Marine and coastal engineering
COWI's services

- Welfare economics and services
- Public administration
- Social development and HRD
- Transport planning and management
- Cadastre and land administration
- Bridges
- Tunnels
- Ports and marine structures
- Roads
- Airports
- Railways and metros
- Telecommunications
- Development assistance
- Urban and regional development
- Environmental and social due diligence
- Geographical information systems and IT
- Mapping
- Energy planning and systems
- Residential buildings
- Educational buildings
- Hospitals and health buildings
- Cultural and sports buildings
- Industrial buildings
- Commercial buildings
- Environmental policy and regulation
- Natural resources management
- Environmental protection
- Health, safety and environment
- Municipal and hazardous waste
- Water and wastewater
- Production and process plants
- Oil and gas
- Coastal engineering

COWI currently provides services within 33 areas of engineering, environmental science and economics.
COWI group

COWI A/S is a leading international consultancy firm founded in 1930. The COWIfonden (the COWI foundation) is the majority shareholder and is totally independent of any third parties. The foundation supports research and development in various fields of consultancy activities. COWI's head office is in Kongens Lyngby, 12 km north of Copenhagen, Denmark.

COWI is a multidisciplinary firm providing services of the highest quality in the fields of engineering, environmental science and social economics.

COWI employs more than 6000 staff of which 3000 are based outside Denmark in subsidiaries, branch offices or projects offices. A high percentage of the employees are professionals holding PhD, MSc or BSc degrees in civil, structural, geotechnical, mechanical or electrical engineering and other academic areas such as geology, hydrology, chemistry, biology, agronomy, sociology, economics and planning.

The annual turnover is at present (2009) EUR 536 million (USD 725 million). About 60 per cent of the company’s turnover is generated outside Denmark in more than 100 countries around the world.

Transportation

COWI has more than 75 years experience in transportation consultancy covering all phases of infrastructure projects from initial planning and feasibility studies over design, construction and commissioning to maintenance management and rehabilitation.

Marine and coastal engineering

The COWI group provides consultancy and design services within the field of marine, geotechnical and coastal engineering from six centres of excellence. The total staff in this field of engineering is presently about 300 and increasing. The total annual turnover on international marine and coastal projects is approximately USD 40 million which makes COWI one of the leading international companies in this specialised field.

The six marine centres

COWI’s Marine and Coastal Engineering Centres reside in COWI’s head office, Copenhagen, Denmark; Ben C. Gerwick, Inc. (BCG), San Francisco, California, USA; Ocean and Coastal Consultants, Inc. (OCC), Trumbull, Connecticut, USA; Gurgaon, Haryana, India; and in COWI’s offices in Doha, Qatar; Abu Dhabi and Dubai in United Arab Emirates.

The offices of BCG and OCC comprise COWI USA, Inc. and from their west and east coast locations perform work in the North and Central Americas and the Caribbean. BCG is an internationally known civil/structural engineering consulting firm specialising in the design and construction of major marine structures. OCC is unique in its speciality of marine and coastal engineering because it has one of the largest groups of professional engineer divers in the United States. BCG’s branch offices in Oakland, California and Seattle, Washington and OCC’s two branch offices located near Boston, Massachusetts and Philadelphia, Pennsylvania extend COWI’s local presence to the major port centres on the east and west coasts of the United States.
Marine and coastal consultancy services and expertise covering all project phases

Investigation phase
- Geotechnical investigations
- Bathymetry & topography
- Underwater engineer diver inspections
- Condition surveys

Feasibility phase
- Generation and development of ideas
- Feasibility studies
- Studies of infrastructure needs
- Layout studies
- Assessment of design data
- Remediation concept development
- Cost estimation
- Construction and procurement scheduling
- Environmental impact assessment

Design phase
- Establishment of design basis
- Study of oceanographically conditions
- Design data studies
- Geotechnical assessments
- Durability design
- Civil and structural design
- Mechanical and electrical installations
- Operational risk assessment

Tender phase
- Development of tender design
- Management of tender procedures
- Value engineering
- Preparation of contract for construction

Construction phase
- Construction management
- Quality, environmental and safety management
- Construction risk management
- Interface coordination
- Programme and budget control
- Site supervision
- Contract and claims management

Operation and maintenance (O&M)
- O&M management systems
- Inspection of structures and installations
- Ranking of maintenance and reinvestment needs
- Repair and strengthening design

Key staff and contact information:
Marine and coastal consultancy

The COWI Group has, over the past years, strengthened and developed its capabilities in marine and coastal engineering both by organic growth and acquisitions.

The organic growth has taken place by hiring staff with international experience and many new graduates. The staff in the six centres of excellence is truly international with a multicultural background.

Experience

The COWI Group possesses extensive international experience in all aspects of port, marine and coastal engineering. This experience is documented by the many successful, completed projects on five continents of the world, from California in the west to Korea in the east and from Tierra del Fuego, Argentina in the south to Greenland in the north.

Focus has been on developing the relationship with our clients with the aim of providing added value to the clients’ projects.

The very diverse, multidisciplinary and multicultural background and professional experience have been brought to bear for the benefit of our clients and the projects we work on.

Quality management

COWI’s marine and coastal services are ISO 9001 certified. All design activities are carried out in accordance with the individual project quality plan tailored to meet the specific requirements of each project.

Services and expertises

COWI’s services cover the whole life cycle of a project from the early ideas over studies and design to the operation phase and rehabilitation or decommissioning.

Our services range from professional advice on a specific problem to comprehensive planning and total engineering design and implementation of large scale projects.

Our involvement in complex and demanding marine projects over the years has led to the development of particular in-house knowledge.

Marine terminals, ports, land development, man-made islands, breakwaters can be mentioned as special fields of experience.

Clients

COWI works for public and private infrastructure owners as well as for contractors. We advocate a close dialogue with the contractor (BOT and design-build projects) in order to take all data into account and to optimise the design and construction.

Understanding our client’s needs and combining this with our knowledge and experience to successful project completion is our goal.
Marine terminals

Oil and Gas

COWI offers completely integrated services relating to oil and gas marine terminals. This includes layout planning, operational and maintenance philosophy, marine construction, electrical systems and mechanical installations.

We plan and manage site investigations, undertake the assessment of geophysical data and define design parameters. We analyse meteorological and oceanographic data and use numerical wave and hydrodynamic modelling software to define design water levels and wave conditions and to calculate wave disturbance at the terminal. COWI uses selected sub-consultants for vessel manoeuvring studies to define dimensions for approach channels and turning basins.

Planning of the berthing head arrangement is based on the project specific vessel range together with loading/unloading requirements. We perform in-house dynamic mooring analyses including vessel downtime assessment.

Facilities design includes berth and loading facilities, breakwaters, access trestle and pipe racks/conveyors. Physical model tests are made by subconsultants, who have worked with COWI for ages.

In addition, facilities design includes tug berths, construction docks, buildings, electrical and mechanical installations, including security features and emergency shutdowns.
Ras Laffan Marine Terminals, Qatar

Ras Laffan Port, Qatar was built in the early 1990s and is now becoming the world's largest liquefied natural gas (LNG) exporting port. The port was designed as an export facility for LNG, Condensate and Sulphur derived from the processing of gas landed from the North Field Gas Reservoir situated 67 km NNE of the Port. Ras Laffan is currently expanding the original port facilities and has identified the need for both new LNG berths as well as new multi-user liquid product berths from which gas-to-liquids (GTL) products can be exported.

COWI has, so far, been involved in the planning, design and construction of the following marine terminals:
- Liquid product berths 1A and 1B
- Liquid product berths 3A and 3B
- LNG berth 3
- LNG berth 4
- LNG berth 5
- LNG berth 6

The liquid product berths are designed to enable simultaneous berthing, mooring and loading of two vessels from 20,000 to 300,000 DWT. The berths have a common approach jetty with approach road and have pipe racks on either side leading from the lee breakwater to the loading platform area. The loading platform accommodates 11 loading arms for each berth. The berths are constructed using mass concrete blocks and consist of breasting and mooring dolphins, quick release hooks, catwalks for access to the mooring dolphins, navigation lights, fenders, fire fighting facilities, ship-to-shore gangway and lighting amongst other topside facilities. The buildings consist of a common control building, an electrical substation and a firewater pump house as well as pipe racks and other piping structures.

The LNG berths are designed to enable berthing of LNG carriers up to 267,000 m³. LNG berths 3, 4 and 6 are constructed using mass concrete blocks some of which weigh up to 700 tonnes. The berths consist of a loading platform with topside structures and equipment, mooring and breasting dolphins, catwalks, berth furniture as well as an access causeway. LNG berth 5 is also designed for LNG tankers up to 267,000 m³ but by using pile supported structures and constructed outside the existing main breakwater before the new main breakwater is in place. Due to the rough seas during construction, pile supported structures are being considered for this berth.
**Services**

- Review of project basis including berth layout study and the geotechnical investigations
- Execution of dynamic mooring analysis
- Preliminary and detailed design of steel structures
- Construction support
- Design of jacket structures to be placed on 10 - 17 m water depth
- Design of module support frames to be supported by the jacket structures
- Design of 0.7 km e-w trestle and access platforms

**Project period**

2006 - ongoing

**Client**

Archirodon Construction (Overseas) Co. S.A.

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**Ruwais third NGL train jetty project, Abu Dhabi, UAE**

The GASCO plant is expanding the export facilities at their Ruwais plant in Abu Dhabi, UAE with a third train export line and the construction of two new berths for export of natural gas liquid (NGL). The berths shall accommodate LPG carriers with a capacity of up to 125,000 m³. The work included design of jacket structures to be installed in 10-17 m water depth, design of module support frames to accommodate topside facilities and design of a 700 m long access trestle to the new loading berths.
Large liquid terminal port,
New York Harbour, USA

Consulting engineering services for a large multi-purpose liquid terminal facility in the New York Harbour area have been provided since 1994, providing marine engineering, dredging, permitting, and program management services. The facility has six recently dredged deepwater tanker berths and twelve barge berths. The services include underwater investigation with registered professional engineer (PE) divers. In the last 5 years we have been responsible for rehabilitation of piers and wharfs, emergency repairs, dredging, and environmental remediation.

Services
• Underwater investigation with PE-divers
• Moored vessel analysis
• Hydrographic survey
• Maintenance dredging

Project period
Ongoing

Client
Large Liquid Terminal Operator

New York Harbour liquid terminal facility

Gabbro berth Mesaieed, Qatar
**Bulk terminals**

Like other ports and port terminals the study and design of bulk terminals rely on general marine engineering and special expertise on the systems for handling of bulk. The latter is normally tailored to the actual type of bulk material to be loaded or unloaded at the terminal.

Otherwise bulk handling terminals can be made at long quays like general cargo or container berths or at jetty structures quite similar to the ones used for oil and gas terminals.

The design thus requires knowledge of the requirements associated with the specific type of bulk material and the various types of handling systems, ranging from traditional grab handling to various types of conveyor belts to systems using pipes for pumping of the material in question.

The designer works with suppliers of such special systems to develop optimum solutions.

COWI undertakes all types of services for bulk terminals ranging from planning, layout studies, hydraulic studies, surveys, environmental assessments, feasibility studies, conceptual and detailed design, tender documents, contracting and contract supervision and management.

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**Ruwais sulphur expansion, Abu Dhabi, UAE**

TAKREER is expanding the production and berth facilities at their plant in Ruwais with a new berth for the export of granulated sulphur. The new berth shall accommodate vessels up to 65,000 DWT. The project involves construction of berthing and mooring dolphins, quadrant beam and support trestle, landreclamation and pivot foundation for shiploader.

Also met-ocean study, dynamic mooring analysis, detailed design of marine facility, tendering and construction support are included.

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**Services**

- Met-ocean study
- Dynamic mooring analysis
- Detailed design of marine facility
- Tendering and construction support

**Project period**

Ongoing

**Client**

Pegasus TSI Inc.
Ports and harbours

The services for ports and harbours are thus multidisciplinary in nature and include, in principle, the same studies and design tasks and types of civil engineering structures as other marine structures. However, of special importance is the specific use of the ports and harbours and which boats or ships they shall accommodate. Each type of vessel and operation and type of loading or unloading equipment has its specific requirements. Such requirements come from experience and are defined in the International Navigation Association (PIANC) guides, such as “Criteria for Movements of Moored Ships in Harbours”, the preparation of which was headed by COWI staff.

Port of Copenhagen

The Port of Copenhagen A/S undertook a large port development project that includes a new ferry terminal in Søndre Frihavn (Southern Free Port) and planned for construction of commercial and residential buildings on the former DANLINK sites. The development includes relocation of ferries operated by DFDS Seaways away from the congested Copenhagen City.

As the client’s representative COWI provided multidisciplinary services and project management, which included the following components:

• Planning and design of quay structures and piers in 9 m water depths
• Dredging plans
• Traffic analysis on the terminal area
• Testing of the proposed layout using 3D real time ship navigation simulation at the Danish Maritime Institute (FORCE)
• EIA (environmental impact assessment) and environmental screening
• Estimate of construction costs including maintenance using successive calculation
• Soil logistics (recycling of polluted soil as landfill within the project area)

COWI, together with the client, have implemented a commercial document control program. Through the internet, this gives all project participants full accessibility and control of digital documents and drawings from the planning phase to the final phase.

Services

• Project management
• Conceptual design
• Prequalification of contractors
• Tender documents
• Contracting and supervision
• Review of contractor’s design
• Traffic analysis
• EIA
• Cost estimate
• Digital document management

Project period

2000 - 2003

Client

Port of Copenhagen A/S
**Container terminals**

Container terminals are normally made in connection with a long straight quay as the terminal requires quite a width perpendicular to the quay to make room for container cranes at the quay front and for transport laterally along the quay and finally for storing/stacking of containers in the container yard.

Container vessels are becoming larger and larger and the latest development in vessel size implies vessels up to 400 m in length and a draft fully loaded in the order of 16 m, thus requiring depth at the quay front of about 17 m. The quay structures for a container terminal are thus quite similar to the ones used for other types of port terminals with the exception that, most often, the crane rails require piles as foundation. These piles can be an integrated part of the quay structure. Otherwise the designer of a container terminal works closely with the operator to develop a tailored optimal system for the specific terminal including the requirements to container cranes and the special type of equipment required for moving and stacking of containers such as straddle carriers. A container yard has very heavy traffic and the design of the heavy duty pavement requires special attention.

**Services**

- Planning of the terminal operational concept
- Site surveys
- Environmental assessment
- Design of marine works
- Specification of container handling equipment. Preparation of tender documents and tender assistance
- Design of onshore works including pavement, roads, mechanical, electrical and buildings

**Project period**

2007 - ongoing

**Client**

Mesaieed Industrial City

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**Berths 7A & 7B - container terminal, phase 1 & 2, Mesaieed, Qatar**

QP/MIC is expanding the berth 7 at Mesaieed Port (located 40 km southeast of Doha, Qatar) into a dedicated container terminal. The berth is for 4,000 TEU Panamax vessels. The new quay wall is a block wall designed with un-reinforced precast blocks for a water depth 13.5 meter. The quay wall is supporting rail for STS-crane. The landside rail is supported by a reinforced crane beam on bored concrete piles.
Wharf embankment strengthening berths 35-37, Port of Oakland, CA, USA

As part of the Port of Oakland “15 meters channel deepening project,” the port is strengthening the Evergreen Terminal (berths 35/37) with the construction of a new waterside crane girder and sheet pile bulkhead wall. As the prime consultant for the structural analysis and design of wharf improvements we performed: new concrete crane girder, concrete piling, steel sheet pile bulkhead wall, fenders, bollards, crane rail, crane anchors, crane stops, seismic monitoring, cable trench and utility vaults and trenches.

The work included development of design criteria for future crane loads, vessel moorings, seismic and geotechnical analyses, electrical design of crane and communication requirements, mechanical design of potable and fire water, drafting, construction phasing, cost estimates, and specification writing.
Marinas and small craft harbours
The planning, development and design of marinas and small craft harbours utilises COWI’s experience in geotechnics, hydraulics and marine/coastal structures.

For marina design COWI has experience in developing the project from the initial surveys and studies through preliminary and detailed design to tendering and construction completion.

COWI has in-house experience covering the core competencies required for marina planning and design which are:

- Demand studies consisting of transport trend analyses, traffic forecasting, financial evaluation and boat mix assessments
- Layout planning and studies including terrestrial and bathymetric surveys, geotechnical investigations, environmental impact assessments, numerical modelling of various hydraulic aspects such as sedimentation and wave disturbance assessment, definition of spatial requirements, optimisation of berth layouts and protection measures such as breakwaters and slope protection
- Infrastructure design being the design and specification of pontoons, walkways, access ramps, moorings, navigation aids, slipways, shiplifts, maintenance and service areas, utilities and security, buildings and roads and fuel and pump-out facilities

Improvement of navigation conditions and future expansion of the Port of Frederikshavn, Denmark
The Port of Frederikshavn is among the 10 largest ports in Denmark and has plans for further expansion.

The improve navigation condition and to meet the future demands, COWI has developed concept designs for a new foreharbour and a future expansion of the northern part of the Port.

Services
- Numerical modelling of wave disturbance and current conditions for optimisation of new foreharbour
- Analysis of expected down time due to wave disturbance
- Assessment of sedimentation conditions
- Full bridge navigation simulations with new foreharbour
- Numerical modelling of sediment spill and spreading during dredging operations
- Geotechnical investigations
- Conceptual design of new foreharbour, incl. design of two new breakwaters and breakwater head caissons
- Conceptual design of future expansion
- Investigation of legal bindings, regional and local planning aspects and requirements to an EIA for the port expansion

Project period
2006 - 2008

Client
Port of Frederikshavn, Denmark
Halul harbour refurbishment, Qatar

Halul Harbour is located on the southern side of Halul island 80 km northeast of Qatar. The refurbishment of the harbour commenced with a review of hydraulic design conditions and numerical wave disturbance modelling to determine the environmental parameters for the breakwater design.

The wave disturbance modelling was undertaken using MIKE 21 BW. Several different arrangements of the western breakwater were modelled to minimise the wave disturbance within the harbour. Based on these findings and with consideration to navigation, optimisation of the breakwater layout was then completed.

Following the agreement of the layout detailed design of the western breakwater was completed using CORE-LOC units as the primary armour. Further, 3D physical modelling was used to confirm the breakwater design. Technical and material specifications were also produced.

Services
- Numerical wave modelling
- Physical modelling
- Engineering design of marine structures
- Technical specifications and drawings

Project period
2001 - 2002

Client
Archirodon Construction (overseas) Co. S.A. Dubai
Coastal engineering is a special field within civil engineering. It includes the physical processes of the sea and coastal regions and the movements of sediments due to the water in motion. It further includes the interaction between interventions and man-made structures and the physical environment.

It is this complexity that makes coastal engineering such a special field compared to many other civil engineering disciplines and what fascinates coastal engineers. The engineer or designer often has to be imaginative and exercise personal judgement in calculations in order to arrive at correct and yet still acceptable structural solutions.

The structures are founded on the sea bed or on the shoreline and exposed to water level changes, currents and wave impacts. Further, the site and the area around the structures are, in many cases, subject to morphological changes which have to be analysed and understood prior to construction. It is our strong aim “to work with nature rather than against it”. This may be taken as our mission statement within coastal engineering.

It is, therefore, natural for us to try and minimise the use of man-made structures on a shoreline and attempt to use beach nourishment wherever possible. In line with this mission we will, when working on marine projects, seek solutions attempting to minimise human intervention, i.e. placing a port or similar installation where it requires the least movement of materials, by, for example, selecting the site and distance from the shoreline such that the quantities in breakwaters and other structures as well as dredging and filling volumes are minimised. Further, it is our aim to seek solutions that involve the smallest possible changes in the natural, physical as well as flora and fauna environment.

Numerical models are more and more used as a tool and COWI has strong in-house capabilities in this field as described elsewhere.
Irish Rail sea defence works
A significant section of the Irish rail network lies close to the shoreline and is subject to ongoing coastal erosion, instability of coastal defence structures and wave overtopping, especially along the east coast between Dublin and Wicklow.

Iarnród Éireann (The National Irish Rail Company) is currently implementing a long-term plan for protection of the coastal railways, as part of the Cuttings and Embankments programme.

Since 2000, COWI has carried out a feasibility study for coastal defence works as part of this Cuttings and Embankments Programme. The study produced a 10-year strategy, in which geotechnical and coastal defence works were planned and prioritised. The project programme included the following coastal projects:
- Malahide Causeway
- Sorrento Point
- Bray Head
- Ballygunnon (south of Greystones)
- Kilcoole
- The Breaches
- Six Mile Point (Newcastle)
- Five Mile Point
- Rogerstown Causeway
- Merrion Gates to Blackrock
- Rosslare Strand

A variety of geotechnical and coastal defence works are adopted in order to suit the local site conditions.

Heavy rock berm structures have been applied to the coastal defences in areas of steep rocky headland where the railway line runs in a series of embankments and rock cuttings supported at their base by masonry retaining structures.

At several locations, the railway runs on top of what is thought to be ancient littoral berm formations. These are fronted by sandy beach and with low hinterland. At these locations, the coastline is subject to rapid coastal erosion. Therefore, new revetments have been established. In order to preserve the amenity of the beaches, the new revetments have been partially buried into the beach and the reconstructed dunes have been planted with marram grass.

At other locations, rock and concrete block revetments behind the beach protect the track.
Breakwater projects

COWI is an international name in the design of breakwaters. Our experience reaches from fundamental scientific research to numerical model studies and physical model testing to design and supervision of construction.

COWI’s staff has more than 30 years experience from over 150 international breakwater projects in 5 continents. The experience includes all types of breakwaters from rubble mound to caisson. In addition, the experience includes an extensive variety of armour units such as quarry rock, cubes, grooved cubes, dolos, tetrapods, accropodes, and CORE-LOC.

COWI uses its in-house capabilities in numerical modelling of wave propagation as the basis for defining design waves and then for the configuration of breakwaters and to perform conceptual analyse and design. We specify and supervise 2D flume tests and 3D physical model tests.

If ground conditions are poor, state-of-the-art soil structure interaction analysis software is used to analyse the breakwater foundation and define soil improvement works as necessary.
Waterfront developments
Waterfront developments include both the development of existing ports and harbours for residential purpose and the study and design of large-scale dredging and reclamation works.

We specialise in developing projects from master planning, surveys, environmental impact assessments, design of edge structures and reclamation, preparation of tender documents to supervision and construction management.

The Lagoons, Dubai, UAE
The Lagoons is a landmark project, and is situated at the end of Dubai Creek, north east of the Ras Al Khor Wildlife Sanctuary. It is formed of seven man-made landscaped islands representing the seven Emirates of the UAE, which, together, will provide extensive navigable waterfront. It is a mixed use waterfront development that will accommodate both high-rise and low-rise residential and commercial buildings, five star hotels, resorts, marinas, a planetarium, a theatre and art centre as well as the iconic Opera House on the existing island. Construction is already underway with an estimated completion date of 2010.

The Lagoons covers an area of almost 16.5 km². Positioned adjacent to Dubai Festival City, with the Ras Al Khor Wildlife Sanctuary to the south-west and the sixth crossing to the north, the development holds a prime location along the Dubai Creek.

Transportation around the islands will be supported by a series of bridges and causeways as well as public transport facilities. Once completed, the facility will have approximately 40 km of waterfront land.

Services
• Several kilometers of concrete block work quay wall and revetments
• Navigational locks providing access to the impounded lagoons
• Navigable canals and waterways
• Excavation, dredging and reclamation
• Hydraulic studies
• Mechanical water quality system
• Navigational locks
• 8 marinas scattered around the site with a total capacity of more than 800 boats

Project period
2008 - 2010

Client
Sama Dubai LLC
The Pearl – Qatar
The Pearl, a project in Qatar involved detailed design of the reclamation works for the 400 hectares new island requiring approximately 13.5 million m³ of fill and the associated sea defence structures for the 40 km of new shoreline.

Numerical hydrodynamic model studies were carried out to determine the hydrodynamic design basis.

The development includes private beaches along most of the perimeter which adds to the aesthetics and exclusiveness of the development. Various concepts have been developed to create a variety of beach environments that are optimised to suit the local conditions and requirements.

Along the shores facing north and east relatively long pocket beaches have been created. The sand is retained between groyne structures. Private open beaches have been separated by beach breakwaters at one of the shorelines facing southwest. Generally, terraced beaches have been used where the wave impact is oblique and an open beach would be eroding. The terraced type consists of a low crested revetment behind which a sand beach is constructed.

Concrete block gravity quay walls are used in the western cove (Porto Arabia) and along the channels in the Venice type development (Qanat Quartier) at the north-west shore to facilitate mooring of boats and to create the confined channel system.

Each of the Isola Dana islands feature a private beach, harbour and terraced beach fringed by a low crested revetment.

COWI has, subsequently to the island design, rendered technical assistance during construction and made design of the marinas.

The island has been inaugurated and the first people will move in early 2008.
Lusail Development, Qatar

The new waterfront development is located along the shoreline north of Doha. It will cover an area of about 21 km² which is about the same size as the entire Midtown and Lower Manhattan in New York.

The project will transform the present shoreline through dredging and reclamation, creating new islands, access channels and beaches. The new development will include low- and high-rise residential housing for about 200,000 inhabitants. Further, the development will include business, corporate and mixed use areas as well as quality beaches with top class hotels, two golf courses and an entertainment district.

From August 2004 to January 2006, COWI completed planning and design activities of the marine and earthworks for the Lusail Development as sub-consultant to Bechtel Overseas Corporation. In February 2006, the owner entered a 2½ year contract with the Chinese contractor Sinohydro for the construction of the marine works.

In early 2006 COWI, in cooperation with Halcrow, Hyder and David Adamson, were selected by Qatari Diar to design and supervise all infrastructure for this multi-billion dollar development project. The construction of the infrastructure works is scheduled to be completed in 2011.
Offshore wind turbine foundations

Over the years COWI has developed innovative off-shore foundation concepts for offshore wind turbines that are today regarded as proven and accepted.

Our foundation design expertise also includes monopiles, four-legged jackets as well as jack-up installed STAR tripods.

The Nysted and Thornton Bank gravity base foundations were innovative designs developed together with the contractors to meet site specific challenges set by foundation conditions as well as fabrication and installation requirements.

COWI’s project approach, combining hydraulics, geotechnics, structural engineering and fabrication/installation procedures into integral solutions, provides the client with optimal solutions for his specific project needs.

COWI’s unique in-house FEM program IBDAS is an integrated design and analysis tool. It allows for integrated parametric geometrical modelling, structural analysis and verification of structures against internationally recognised codes and standards as well as generation of construction drawings.

The features include static and dynamic analysis in the full range of limit states: ULS, SLS, FLS and ALS.

Other state-of-the-art design numerical models and design tools used by COWI in all phases of the project include ROBOT for structural design, MIKE 21 for numerical hydraulic modelling, PLAXIS for geotechnical design, ABAQUS for soil-structure interaction and SESAM for jacket structures.

The verification of structural strength and the stability in the construction phase are coherent in the design activities.

This includes impacts during transport and installation such as loads induced from lifts, dynamic impact during transportation, and impact during installation.

We conduct installation studies taking the permissible weather windows into account and we provide the client with a basis for optimising his installation requirements.
Nysted offshore wind farm at Rødsand, Denmark

Denmark has formulated an energy policy giving high priority to sustainable energy, where wind turbines are very important elements. Several offshore wind farms are planned and COWI served as consultant for the one at Rødsand.

COWI has carried out detailed design for 72 wind turbine gravity foundations located in the Baltic Sea some 9 to 10 km off the southern coast of the Danish island of Lolland. They are 2.2 MW Siemens wind turbines.

The wind turbines are founded at 7.5 to 12.75 m depth on stiff clay till. The gravity foundations are open reinforced concrete structures that are subsequently filled with ballast and covered with armour stones. The foundation is provided with an ice cone. The design is based on an optimal utilisation of the subjacent soil conditions versus load conditions when defining the foundation level of each position.

The foundations are designed to sustain cyclic loads from wind, wave and ice forces during their 25 year lifetime.

The detailed design included geotechnical, structural and scour protection design, the latter validated by hydraulic model tests. The geotechnical and structural designs were carried out using state-of-the-art numerical tools, e.g. PLAXIS and IBDAS.

Rødsand 2

COWI in a joint venture with Aarsleff and Bilfinger-Berger is carrying out basic and detailed design of 90 wind turbine foundations, located off the southern coast of the Danish island of Lolland. The wind turbines are 2.3 MW Siemens to be founded at 6 to 12 m water depth. The services comprise installation loads, hydraulic load assessments, structural design and geotechnical design.
Thornton Bank offshore wind farm, Belgium
The Thornton Bank is located in the North Sea some 30 km off the Belgian coast. When fully developed, the Thornton Bank offshore wind farm will comprise approximately 54 wind turbines. The first phase completed in 2008 comprised 6 wind turbines.

The wind turbines for the first phase are REpower 5 MW turbines. The turbine hubs are 94 m above sea level. The gravity base foundations for the wind turbines are founded in sand of medium grain size.

In 2003-2004 COWI carried out a concept study for alternative foundation solutions including the innovative conical shell structure eventually adopted by the project owner.

The prestressed concrete foundation structure is composed of a cylindrical shaft on top of a conical base transferring the loads from the wind turbine directly to the base slab.

The post-tensioned structure provides favourable strength and stiffness properties as well as fatigue and crack resistance.

At the deepest location, the gravity base foundation structure extends from -27 m TAW to +17 m TAW. The base diameter is 23.5 m and the shaft diameter is 6.5 m, matching the diameter of the turbine tower.

The foundation gravity base structures are prefabricated on land, and installed at sea by a heavy lift crane, on a pre-installed gravel bed.

The weight of the concrete foundation structure is about 2,700 tonnes. After placing, the foundation is ballasted by a combination of sand and heavy fill, sufficient to ensure the stability against overturning moments. The total dry weight may of the ballasted gravity base foundation be up to 7,000 tonnes, depending on quantity and type of infill.

Services
- Structural design of foundation
- Geotechnical design
- Hydraulic design of installation stages
- Numerical and physical hydraulic modelling of installation stages, including dynamic loads and scour
- Appurtenances design including boat landing and J-tubes
- Project follow-up during construction stage

Project period
2006 - ongoing

Client
Dredging International n.v., Belgium
Locks, dams and barriers

We have a proven track record of providing cost-effective solutions to lock and dam projects using off-site prefabrication, float-in and in-the-wet construction technology. Our unique solutions minimize risks and reduce the time for construction through the use of innovative design and construction methods that avoid long lead times. Our expertise includes pump stations, cofferdams, marine skidways, precast yards, bulkheads, dewatering, underwater repair, levees, floodwalls, canal lining, flexible revetments and articulated concrete mats.

Our services include soil-structure-interaction and foundation analyses, FE modelling, waterway traffic and navigation studies, dredging design, cofferdams, float-in and in-the-wet construction methods, heavy lift and transportation technology, seismic analyses, hydraulic modelling, fish-bypass structures, coastal engineering and geotechnical engineering.

New Orleans flood protection barrier, USA

Ben C. Gerwick, Inc. is responsible for the detailed design of the flood barrier and the monoliths and foundations, for the main sector gate structure which will be used to regulate navigation, tidal flows, and storm surge into the inner harbour navigation canal (IHNC) in New Orleans.

The federally funded contract is for construction of a storm surge barrier to keep surges from entering New Orleans’ inner harbour navigation canal. Failures of floodwalls overwhelmed by storm surge during Hurricane Katrina in 2005 along IHNC contributed greatly to the flooding of the city.

The IHNC barrier is to be built by the end of 2011 near the confluence of the Gulf intracoastal waterway and the Mississippi River Gulf outlet, a natural funnel identified as an area of critical vulnerability. Depending upon the design and site chosen, the final structure could be longer than 2.7 km. It is to include a combination of static and gated barriers that are to remain open for shipping, except during storm-surge emergencies. The contract, which began on September 2008, included “advanced measures” to reduce the storm surge flood risk for residents around IHNC until the barrier is finished.

Services
- Detailed design

Project period
2008 - 2009

Clients
The U.S. Army Corps of Engineers and Louisiana’s Coastal Protection and Restoration Authority
Braddock Dam lock #2, Monongahela River, USA

We took the lead in designing the float-in precast dam segments and developing “in-the-wet” construction methods and procedures including:

- Conceptual design of the cast and launch system for the precast dam segments
- Transport, positioning and immersion of the segments on to pre-installed foundations
- Developing a cast and launch facility for two 11,000 tonnes dam segments
- Designing a 100 m long precast shell with sufficient strength for launch, transport and immersion while maintaining a 3 m maximum draft
- Developing a transport, positioning, immersion and dam completion plan that can safely accommodate a 500-year flood on 48-hour notice
- Developing a positioning system with +/- 35 mm vertical and +/- 50 mm horizontal tolerances
- Drilled pier foundation layout and preliminary design
- Underbase grouting and tremie in-fill concrete plans
- Risk analysis of the segment, launch, transport outfitting and installation
Olmsted locks and dam, USA

After construction, the precast shell segments will be lifted by a 5,100 tonnes gantry crane to a skidway where they will be lowered down into the water on a cradle using push-pull units. Once they are in the water they will be lifted by a catamaran barge and positioned in the river.

As part of the detailed design and construction of the Olmsted Dam, we provided the detailed design for the new dam and also construction design support of the precast yard including the marine skidway for load-out of the pre-cast shell segments. The construction design encompassed concrete and steel retaining walls, gantry crane beams, skidway rail including beam and foundation system both above and below water, precast shell cradle, steel frame tremie mat templates, lifting/mating details for the precast shells, mooring anchors and dolphins. We also completed the shell design for the navigable pass precast segments, paving blocks and the lifting frame for the navigable pass segments and supported the design of the tainter gates.

Olmsted, Ohio River between Illinois and Kentucky

Aerial view of Olmsted Dam precast yard showing the five 46 m × 38 m concrete slabs where the precast concrete shells will be cast.

Services

- Casting yards/launch system
- Diving activities
- Dredging
- Heavy lift systems
- Off site prefabrication
- Positioning control systems
- Screeding/subgrade preparation
- Concrete durability
- Headed reinforcement
- Pre-cast concrete
- Precast shells (hulls)
- Tremie concrete
- Non-linear soil pile interaction
- Ice loading/abrasion resistance
- Liquefaction
- Mooring and berthing
- Seismic analysis
- Seismic non-linear soil pile interaction
- Constructability studies
- Cost estimating
- Scheduling preparation/review
- Specification preparation/review
- Value engineering

Project period

2005 - ongoing

Client

U.S. Army Corps of Engineers, Louisville District
Seawater intake and outfalls

The design of large civil works in the marine environment draws on all of COWI’s experience in hydraulics, geotechnics and structures. COWI has the specialist resources required for all aspects of the civil engineering design of seawater intake and outfall systems, including:

- design of intake channels, pipes and bell mouths
- assessment of impact on long shore sediment transport and coastal morphology
- assessment of impact on hydrodynamic conductions around intake/outfall
- assessment of maintenance dredging requirements
- hydraulic and structural design of pump stations
- hydraulic and structural design of culverts
- design of outlet weirs
- recirculation studies to verify location of outfalls
- environmental impact assessment

Seawater intake and outfalls

Shoaiba steam power plant, Saudi Arabia

The plant located on the Red Sea Coast south of Jeddah is a major power and desalination plant with water intake and outfall structures at the shoreline.

Services
- Design of large intake structures consisting of glass reinforced plastic pipes and acropode breakwater intake basin and outfall weir, canal and guiding structures

Completed
2001

Client
Saudi Archirodon Limited
Structure investigation and maintenance

The aging port infrastructure provides significant opportunities for marine structure underwater and topside investigation, remediation and maintenance. Much of this waterfront infrastructure was constructed in the early to mid-1900s.

**Underwater inspection**

The below water structures, not visible during routine inspections, can be overlooked and are the most vulnerable to environmental attack and deterioration.

Solutions that include remediation design to extend the existing structure service life, restore load ratings, and design of replacement and new structures are provided. The repaired and new structures are designed to meet today’s codes, including seismic requirements.

Our services include underwater investigations using surface supplied air with one of the largest contingencies of 20 professional engineer and engineer divers in the United States, half of which are registered professional engineers. The services live up to safety standards and regulations including the US Occupational and Health Administration (OSHA), US Coast Guard, Association of Diving Contractors guidelines, and our own Dive Safety Manual.

The engineers who perform the inspections also write the investigation reports, develop recommendations, repair schemes, alternatives and prepare the designs. We strongly believe that this approach provides clients with the most cost effective and constructible designs.

We further operate highly portable but powerful mini remotely operated vehicles (ROV) that has a range of 230 metres. This gives the dive team the ability to assess safety concerns about a potential dive, view areas that may be considered hazardous for manned dives and provide rapid deployment because of its portability.

ROV safety assesses damaged navigation structure in deep water
Service life design
Internationally, COWI provides the only available reliability-based service life design methodology against chloride- and carbonation-induced corrosion of reinforcement in concrete.

Marine structures are usually now designed for 100, 120 or even 200 years of service life. This surpasses by far the assumed design life on which most codes and standards are based.

COWI’s recognised leading position within durability design and concrete technology is based on more than 40 years worldwide experience within the design, operation and maintenance of exposed reinforced concrete structures.

COWI has been spearheading the international research and technical development of the rational service life design of concrete structures, i.e. in European research projects such as: DuraCrete, DuraNet and DARTS, and chairing all durability-related activities within the international organisations of CEB (Comité Euro-international du Béton) and now fib (Fédération Internationale du Béton).
Risk and decision support
COWI offers all types of risk assessments for projects. Risk is inherent in any activity. All decisions or actions may result in unwanted consequences. Thus, the proper procedure is always to consider risk and to make use of the information gained in the decision process.

Project risks include development risks, construction risks, operational risks, financial risks and revenue risks.

Risk management
Risk management is basically a managerial tool to support the decision maker.

Experience shows that implementation of risk management will result in profitable decisions and improved allocation of resources.

Risk management can lead to decisions supporting the decision maker’s goals.

Risk management ensures consistence and transparency in the decision process and provides a basis for risk communication.

Risk assessment
In many cases, risk management requires detailed quantitative input.

To this purpose, risk assessment makes use of probability calculus and statistics, which are applied to the underlying physical or economic models.

The quantitative output can easily be expressed in economic terms, which is especially useful in cost-benefit analyses.
**Design tools**

COWI uses state-of-the-art numerical models and tools in all phases of projects.

**LITPACK**
LITPACK is a state-of-the-art numerical model for the simulation of shoreline developments including erosion and accretion.

**HOLEBASE**
HOLEBASE is a database system for geotechnical data. It allows for proper storing and analysis of data and presentations in AutoCAD.

**SESAM**
SESAM is a finite element program used for analysis and design of steel jackets structures.

**IBDAS**
IBDAS is COWI’s own integrated design and analysis software tool. It allows for geometrical modelling, structural analysis and verification of engineering structures and generation of construction drawings.

**OPTIMOOR**
OPTIMOOR is a computer program for the analysis of vessel moorings.

**ROBOT**
ROBOT is a finite element program for analysis and design of beam, truss, slab, shell and 3D structures.

**SESAM**
Sesam is a finite element program used for analysis and design of steel jackets structures.

**PLAXIS**
PLAXIS is a finite elements program specifically developed for numerical analysis of geotechnical and underground structures and soil-structure interaction.

**ABAQUS**
ABAQUS is one of the leading multi-purpose finite elements programs for a wide spectrum of numerical analyses in engineering and natural science with special focus on FEM and soil-structure interaction.
Numerical modelling using MIKE 21

COWI has acquired the professional engineering software package MIKE 21. MIKE 21 is applicable to the simulation of hydraulic and related phenomena in lakes, estuaries, bays, coastal areas and seas, and consists of more than twenty modules covering coastal and environmental hydraulics, sediment and wave processes. MIKE 21 provides the design engineer with a unique and flexible modelling environment using techniques, which have set the standard in 2D modelling.

MIKE 21 NSW and SW are spectral wave models, which are capable of calculating the growth and decline of wind waves in the nearshore region. The models include the effect of wind, refraction and wave breaking.

Nearshore wave modelling - modelled wave height and direction for wind from north north east. The figure show the modeled wave field in the sea between Bahrain and Qatar. The colours illustrate the wave height and the arrows show the wave direction. The length of the arrows is proportional to the wave height.

Flushing - concentration of artificial tracer after 104 hours simulation for the Development situation.
Selected references

Al Zorah Development – Ajman, UAE
Description: A parcel of land, approximately 12 square kilometres, is going to be developed along the coast of Ajman by the Al Zorah Development (Private) Company Limited. One of the features of the development will be an existing mangrove area. The mixed-use development will stretch along 3 km of coastline and include commercial, residential, recreational, educational and healthcare facilities as well as a golf course, marinas and hotels. COWI’s part of the project concerns environmental and engineering services related to the marine works. The environmental impact assessment considers both terrestrial and marine aspects and includes studies of air pollution, noise and cooling water from a nearby power plant.

Client: Al Zorah Development (Private) Company Limited
Project period: Ongoing
Services: Numerical modelling of waves, currents and water levels, assessment of beach stability, wave disturbance in marinas, flushing characteristics of the channels and water bodies, eutrophication modelling study, environmental impact assessment, power station impact study, dredging and reclamation, marina design, design of marine structures, cost estimate, assistance during tendering and construction supervision.

Analyses for Aframax tankers, Alaska
Description: Mooring analyses completed for Aframax tankers to assess limits for transfer of oil products. The berth has a tidal range of 6 m between mean lower low water and mean higher high water, and currents running parallel to the berth can reach 4-7 knots. In the winter months, the berth is exposed to ice formation and ice floes. Part of the study was to determine the capacities of existing mooring hardware and assess the affects of ice floes on vessels moored at the berth.
Client: Tesoro Maritime Company
Project period: 2007 - 2008
Services: A probabilistic analysis was employed to determine the frequency of ice floes, and their distribution in terms of size, thickness, speed, and proximity to the berth during passage. Dynamic mooring analysis simulations were utilized to determine the excursion of moored vessels, the tension in mooring lines, thrust on fenders, and loads incurred to mooring hardware.

Conoco Phillips, Rodeo terminal upgrade, Richmond, CA, USA
Description: Develop options for upgrading the Rodeo terminal facility to accommodate 200,000 DWT tankers. The main purpose of the study was to investigate the possibility of berthing a 200,000 DWT Polar tanker at the Conoco Phillips Rodeo facility, and secondly, determine what structural upgrades would be required according to MOTEMS (Marine Oil Terminal Engineering and Maintenance Standards).
Client: Conoco Phillips
Completed: 2003
Services: Mooring analyses, structural analyses, cost estimates, quantities and MOTEMS compliance.
**Shoaiba new tanker terminal, Saudi Arabia**

Description: New marine terminal for unloading of 100,000 DWT tankers. The terminal consisted of 500 m access causeway, 180 m access trestle and piled jetty structures, steel piles and concrete deck.

Client: Archirodon (Overseas) CO.
Completed: 2002
Services: Assessment and design of the terminal structures.

**Al Dana Island and RAK Canal project, UAE**

Description: COWI is rendering design services to develop an offshore island complex and a canal through existing land located along the coast of Ras Al Khaimah. This project includes development of a cluster of man-made islands covering 5 million square metres to accommodate commercial and residential complexes and hotels as well as a canal of 18 kilometre ‘snaking’ through the adjacent existing land area. The concept design for the RAK Canal will focus on the feasibility of this part of the project, i.e. flushing of the canal and the need and cost for installing a mechanical flushing system and/or sluices and locks, costs of excavation and marine structures, etc.

Client: Dredging International, who has signed a contract with Rakeen, a company representing the Government of the Emirate of Ras Al Khaimah, UAE.
Project period: 2008 - 2009
Services: Numerical modelling of waves and currents, numerical environmental modelling, concept design, preliminary design, detailed design.

**Caleta La Mision Port, Tierra del Fuego, Argentina**

Description: Review and redesign of the project and all structures for this port consisting of a 1.6 km trestle on piles, a berth for 25,000 DWT vessels and a main island breakwater for protection of the berth.

Client: UTE JV Andrade Gutierrez-Ormas
Completed: 2002
Services: Studies of waves and tides in numerical modelling, design basis, master plan, navigation study, quarry assessment, detailed design of CORE-LOC breakwater, 2D and 3D model tests by DHI, design of quay and deck structures, specifications and cost estimates.

**Egyptian (LNG) project, Idku, Egypt**

Description: Idku is located on the Mediterranean coast 50 km east of Alexandria. An export terminal for LNG was needed due to the finding of sizeable gas fields. The terminal caters for 140,000 m³ LNG vessels. It consists of a construction harbour on the side of which a 2.4 km long access trestle extends out to the berth for the gas tankers. The mooring and turning area is protected by a 850 m long island breakwater located in an area with up to 15 m of soft clay. The trestle is supported on steel piles and the composite superstructure modules are 40 m long. The site is very exposed with offshore design waves of \( H_s = 11 \) m reduced to approximately 6.8 m at the breakwater by wave breaking as the water depth is 12 to 13 m.

Project period: 2002 - 2004
Client: Archirodon Construction/Bechtel International
Services: Assessment of geotechnical investigations, hydrographical analyses, breakwater design, dynamic mooring analyses, design of access channel and navigational lights, vessel downtime assessment, design of jetty structure, seismic analyses, building design, electrical and mechanical design.
**Mesaieed small craft berth, Qatar**

Description: The small craft harbour is for mooring of tugs and pilot boats. It consists primarily of gravity block structures.

Client: Grandi Lavouri Fincosit (Middle East W.L.L)

Completed: 2002

Services: Definition of design basis, specification and interpretation of marine investigations, specifications of ground improvement, detailed structural design of berth, detailed design of slipway and coastal protection, construction report and drawings, construction support.

**New York City cruise terminal dredging, USA**

Description: The New York City cruise terminal in Manhattan serviced over 1 million passengers from most of the major cruise lines in 2006 and the economic impact of the cruise industry to the City was over USD 1 billion. Since these official numbers were reported for 2006, a steady growth in passengers and economic benefit for the City has occurred. Situated on the west side of Manhattan on the east bank of the Hudson River, up to 275,000 cubic meters of maintenance dredging is required every year.

Client: New York City Economic Development Corporation (NYCEDC)


Services: Hydrographic surveys, sampling and analysis plans, sampling and testing of dredge materials, dredge plans and specifications, cost estimates, and volume calculations and performed resident engineer services.

**Dune restoration and stabilization, Bahamas**

Description: In August and September of 2004, back to back hurricanes, Hurricane Frances and Hurricane Jeanne, followed almost identical paths over the Bahamas, resulting in extensive wind damage and erosion. While many of the homes were severely damaged, others were left teetering on the brink of scarped dunes only a few feet from collapse. A site visit was performed to assess the current conditions followed by an evaluation of different options for restoring the dunes, and for providing protection against future storms.

Client: Scotland Cay, Bahamas

Completed: 2005

Services: The chosen design consists of sand fill in front of homes and placement of geosynthetic sand-filled bags on the lower dune face.

**Qasr Al Alam New Seawall, Oman**

Description: New blockwork seawall for protection of the Royal Palace in Muscat plus small craft landing platform

Client: Tarmac Alawi L.L.C.

Completed: 2002

Services: Assessment of geotechnical condition as well as seismic design, design of layout and cross-sections of wall, design of wall sections and outfall structures for storm water run-off, drawings and material specifications.
Beach Nourishment on Funen, Denmark
Description: A comprehensive coastal survey was undertaken by COWI, in which topographic and bathymetric surveys were conducted along with geological and morphological studies and assessment of the littoral transport. Gradual removal of sediments and breakdown of the existing groynes resulted in shoreline retreat, leaving a beach consisting mainly of gravel and pebbles. Using a hopper dredge approximately 115,000 m³ of sand was placed along a 2.2 kilometre stretch of coastline resulting in an initial advance of the coastline by approximately 40 m. The result of the beach nourishment is an immediate advance of the beach and a long term supply of sediment to the adjacent coastal areas in the downstream direction. Future development of the coastline is monitored by periodic bathymetric surveys and land surveys, which will form the basis for future maintenance of the beach.
Client: Det Nordfynske Kystsikrings-, Dige- og Pumpelag
Completed: 2004
Services: Beach nourishment, protection, breakwater and groyne.

Shoreline Storm Damage Reduction, Chicago, IL, USA
Description: Shore protection for 530 m of shoreline avenues along Lake Michigan, between Diversey and Fullerton, consisting of revetment, concrete promenade and stepped slabs, steel sheet piling, and rock fill.
Client: U.S. Army Corps of Engineers, Chicago District
Completed: 2004
Services: Detailed design.

Beach at Al Sharq Resort, Doha, Qatar
Description: Al-Sharq Resort is located in Doha. The previous shoreline was characterised by a shallow foreshore and the bay towards east was severely affected by siltation. The previous beach quality was not acceptable for the luxurious resort. COWI was therefore contracted. The resort beach is sheltered by Doha Port but is orientated towards the dominant northerly and north-easterly winds. The shallow bay at the eastern half of the site has been reclaimed to provide a continuous beach. Additionally, a blue water basin has been dredged along the new beach to provide deeper water. The land formed by the headlands has been utilised as park with grass and palm trees.
Client: Qatar National Hotels Company
Completed: 2005
Services: Geotechnical investigations, design of beach, coastal protection and environmental impact assessment (EIA).

Development Plan for Kronborg Castle and Elsinore Harbour, Denmark
Description: Kronborg Castle is on UNESCO’s World Heritage list. Restoration of Kronborg’s fortification and the marine development of the abandoned shipyard.
Client: Slots- og Ejendomsstyrelsen, Denmark
Project Period: 2005-2011
Services: COWI is the client’s consultant and provides multidisciplinary services within project management, risk assessment and successive calculation of costs, traffic analysis, geo- and environmental investigations, marine biology, numerical wave modelling, condition surveys, authority contact, architectural coordination, archaeology, conceptual design, tender, contracting and supervision.

Danaat Howar Islands Development, Bahrain
Description: Large scale island development project.
Client: Southern Area Development Company, Bahrain
Completed: 2001
Services: Master plan revision, numerical wave, current, water quality and sedimentation modelling, engineering design of marine structures, specifications and contract documents.
Dubai Maritime City development, Dubai, UAE
Description: The project included new large reclaimed area in front of Port Rashid adjacent to the Dubai Dry Dock (DDD). The new area required the relocation of the main breakwater protecting the DDD as well as additional perimeter protection and marine structures.
Client: Archirodon Construction
Project period: Ongoing
Services: Design basis, change of basic layout, numerical wave disturbance study, design of all breakwaters and revetments, vessel manoeuvring study and technical services for construction support.

Casting basin Costa Azul, Baja California, Mexico
Description: Detailed design of a 105 m wide by 155 m long and 8 m deep casting basin facility. The basin served for manufacturing of concrete caissons that were floated out and sunk to form a breakwater that protected an LNG terminal approximately 20 km north of the basin.
Client: Costain - China Harbour JV
Completed: 2005
Services: Feasibility studies, oceanographic studies, detailed design, structural design, geotechnical analyses and design, hydraulic and dewatering design, coastal engineering, downtime assessment.

Cooper River Bridge, Charleston, SC, USA
Description: Design of drilled shaft foundations for the in-water piers. Drilled shafts were 3 m diameters. Design of artificial islands for protection of main span bridge piers against ship collision. The islands are 20 m high, built from 346,000 m³ of rock comprising an outer layer of primary and secondary rock armor placed on a filter and quarry run core. Construction included 340,000 m³ dredging for foundation of the islands.
Client: South Carolina Department of Transportation
Completed: 2005
Services: Detailed design and ship collision risk analysis.

Inner harbour turning basin, Port of Oakland, CA, USA
Description: Design of a 12 m tall bulkhead required for "widening of inner harbour turning basin (ITHB) - phase 1B bulkhead, dredging, and demolition of piers 2 & 6".
Client: DUTRA Construction
Completed: 2006
Services: Geotechnical analysis and design, numerical modelling, structural design, seismic design, value engineering, construction staging, construction support and supervision, pile load test evaluation.

Dubai Maritime City development, Dubai, UAE
Description: The project included new large reclaimed area in front of Port Rashid adjacent to the Dubai Dry Dock (DDD). The new area required the relocation of the main breakwater protecting the DDD as well as additional perimeter protection and marine structures.
Client: Archirodon Construction
Project period: Ongoing
Services: Design basis, change of basic layout, numerical wave disturbance study, design of all breakwaters and revetments, vessel manoeuvring study and technical services for construction support.
Saranda Gateway, Albania
Description: COWI has completed a multidisciplinary project involving Port planning and engineering, and environmental impact studies. The overall objective of the Saranda Gateway project is to support the transformation of Saranda’s downtown port into a dedicated ferryboat and passenger terminal to facilitate the access of passengers and vehicles to Albania’s valued southern coastal zone. The transformation into a tourist and commercial gateway involves the following elements: Relocation of the existing cargo berth in Saranda Bay to a refurbished all-cargo berth facility in the nearby Limioni Bay, conversion of the existing cargo berth in Saranda Bay to a 180 m long cruise liner berth and construction of a yacht marina.

Client: Ministry of Public Works, Transport and Telecommunication, Albania
Completed: 2007
Services: Port planning and engineering, environmental impact study, bathymetric and topographic surveys, magnetometer and side scan sonar survey, geotechnical investigations and geological studies, archaeological survey, benthic flora and fauna survey, water and sediment quality sampling and analysis, numerical modelling of current and waves, traffic studies and socio-economic studies.

Batumi terminal, Georgia
Description: Upgrading and development of existing container terminal in Batumi.
Client: ICTSI
Project period: Ongoing
Services: Civil works, building and infrastructure works.

Museum of Islamic Art, Doha, Qatar
Coastal engineering study
Description: The museum was located in the water off the shoreline in the Doha Bay. The museum and the surroundings required coastal protection works.
Client: Ministry of Municipal Affairs and Agriculture, Qatar
Completed: 2002
Services: Surveys, numerical modelling of waves and current and water quality, design basis, detailed design of edge treatment slopes, structures, sea walls, construction supervision.

Tuborg Syd, marine works, Denmark
Description: Tuborg Syd (south) is a development of the former Tuborg Brewery Port. The port basin is transformed into housing and recreational areas including 210,000 m² of buildings. The development is given a maritime environment with marina and canals in between the buildings.
Client: Carlsberg Properties
Project period: Ongoing
Services: Master planning of marina in collaboration with the architect, assessment of geotechnical conditions, numerical modelling and hydraulic studies, coastal stability analysis, design of new protecting rubble mound breakwater, design of all works/structures, tendering, contracting and supervision of marine works construction.
**Sutong Bridge, scour protection, P.R. China**

Description: The Sutong Bridge over the Yangtze River is the world’s longest cable-stay bridge with a span of 1088 m between the main pylons. These are founded in the river bed in a water depth reaching about 30 m.

Client: Jiangsu Province SuTong Bridge Construction Commanding Department

Completed: 2005

Services: Expert engineering services and construction management for the bridge and its scour protection. For the scour, COWI prepared assessments of the hydraulic design data, desk study of scour and conceptual and recommendations on detailed design of the scour protection consisting of temporary protection of sand bags and permanent protection using quarry stones with falling apron at the edges to cope with potential large scour depths.

**Qatar-Bahrain causeway**

Description: This road-link will connect the west coast of Qatar near the Zubarah fortress with the east coast of Bahrain south of the capital Manamah. Being exactly 40 km coast-to-coast, it will be the longest man-made road-link in the world. The road-link will be of motorway standard with traffic lanes and emergency lane in each direction. The 40 km is made up of 18 km embankments and 22 km marine bridges including two navigation span cable-stayed bridges, one close to the coastline of Bahrain, one on the Qatar side close to the international border.

Services 2001-2002

COWI was appointed to undertake the preliminary engineering and environmental investigations and studies for the causeway and completed the studies in only 10 months. The marine modelling studies for the Qatar-Bahrain causeway project included modelling of current, sediment dispersion from dredging activities and waves using MIKE 21. By compensation dredging the final solution had zero impact on the water exchange.

Studies: Planning, traffic, topography and bathymetry, geology and geophysics, geotechnique, hydrography, meteorology, marine modelling, environment and ecology, risk assessment, design basis

Conceptual design: Alignment, roads and plazas, embankment and fill depots, bridges tolling & border facilities, mechanical and electrical installations

Client: Ministry of Municipal Affairs and Agriculture, Qatar

Services 2008-2013

In May 2008 an agreement was signed between the Qatar-Bahrain Causeway Foundation (representing the two governments) and the QBC Consortium to design and build the causeway. At the same time, COWI signed an agreement with the QBC Consortium to act as design consultant for the causeway project.

COWI’s services will be undertaken in three phases:

Phase 1 over five months: update and amend the conceptual design carried out in 2002 including re-assessing the environmental conditions and conduct an update of the EIA studies made during 2002. Included in this phase is a study of optional provision to be implemented to facilitate the later addition of a rail-link along the causeway alignment.

Phase 2 over the next three months: a basic design to enable a firm lump sum to be established.

Phase 3 over the next 51 months: construction of the causeway. COWI undertakes detailed design and provides on-site follow-up services during this period.

Client: QBC Consortium (Vinci, Hochtief, CCC, QDVC and Dredging International/MEDCO)

**Confined disposal facility (CDF) and commercial wharf, Everett, MA, USA**

Description: Remediation of a 2.5 hectare site requiring containment and stabilization of in-situ and dredged sediments. The CDF structure consisted of nine continuous 12 meter wide by 34 meter long cells consisting of HZ king piles and AZ sheet piles. The structure was designed to withstand a variety of intermediate loading conditions during construction, including a 5 meter tide variation. The CDF and concrete deck structure was designed with a capacity of 57 kilopascals to accommodate the crane loads expected for the industrial use of the facility.

Client: ARCADIS BBL

Completed: 2007

Services: Provided waterfront structural engineering for the CDF design from concept design through final design. During construction reviewed contractor’s submittals and performed full time resident engineer services, including underwater investigations.
Double dry-dock at Ras Laffan, Qatar
Description: Eight kilometres offshore, Qatar Petroleum is building a giant double dry-dock due for completion in 2010. The dry-dock – Nakilat Ship Repair Yard – lies off the port of Ras Laffan and will be capable of receiving the very largest vessels sailing with LNG, liquified natural gas. The project has a total value of USD 450 million.
Client: Main client is QP/Nakilat
Project period: 2006 - 2008
Services: Responsible for the offshore design – including quays, foundation piles and block walls for the dry-dock – and the design of onshore buildings, project coordination and supervision.

Al Reem Island Plot 4, Abu Dhabi, UAE
Description: Al Reem Island is a multi-billion dollar man-made island and residential, recreational and commercial development on reclaimed land in the shallows off the coast of Abu Dhabi. Plot 4 is being developed into a mixed, residential and commercial zone. The basis for the Al Reem Island Plot 4 is in providing high-class facilities, restaurants, shopping, business facilities and residential units resulting in a unique lifestyle for residents and visitors alike.
Client: Private investor
Project period: 2007 - 2008
Services: Conceptual design of edge treatment structures, breakwaters and navigational canals, establishing marina operational basis and marina concept design and modelling of water flushing to validate master plan from a marine point of view and assessment of waves and wave disturbance in marinas.

The World - France & Spain, Dubai, UAE
Description: The project is a mixed use hospitality destination within The World project in Dubai. The project involves two of the most desirable locations; Spain and France Islands with an allowable gross floor area of approximately 120,000 square metres that will be developed with a hotel, villas, a marina and retail.
Client: Select Group
Project period: Ongoing
Services: Marine and geotechnical engineering services including: marine basis of design, sketch design and interaction with master planning process, hydraulic and sediment modelling and assessments, detailed design of edge treatments, outline design of marina, tender documents, preparing technical, specifications for a preliminary site investigation, assessing the subsurface site conditions, if deemed necessary, identifying the proper and efficient technique(s) for ground improvement, providing the foundation recommendations for all infra and superstructures of the site, and marine structures.

Beirut Central District, marine works, Lebanon
Description: Marina and seafront structures. Marina protected by major accropode breakwater. Seafront, 1.3 km long, consisting of large concrete caissons with wave-absorbing chamber (Jarlan-principle) and wide man-made reef in front.
Client: SOLIDERE
Completed: 2000
Services: Construction management and special marine, geotechnical, coastal and materials engineering expert services.
Dellis Cay development, British West Indies
Description: The developer ‘O Property Collection’ is currently developing a multiple facility tourist complex with low-level hotels and condos on the island of Dellis Cay, part of the Turks & Caicos Islands.
Project period: Ongoing
Client: O Property Collection
Services: COWI has been appointed as marine consultant to the project. Numerical modeling of the hydraulic environment including the impact of hurricanes, i.e. waves and storm surge, resulting in the development of a protection strategy and definition of design flood elevations for the island. Preparation of alternative concepts, cost estimation and production for a master plan for Marina Cay reclamation (70 acres). Detailed design and tender documents for 1.5 km of beaches including beach nourishment, detached rubble mound breakwaters and timber groynes. For some of the protecting structures, newly developed innovative and cost effective designs using geotextile tubes were used. These are buried under normal conditions and active only during hurricane impacts. A cargo handling jetty and ro-ro berth. A 50,000 m³ saline lake with tidally driven flushing system.

Halul Harbour upgrade, Qatar
Description: Halul harbour is a supply base located on Halul Island 80 km off the coast of Qatar. The harbour is on the south side of the island and is protected by two CORE-LOC breakwaters.
Client: Consolidated Engineering Construction Ltd.
Completed: 2004
Services: Port planning, definition of site investigations, detailed design of breakwater and concrete quay and sheet pile quay and access road, design report and construction drawings.

Study of transport corridor from Umm Qasr via Basrah to Baghdad, Iraq
Description: The recovery of the Iraqi economy is dependent on a fast revival of the Iraqi transport infrastructure. The commercial ports in the south of Iraq play an important role in the transport infrastructure. The study of the transport corridor from Umm Qasr via Basrah to Baghdad has involved: Procurement and training of Iraqi authority staff in the use of state-of-the-art surveying equipment (ports, waterways and roads), condition surveying of the main infrastructure in the corridor (ports, waterways and roads), transportation forecasting, project identification and planning for two pilot projects (Umm Qasr and Road # 26).
Client: Royal Danish Ministry of Foreign Affairs (Danida)
Project period: Ongoing
Services: Port planning, transport economy, GIS, hydraulic and sediment modelling, environmental impact assessment, marine and road surveying, tender design.

Qatalum project, Mesaieed, Qatar
Description: Qatar Petroleum and Hydro Aluminium AS are developing an aluminium production plant at Mesaieed Industrial City, Qatar. The project involves construction of a jetty with mooring dolphin to handle import of raw materials (bulk alumina, coke and liquid pitch) for the production of aluminium at the plant. The jetty shall accommodate bulk carriers up to 70,000 DWT. An access trestle shall be constructed to connect the jetty to land.
Client: Archirond Construction (Overseas) CO. S.A.
Project period: Ongoing
Services: Met-ocean study, mooring analysis, detailed design of access trestle, jetty and mooring dolphin.