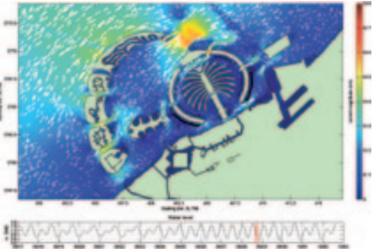


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Scour assessments
 Scour of the seabed occurs in the vicinity of structures that are exposed to strong hydrodynamic processes. Along the Dubai coast, scour of the seabed was assessed between the trunks of the palms and the existing shoreline, around bridge-piles and along pipelines. Assessment of scour was based on detailed computations of hydrodynamics around these structures and enabled our clients to take appropriate measures for mitigating the effects of scour.



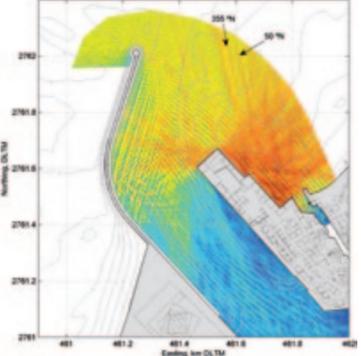
The following mathematical modelling software tools are frequently applied in our Dubai projects:

- Delft3D: comprehensive modelling package to model currents, waves, sediment transport and morphological developments in an interactive way
- UNIBEST: longshore sediment transport and coastal evolution model
- PHAROS: wave penetration model
- HABITAT[®]: spatial modelling tool for marine ecological impact assessments

Mathematical modelling
 Our calibrated and validated mathematical models form a solid basis for the prediction of the hydrodynamic and morphological processes along the Dubai Coast. These models have been set up for the assessment of tidal water level variations, currents, storm surges, operational and extreme wave conditions and long-term morphological developments. The mathematical models are frequently updated with the latest coastal developments and validated against newly available measurements. This results in an up-to-date and readily applicable database of different models that enables us to provide our consultancy services in an efficient and cost effective way.



Our Clients
 Since the early start of the coastal developments in Dubai, Deltares has worked with the leading developers like Nakheel, Limitless, Sama Dubai and Meraas. In addition, continuous cooperation was established with a wide range of consultants (e.g. Royal Haskoning, Tebodin Middle East, Mouchel, Atkins, Moffat & Nichol), dredging companies (e.g. Van Oord, Jan de Nul, Boskalis), architects and masterplanners.



Deltares
Innovative solutions for water and subsurface issues

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Dubai Coastal Developments

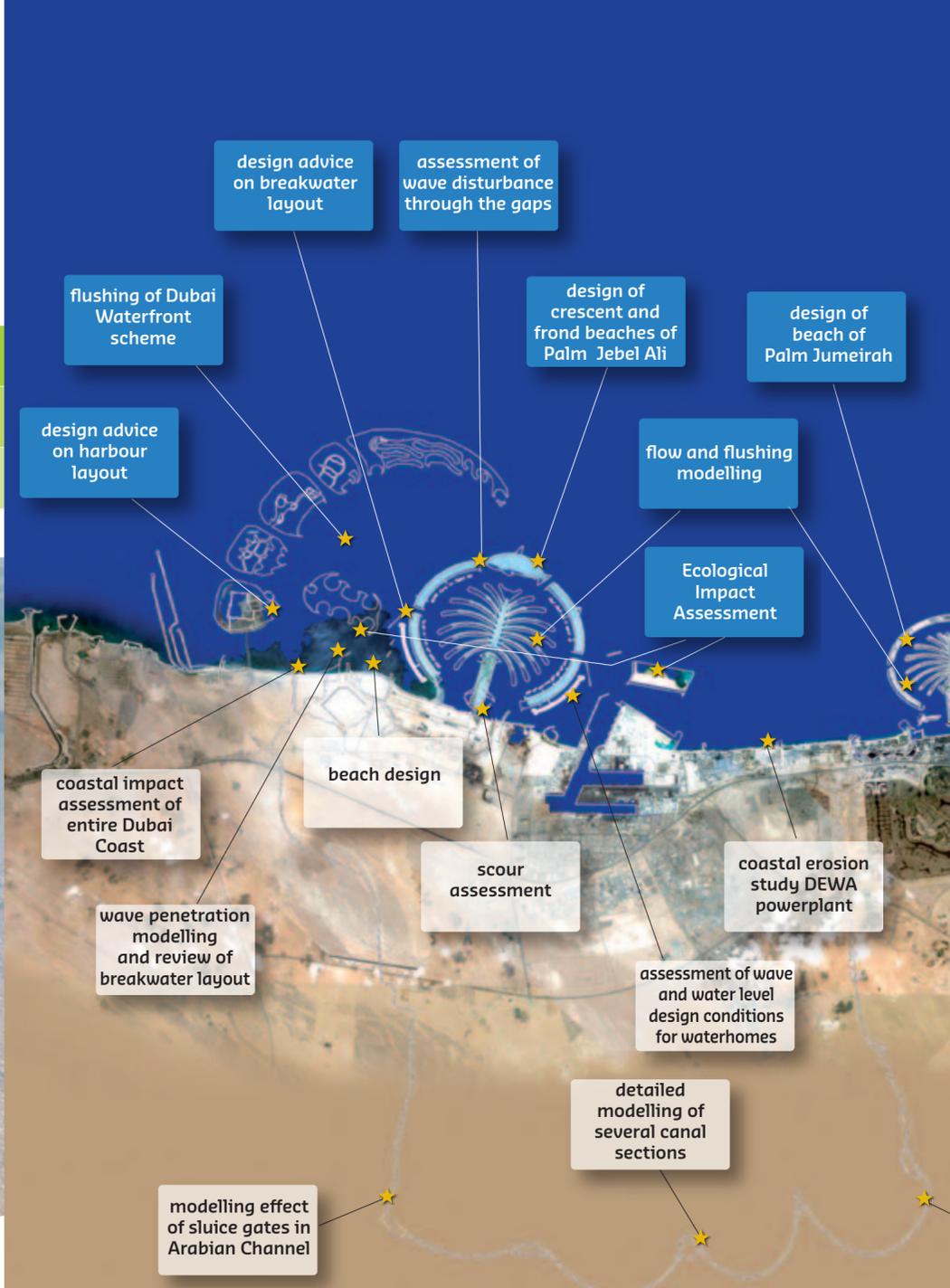


Deltares (formerly Delft Hydraulics) has been involved in the recent wave of Dubai coastal developments from their inception in 2000. Our involvement commenced with a detailed hydrodynamic, water quality and morphology study for the first palm island: Palm Jumeirah. This study defined the start of a continuous key involvement in all of the main well-known Dubai coastal developments: Palm Jumeirah, Palm Jebel Ali, The World, Dubai Waterfront, Arabian Canal, Palm Deira and Jumeirah Gardens.

The exceptionally high rate of development adopted in Dubai required fit-for-purpose and timely advice, always ensuring the highest level of quality.

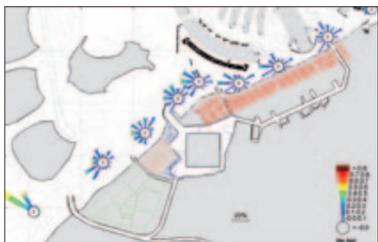
Deltares provides high-end specialist services for the design, planning, construction and impact monitoring of coastal infrastructure projects. Our key asset is that we cover all disciplines playing a role in the design and construction of a coastal infrastructure project, from pre-feasibility assessments to post-construction impact monitoring.

With our expert knowledge of coastal processes and continuously developing software and laboratory facilities, we are well equipped to optimise designs, identify possible cost reductions as well as safety issues, and conduct environmental impact assessments.



Where did it all start?

Deltares has gained experience in the Arabian Gulf since the 1980's. In 1994 a mathematical model of the Arabian Gulf was developed which was well validated against measurements. This model gave insight in the complex tidal motions of the Gulf and provided a sound basis for a wide range of detailed hydraulic applications such as recirculation modelling for power and desalination plants and layout and structural design of coastal structures.



Environmental conditions

Environmental conditions form the basis of detailed design of artificial islands, land reclamations and other coastal structures. The operational and extreme water levels, currents and wave conditions along the Dubai coast were assessed on the basis of extensive data analyses and mathematical modelling with our Delft3D model of the Dubai coast. A regular update of the environmental conditions was required in order to address aspects like changed currents and wave sheltering due to construction of new coastal developments.

Coastal structures

Given a master plan drawing of a coastal development and the established environmental conditions, our team of structural design experts efficiently reviewed and optimised edge structures in terms of hydraulic stability and wave overtopping.

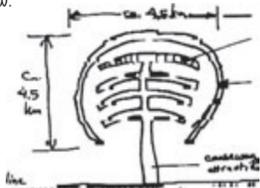


The design of several breakwaters for the protection of the Dubai coastal developments against severe wave attack was tested by means of scale tests in our facilities. In these tests the stability of armour layers and the amount of wave overtopping for different design alternatives were quantified under a series of severe storm conditions. Based on the results of the scale tests, the designs were validated or optimised.

Optimisation of marina designs

As part of the coastal development projects several small and large marinas were planned at various locations within the new schemes. Deltares provided assistance in the design of the layout of the marinas with respect to wave penetration, navigation and mooring conditions. To support the optimisation of the designs, wave penetration modelling was carried out in order to quantify optimal breakwater lengths and orientations resulting in minimal wave disturbance inside the marina.

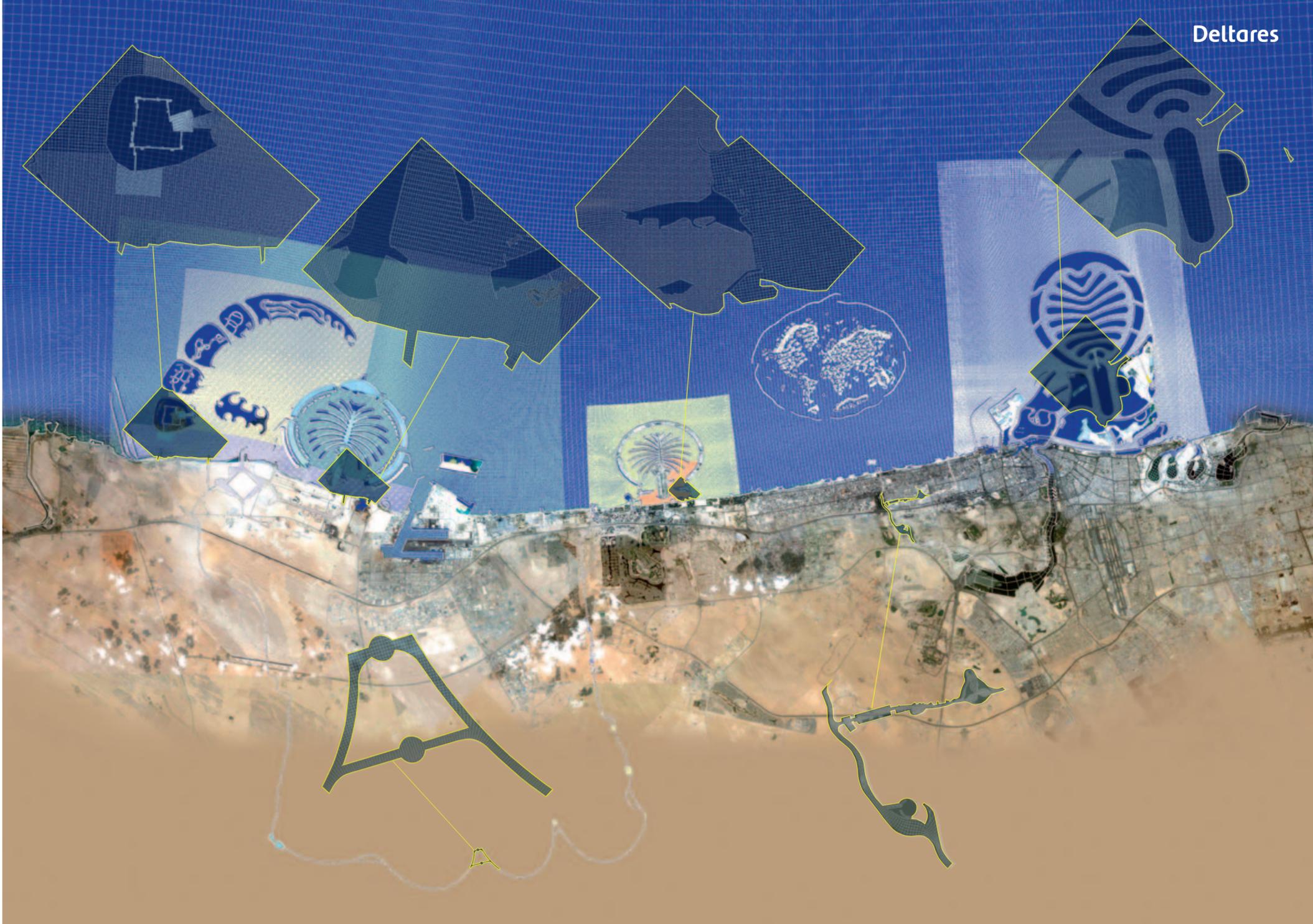
Our experience and continuous presence in the Gulf resulted in an invitation by the Palm developers to contribute to feasibility assessments related to the first palm island (Palm Jumeirah) in 2000. The first sketch of the island is displayed below.



Overview of study activities

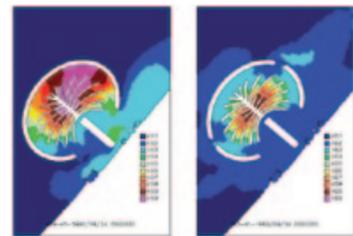
The coastal environment of Dubai is governed by processes like waves, tide- and wind-related water levels, currents and sand transport. Particularly, during northwesterly storms, known as Shamals, the intensity of these processes can be severe. When developing new land, beaches, marinas or harbours in this type of environment, a detailed assessment of the governing environmental conditions is crucial. Based on the derived environmental conditions at the coast of Dubai, Deltares performed the following assessments:

- Determining hydraulic conditions (wind, wave, water levels)
- Design advise and testing of coastal structures
- Optimisation of marina designs
- Beach design
- Coastal impact assessments
- Water quality assessments
- Marine ecology baseline and impact studies
- Impact assessment of dredging activities
- Scour assessments



Beach design

One of the objectives of the Dubai coastal development projects was to increase the beachfront length of Dubai significantly. For this purpose beaches were planned on all new islands. In early stages of the masterplanning of such schemes, Deltares was requested to advice on optimal beach orientation and protection from a viewpoint of beach stability. In later stages of the design process, detailed process-based numerical modelling was carried out to evaluate beach stability and to optimize the beach layout. For each case our most suitable model was selected, depending on the complexity of the situation and the locally dominant physical processes. Based on these model studies, recommendations were given on aspects like beach slopes, beach shape and overall orientation, and on required structures to minimize sand losses.



For most of the new beaches, and at some of the existing beach schemes, future maintenance was inevitable and beach maintenance plans were developed.

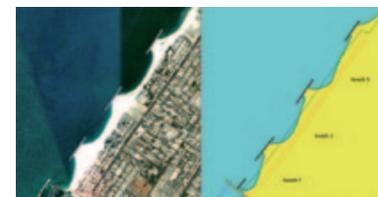
modelling package, water refreshment times were computed and improvements in schemes were suggested. Detailed water quality modelling assessments including primary production, transport, dispersion and decay of nutrients were carried out for confirmation and further optimization of the schemes.

This, for instance, resulted in the construction of gaps in the crescents of Palm Jumeirah and Palm Jebel Ali.



Coastal impact assessments

The various coastal development projects changed the waves, currents and sediment transport patterns along the Dubai coast. With a calibrated shoreline model (UNIBEST) the coastal impact of each new scheme was predicted. Given the constant flow of new plans, these predictions were updated on a regular basis. A link between our wave models and the shoreline model provided the flexibility to implement such updates efficiently in a reliable and consistent manner. Where (local) adverse effects were predicted, advice on mitigating measures was provided, taking into consideration possible changes in the nearshore environmental conditions caused by future new development projects.



Water quality assessments

One of Deltares' first recommendations to the Palm developers was to ensure sufficient refreshment of water inside the palms and various canal schemes. With our Delft3D

Marine ecological impact assessments

Marine ecological impact assessments were conducted using marine habitat surveys in combination with results from other modelling components, such as local hydrodynamics and sediment transport characteristics. The impact assessments were based on quantitative analyses and evaluation of potential impacts of the planned developments on the local (sensitive) marine habitats. The marine ecological impact assessments were carried out using the dedicated spatial modelling tool HABITAT®. This tool enables a quantitative assessment of the areas at risk and demarcates the influence zone on the basis of expert knowledge.



Impact assessment of dredging activities

During dredging and reclamation activities fine sediment particles can be entrained in the water and may be transported under the influence of the currents. Deposition of the fines may affect sensitive marine habitats. With our Delft3D modelling package we were able to quantify the transport and deposition of the fine sediment particles under variable tidal and wind conditions. Based on the modelling result advice was given on the use of specific dredging equipment and timing of dredging activities.