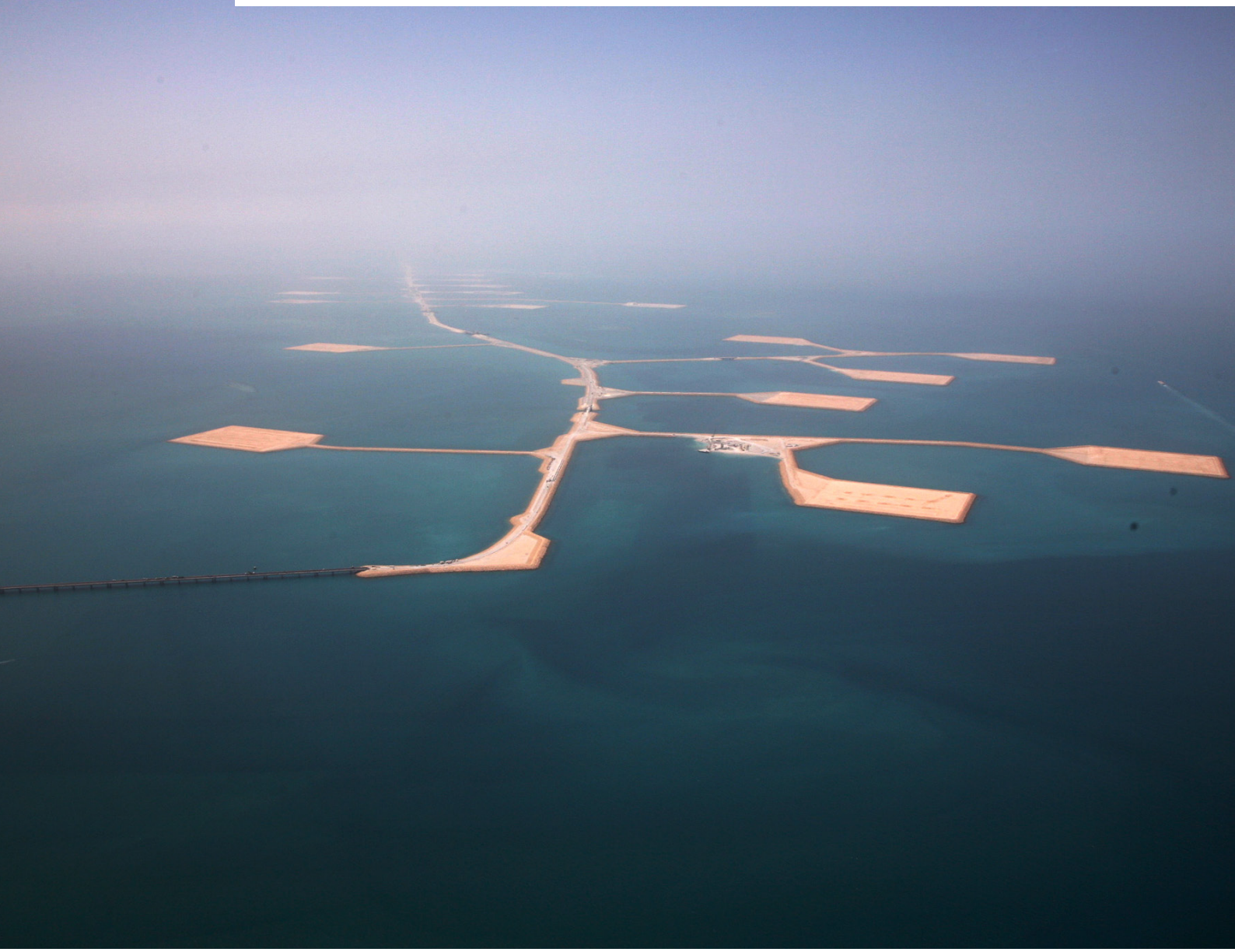
Jan De Nul GROUP

MANIFA FIELD

CAUSEWAY AND ISLAND CONSTRUCTION PROJECT



1 MANIFA OIL FIELD

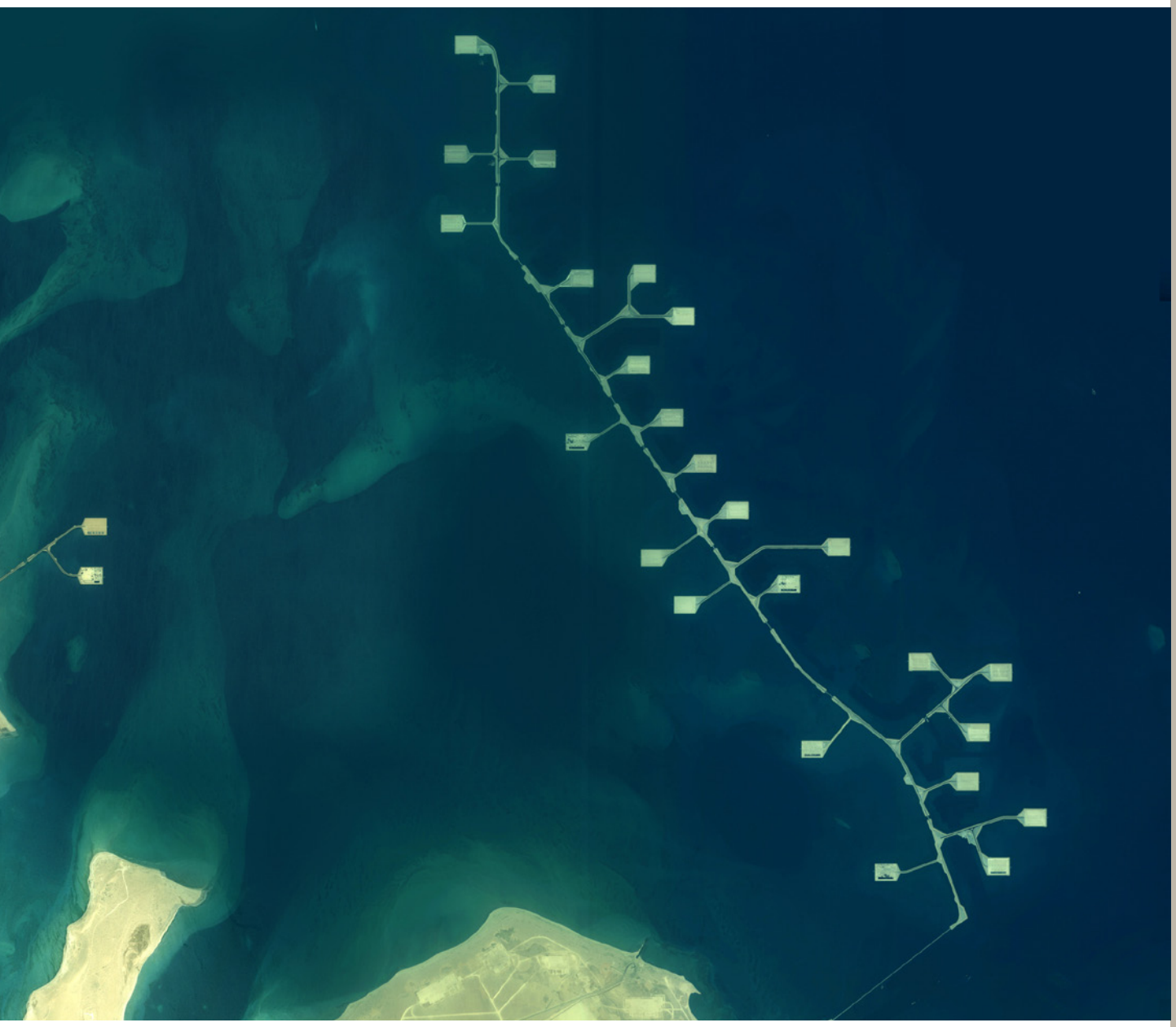
The Manifa Field Causeway and Island Construction Project, constructed by Jan De Nul Group, is by far one of the most prestigious projects ever realized in the Kingdom of Saudi Arabia.

The Manifa Oil Field is part of the Kingdom's most important crude oil fields. The field can deliver 900.000 barrels per day when fully operational. It is the largest offshore development ever undertaken by Saudi Aramco since their establishment 76 years ago.

The combined value of the contracts for Jan De Nul Group makes it one of the largest dredging contracts in recent years – worth 1.2 billion dollars. Jan De Nul Group engineered, procured and constructed the Manifa Oil Field Causeway and Islands Project as Main Contractor.

The Project is located on the east coast of Saudi Arabia, in the Arabian Gulf about 250 kilometers south of Kuwait.

The Manifa Causeway Project was an enormous worksite, covering a total area the size of Manhattan.



2 PROJECT DESCRIPTION

2.1 CLIENT

The Client and end-user is the Saudi national oil company Saudi Aramco, the largest crude oil producing company worldwide.

2.2 LOCATION AND CONSTRUCTION

The location is critically complex. The shallow waters of the Manifa oil field make it impossible to use common offshore oil drilling platforms. For that reason Saudi Aramco opted for the construction of 25 oil drilling islands covering the entire Manifa Oil Field.

Over a period of 3 years, 25 oil drilling and production islands with each 10 drilling wells for heavy duty crude oil, and two water injection islands had to be designed and built; causeways with a total length of 41 kilometer, including 14 bridges, of which the longest 2.4 kilometers, to connect the islands with each other and with the shore had to be engineered and constructed; 2 berthing areas and 1 roll-on / roll-off facility for supply vessels had to be constructed; and shore approaches for pipelines and cables had to be dredged.

Islands and causeways consist of hydraulically reclaimed sand volumes, shaped to final lay-out, covered with geotextile and rock revetment.

After reclamation, each island is compacted and finished with a marl layer to receive the drilling equipment. Asphalt roads are constructed on causeways and bridges.

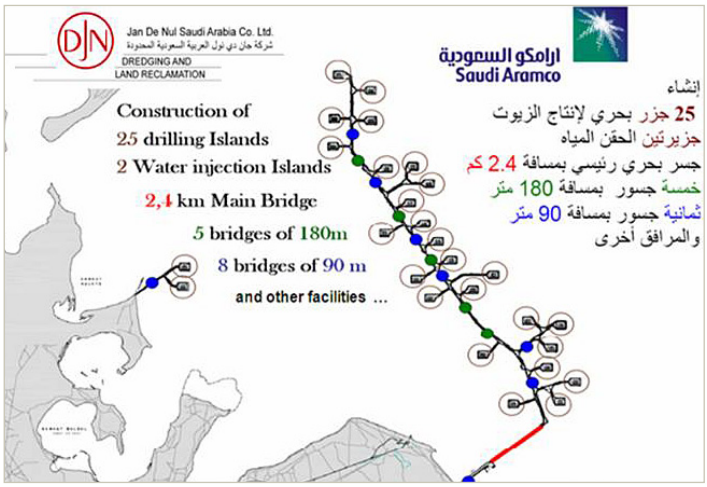
2.3 FACTS & FIGURES

FACTS

- Design was optimized to a large extend
- A high quality assessment and quality control of materials, construction and installation was required
- Considerable amount of different materials was used
- The site area covered about 80 km²
- The project entailed labour intensive and various different activities

FIGURES

- 25 oil drilling islands and 2 water injection islands
- 41 km causeways and roads
- 121 km rock revetment
- 14 bridges (1 main, 5 short and 8 culvert bridges), the longest 2.4 km
- 2 berthing areas, and 1 RoRo facility
- 52,000,000 m³ of dredged material
- 12,000,000 tons of rock for rock revetment
- 6 quarries, up to 600 km from site
- 150,000 m³ of concrete cast on site
- 9 km subsea trenching
- 6,000 m subsea pipeline removal
- 2 pipeline shore approaches
- 8 dredgers and 100 units floating equipment
- 300 units heavy construction equipment
- 3,000 workforces, 24 hrs operation, 40 nationalities
- Camp infrastructure for 2,000 residents

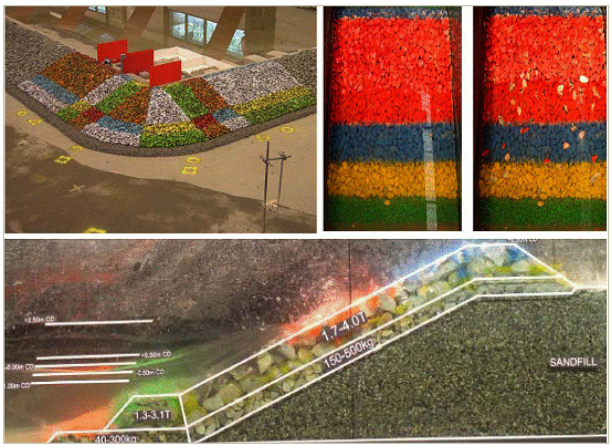


3 ENGINEER, PROCURE AND CONSTRUCT CONTRACT

The Causeway and Islands EPC package was the first Lump Sum Turn Key contract awarded for the Manifa Program, including 6 major offshore and onshore contracts. Jan De Nul NV (OOK) and Jan De Nul Saudi Arabia Co. Ltd. (IK), both subsidiary of Jan De Nul Group, took part in the engineering, procurement and construction of this megaproject. Jan De Nul Group designed and executed the works as Main Contractor, with several construction packages subcontracted to other international or local contractors and suppliers.

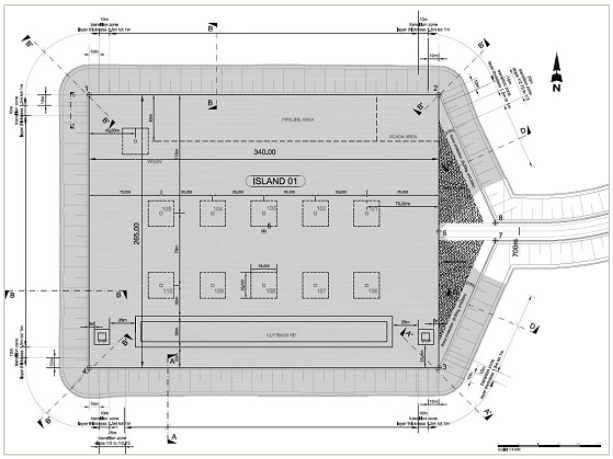
3.1 50 YEARS DESIGN LIFE

The design life of the project is 50 years. Therefore several case studies were performed for many different locations in the work and for a storm with a return period of 100 years. The required different gradings for the rock revetment on different locations was obtained through detailed numerical wave modeling and then tested by physical modeling in wave flumes and wave basins (2D/3D) by the designer in close cooperation with the laboratories of the University of Ghent (Belgium), of Sogreah (France) and of DHI (Denmark).

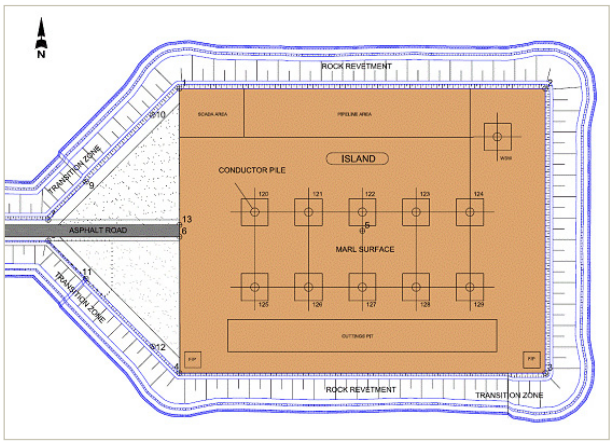


Different 2D/3D model testing in the following laboratories: University of Ghent (Belgium), Sogreah (France) and DHI (Denmark).

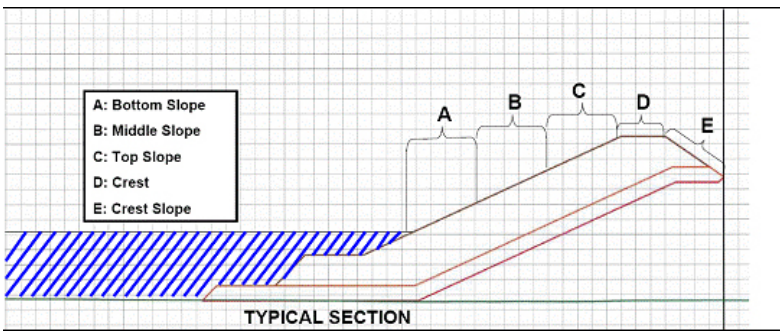
Frequent regular site inspections for the construction works carried-out by experienced JDN QC inspectors assisted by Saudi Aramco inspectors and independent 3rd Party inspectors (SECO).



Different levels above water on the breakwater inspected by the QC inspectors and surveyors. The portion under water was surveyed by certified divers and a survey boat.



Typical Island Layout

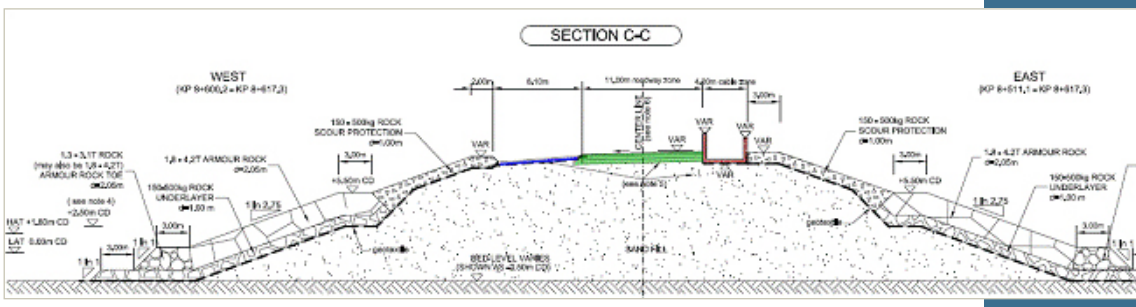


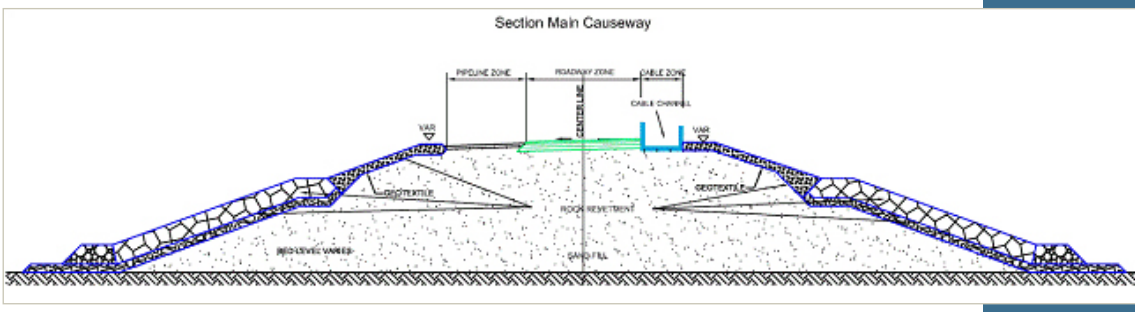
3.2 ISLANDS

Each island made provision for 10 production wells and 1 water injection well. The drill sites were prepared by installing a 25 m x 25 m compacted marl platform 1.95 m deep on each location, a fibreglass cellar and driving a 24 m long 'Conductor Pile' in the centre. The entire island surface is subsequently covered with compacted marl. Additionally one cutting pit and 2 flare pits were foreseen on each island.

3.3 MAIN CAUSEWAY

Stretching from the shoreline at Manifa, the main causeway goes offshore to the west approximately 4.2 kilometres and then turns north towards island 25 for a total length of 21 kilometres. Considering the cross section, the main causeway can be divided into 3 sections as per function: Pipeline Zone, Road and Cable Zone. As their names indicate, the zones are designated specifically to cater for different aspects of the eventual production facility.

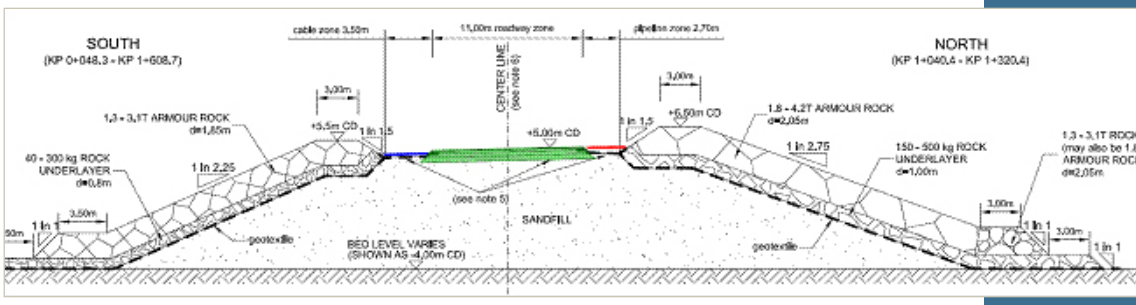




Typical cross section of main causeway (M06)

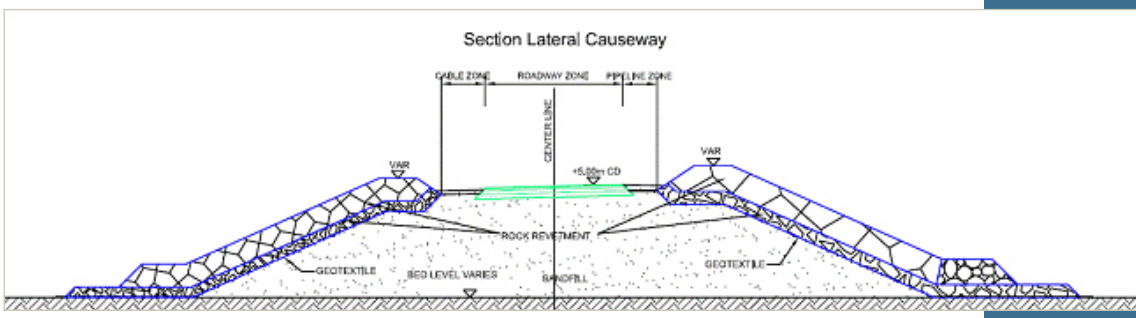
3.4 LATERAL CAUSEWAYS

Connecting each of the islands to the main causeway, the lateral causeways have the same designated zones as the main causeway with the exception that no cable channels are present on the laterals.

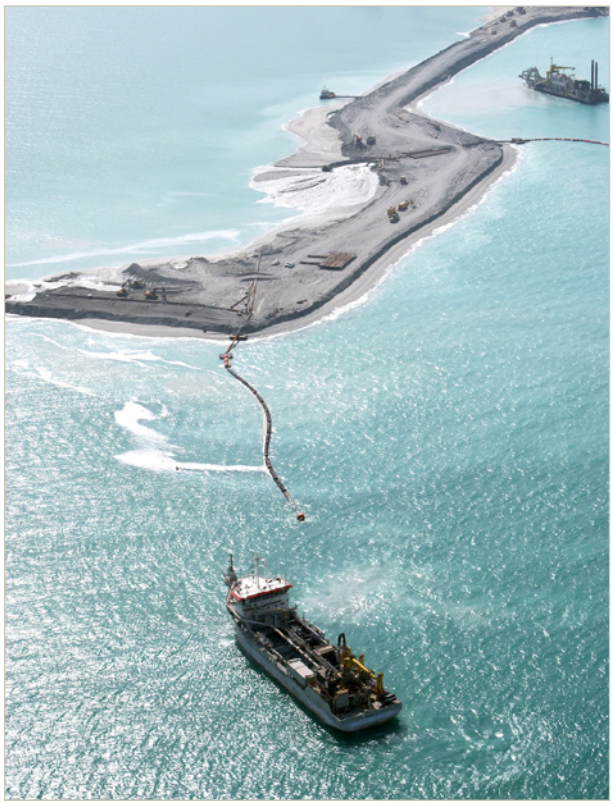


3.5 TRENCHING AND SHORE APPROACHES

Two shore approaches along with various offshore pipeline trenches were dredged on the Manifa Causeway Project, providing pipe lying possibilities for pipeline contractors. The total quantity for trenching exceeded 2 million m³.



4 SCOPE OF WORKS



4.1 RECLAMATION OF ISLANDS AND CAUSEWAYS

The reclamation activities were executed to construct the main and lateral (secondary) causeways to service 25 drilling / production islands and 2 water injection islands. The causeways support a roadway and facilities / zones for the future installation of pipelines, electrical cables and associated facilities. 50,000,000 m³ of sand was dredged, tested and reclaimed to complete these islands and causeways. A total of 11 dredging spreads were mobilized to perform the reclamation works.

Start 8 March 2007
End 26 Jan 2010

4.2 REVETMENT OF ISLANDS AND CAUSEWAYS

A strong type of geotextile filter layer (4,500,000 m²), produced in Belgium and specifically produced for the Manifa Project, was installed on the dredged island and causeway slopes to prohibit erosion of the dredged sand slopes. Different armour layers were installed to provide protection against wave attack and to limit overtopping by waves during periods of storm. The rock revetment for islands and causeways comply with the requirements for stability performance and overtopping. Drainage systems for surface water and storm wave water were also constructed. An amount of 13,000,000 tons of rock was sourced in different quarries, tested, transported and installed to complete the revetment.

Start 14 Sept 2007
End 23 Apr 2010

4.3 ONSHORE ACCESS ROAD

A 16 km marl access road was designed and constructed, from the existing Manifa paved access road to the touchdown point for Causeway to the 2 water injection islands 26 & 27.

Start 12 Jun 2008
End 7 Oct 2008

4.4 DRILL SITE PREPARATION

The islands are finished with a compacted marl layer to allow access and working area for the drilling equipment. Steel tubular"conductor" piles - finished with a fibreglass cellar - are installed at each drill well.

Start 10 Aug 2009
End 14 Sept 2010

4.5 ASPHALT PAVEMENT ON THE CAUSEWAYS

A total of 52,000 m³ of asphalt was consumed to complete the road construction. In total, 47.9 km of causeways and bridges was asphalted.

Start 24 Jun 2009
End 8 Apr 2010

4.6 ESCAPE JETTIES

For evacuation purpose and safety reasons, each island needs to have two exits. Therefore, the client requested the construction of escape jetties and launching mechanism for lifeboat on each island. This structure is composed of 2 bridge piles, 2 concrete crosshead beams, 2 pre-stressed I-beam, set of handrail, concrete stairs and slab, and a lifeboat mechanism module. This structure provides an escape or access away from an ongoing drilling process on a certain island, in case H2S emits.

4.7 MAIN BRIDGE, SHORT BRIDGES AND CULVERT BRIDGES

A 2.4 km long bridge at the southern end of the main causeway, together with 5 short bridges (180 m each) and 8 culvert bridges (90 m each) spaced along the causeways were constructed. Alongside the 5 short and 8 culvert bridges, an additional pipeline bridge was built.

Each bridge consists of a certain number of modules of 90 m each. These are connected by expansion joints.

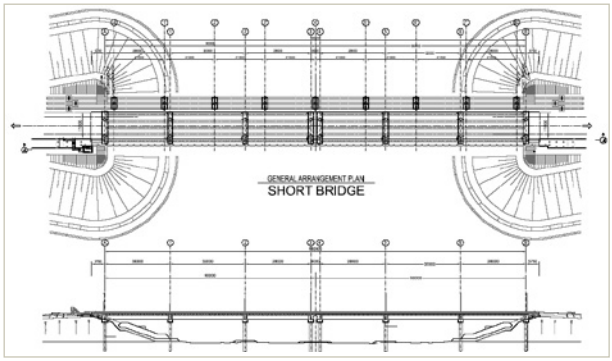
For the performance of the offshore concrete works, a floating concrete batching plant barge of approx. 22 m x 60 m, equipped with a minimum batching plant capacity of 50 m³/hour, was mobilized.

4.7.1 FACTS SHEET MAIN BRIDGE

The long main bridge contains 27 modules of 90 m (2,430 m x 13.90 m).

- 216 pcs bridge piles driven till refusal
- 108 pre-casted cross head beams
- 405 pre-stressed I-beams
- 17,312 pre-casted planks
- 4,860 lm of concrete deck slabs & steel handrails

Start **2 Mar 2008**
End **16 Feb 2010**

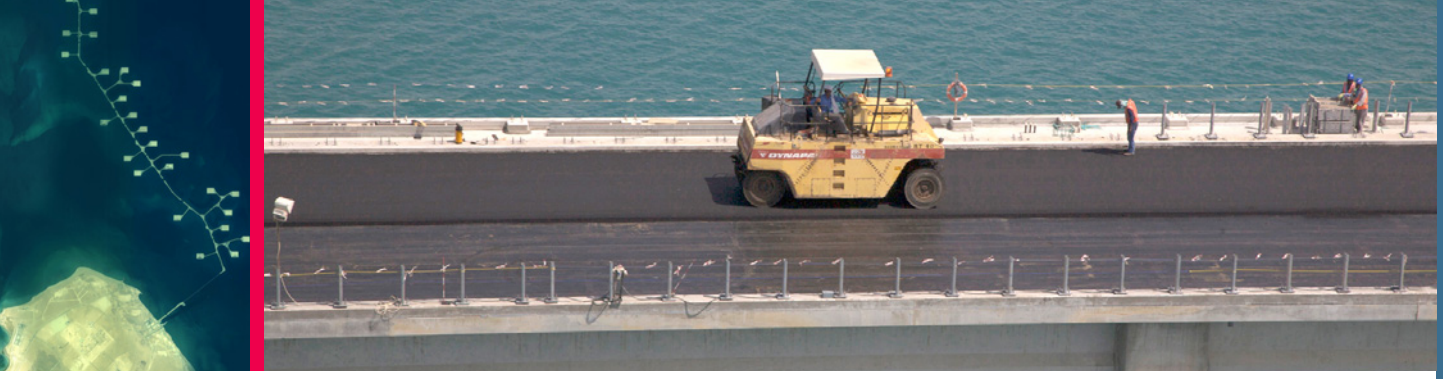


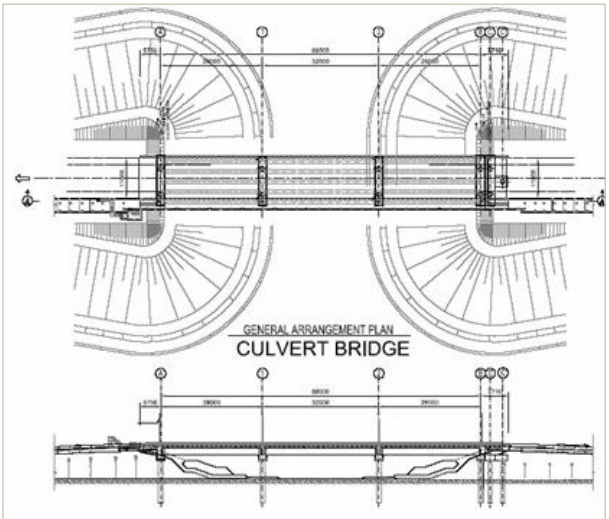
4.7.2 FACTS SHEET SHORT BRIDGES

Each of the 5 short bridges contains 2 modules of 90 m (180 m x 13.90 m).

- 125 bridge piles driven till refusal
- 85 pre-casted crosshead beam
- 150 pre-stressed I beam
- 6,725 pre-casted planks
- 8,415 lm of deck slabs
- sets of handrail

Start **6 Nov 2008**
End **21 Apr 2010**





4.7.3 FACTS SHEET CULVERT BRIDGES

Each of the 8 culvert bridges contains 1 module of 90 m (90 m x 13.90 m).

- 128 pcs of bridge pile driven till refusal
- 72 pcs of pre-casted cross head beam
- 120 pcs of pre-stressed I-beams
- 5,376 pcs of pre-casted planks
- 6,736 lm of deck slabs

Start 3 May 2008
End 14 Apr 2010

4.7.4 FACTS SHEET BRIDGE MODULE OF 90 M

- 8 steel piles OD: 1,219.20 mm, t = 22.20 mm
- 4 precast crosshead beams
- 15 precast I-beams
- 650 precast planks
- 4 in situ diaphragm beams
- 1 in situ deck concrete slab of 13.90 m width
- 2 in situ/precast cantilevers
- 1 asphalt pavement of 11.00 m width

4.8 RORO AND BERTHING FACILITIES

A shoreside RoRo facility including quayside and fixed RoRo ramps, adjacent to the landward section of the main causeway, as well as two berthing areas (north and south) including quayside and fixed RoRo ramps, on the main causeway, were constructed to accommodate vessels of Saudi Aramco.
The RoRo and Berth Area South consist of a pavement area (150 x 100 m), a ramp A with quay wall and a ramp B as Roll-on-Roll-off ramp. The Berth Area North only consists of a pavement area with quay wall.
The quay wall are executed as reinforced concrete bored piles with a double row of jet grout piles to avoid soil escaping towards sea. On top of it an anchored concrete capping beam is constructed with boulders and fenders.

4.8.1 FACTS SHEET RORO FACILITIES

- 3,465.50 m of bored piling works
- 8,117.50 m of jet grouting
- 52 pcs of tie rods
- 1,937.50 m³ of casting capping beam
- 6,100 m³ of subbase layer
- 6,766 m³ of casting deck concrete
- 53 pcs of fenders and bollards

Start 24 Mar 2008
End 3 Jul 2010

4.8.2 FACTS SHEET BERTH AREA SOUTH (BAS)

- 3,986 m of bored piling works
- 8,386.50 m of jet grouting
- 56 pcs of tie rods
- 357 m³ of casting capping beam rear
- 82 m³ of casting capping beam parapet
- 1,272 m³ of casting capping beam front
- 5,254 m³ of subbase layer
- 4,762.90 m³ of concrete paving rear
- 619 m³ of deck concrete for ramp A
- 371 m³ of deck concrete for ramp B
- 1,096 m³ of concrete paving front
- 53 pcs of fenders and bollards

Start 29 Oct 2008
End 6 Jul 2010

4.8.3 FACTS SHEET BERTH AREA NORTH (BAN)

- 2,249 m of bored piling works
- 5,125 m of jet grouting
- 35 pcs of tie rods
- 189.30 m³ of casting capping beam rear
- 29 m³ of casting capping beam parapet
- 888 m³ of casting capping beam front
- 1,898 m³ of subbase layer
- 1,197 m³ of concrete paving rear
- 976.50 m³ of concrete paving front
- 24 pcs of fenders and bollards

Start 9 Oct 2009
End 5 Jul 2010

4.9 PIPELINE REMOVAL

Redundant section of a subsea pipeline had to be cut and moved to a dedicated area, adjacent to the remaining pipeline.

Start 12 Apr 2008
End 29 Mar 2010

4.10 ADDITIONAL DREDGING WORKS

- A new access channel in order to provide access to vessels
- Shore approaches for cables and subsea pipelines
- Subsea pipeline crossings of navigation channels
- Dredging in borrow areas for reclamation purposes

Start 21 Apr 2007
End 20 May 2010

5 CHALLENGES

5.1 EQUIPMENT REQUIREMENTS

The construction and dredging fleet consisted of

- 11 pieces of dredging spread including Cutter suction dredgers, Trailing hopper dredgers and Splithopper barges;
- About 50 auxiliary vessels varying from tugboats, multicats, crew vessels, fuel vessels;
- 40 barges and pontoons, including several heavy lift crane barges, positioning pontoons, floating workshops and floating batching plant for offshore concrete;
- 150 pieces of heavy equipment varying from extra long reach excavators, dump trucks, wheel loaders, bulldozers, compactors, rollers and concrete miners.

Due to working in shallow waters, only vessels with limited draft could be deployed for the construction of the Manifa field.

5.2 QUALITY MANAGEMENT SYSTEM (QMS)

The rocks required to be installed as rock protection on the islands were purchased in the Kingdom of Saudi Arabia, at several quarries, up to 600 kilometers inland from the worksite.

Before transporting a batch of rocks, the batch was tested daily on density and resistance, in laboratory at the quarries and at site. Actual field drop tests are performed as well as shape and grading verification. These tests resulted in an extensive database of rock gradings. The gradings were limited for logistical reasons.

Main target was to deliver good quality materials and to install within the design limits. A practical QMS structure had to be set up, to be able to respond quickly, and to be able to follow the construction progress.

- More then 13 internal audits
- 3 fully equipped site 3rd party laboratories, offering the possibility to intervene easily and quickly in case negative trends were noticed for the dredged sand, rocks, aggregates, marl, concrete and asphalt productions.
- More than 50 QC inspectors on site and in the quarries.

5.3 LOGISTICAL CHALLENGES

- Deliveries and supplies of equipment and materials such as rocks, aggregates, containers, equipment, fuel, food, etc to a remote working location;
- Workforce and personnel: to source, employ and accommodate a workforce of - at peak periods - more than 3,000 labour with more than 40 different nationalities.
- Accommodation for workforce: construction of a camp in the remote desert for more than 2,000 workforces;
- Environment: Preservation of the existing sea fauna and flora, as well as the livelihood of local fishermen. In that sense, bridges were chosen, instead of dikes, to allow for the continued flow of the tides in and out of the bay and to preserve the original water quality.

OFFSHORE **MANIFA FIELD**

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