Deltares

Enabling Delta Life



# Coastal protection and beach design

**Due to the attractiveness and suitability of coastal zones for various functions (such as recreation, nature and industry) they often contain a high concentration of population, infrastructure, natural value and economic assets. Worldwide an acceleration in the urbanisation rate of coastal zones can be observed in the last decades.**

Given the natural dynamics of most sandy coasts, at many places there is a necessity of measures to mitigate the effects of coastal erosion. Sometimes this erosion has a natural cause (for example natural gradients in sediment transport, sea level rise), while in some cases it is induced by the action of man (for example by disturbance of the sediment balance due to the construction of a port or land reclamation, sand mining or reduction of river sand supply to the coast caused by the construction of river dams).

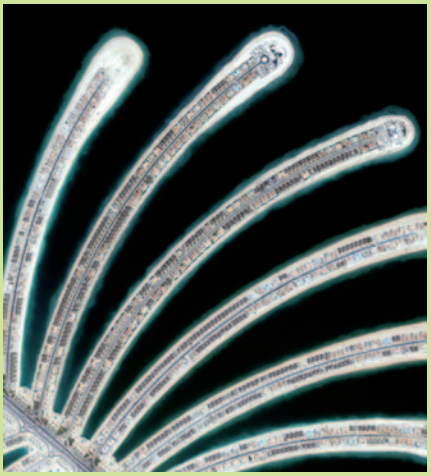
At the same time we see a growing demand for new high-value recreational developments in the coastal zone (such as tourist resorts and hotels) which require the creation of new beaches. Such developments may be planned along an existing shoreline or they may be part of (large-scale) land reclamations.

These problems and developments require coastal protection and beach design studies. Coastal protection studies include the protection of sandy coasts against natural erosion (beach preservation), as well as coastal impact assessments. In coastal impact studies man-induced shoreline changes due to planned coastal works are predicted and measures to mitigate adverse effects (such as coastal erosion) are designed. In beach design studies advise is given on the creation of new beaches or improvement of existing beaches - in such a way that the requirements of the beach owner are met (in terms of surface, slope, stability, aesthetics and swimming conditions) and beach maintenance is minimised.

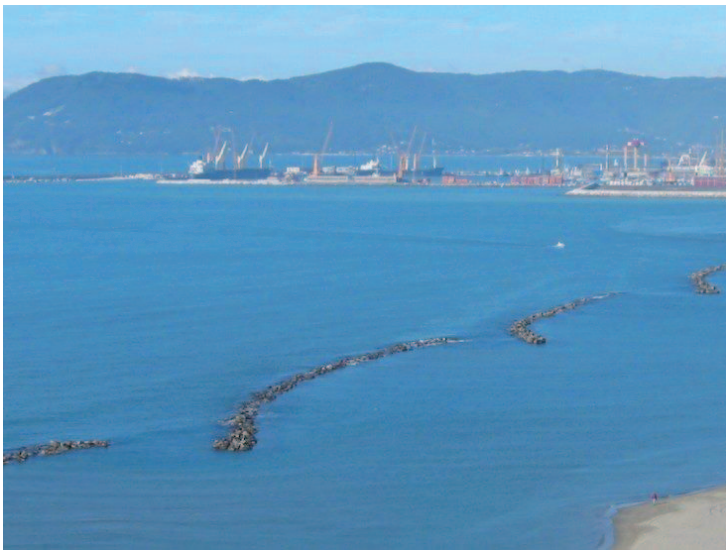
## Problem definition - examples

*The high value Carrara coastal zone in northwest Italy suffers from beach erosion. In the past a large variety of coastal protection works has been designed and constructed by different parties, with mixed local success. The implementation of these schemes over the last decades has resulted in a very dense pattern of coastal structures and a shift of the erosion problem further down the coast. Deltares was requested to analyse the problem and to evaluate options for a more integral solution.*

*Beach erosion was observed along part of the Dubai coastline. Deltares was requested to analyse the problem and to advise on mitigating measures, so further damage to coastal assets could be minimised.*



*With the construction of the Palm Islands, the beachfront length in Dubai was increased significantly. Deltares carried out model studies to optimise the beach cross-sections and to predict future beach maintenance.*



*Recreation, housing and industry in the coastal zone: existing situation along the Italian coast*

### Approach

Our advice is based on in-depth knowledge of the relevant physical processes and an integral understanding of the behaviour of the coastal system, supported by the use of state-of-the-art tools. With the broad knowledge base present within Deltares, we can offer an integral approach in which various issues (such as water quality, ecology, navigability and the stability of structures) are included in order to provide advice which is sustainable, with minimal conflicts between the different interests. The local coastal management strategy is included in our evaluation in order to ensure that our recommendations comply with local Coastal Zone Management plans.

Since optimal solutions or measures are site-specific, the first phase in a coastal study is always a thorough assessment of the area and the natural system. This assessment usually covers an area larger than the project site itself. With the natural system well established, predictions of future coastal or beach behaviour are made and - if relevant - recommendations for mitigating measures are given. Knowing that any interference with the sand balance in the study area may adversely affect other parts of the coastal system and the marine ecology, the impact of beach protection schemes or new beach development on adjacent coastal sections is taken into consideration. This may in some cases result in recommendations for 'soft measures' (sand), sometimes for 'hard measures' (structures) or a combination of soft and hard measures to mitigate adverse effects.

We can adopt different levels of study, ranging from a desk assessment to detailed numerical morphological modelling or physical modelling in our laboratory facilities. The approach and required detail of the

study depends on the phase of the project development and is tailored to specific issues raised by our Clients, to ensure useful and high quality advice for each phase. Whatever approach is adopted, our studies are always carried out by experienced coastal specialists.

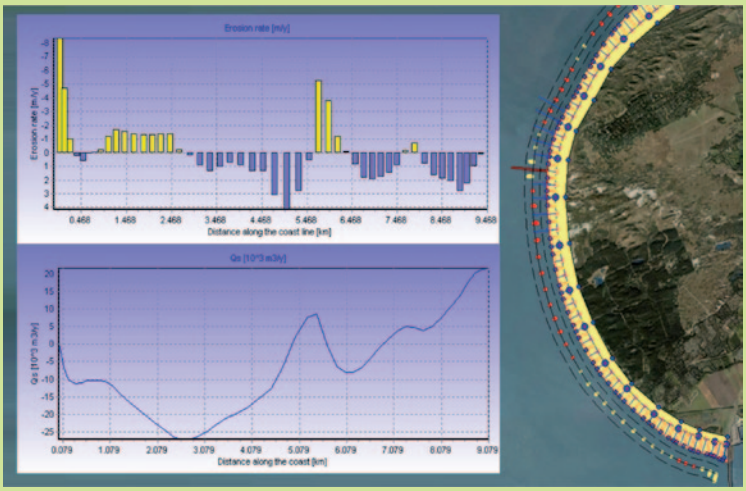
### Desk assessments

For relatively simple coastal systems and problems, a desk assessment based on expert judgement by our specialists in the field of coastal morphology can be carried out in order to analyse the situation and to recommend possible measures or further study steps. Such an assessment is often supported by indicative computations. Desk assessments are particularly useful in an early stage of new beach development projects, when our coastal specialists discuss the possibilities and limitations with the master planners and landscape architects. This reduces the chance that in a later stage modifications to the master plan are required and in some cases it leads to cost savings in an early stage of the project.

### Numerical modelling

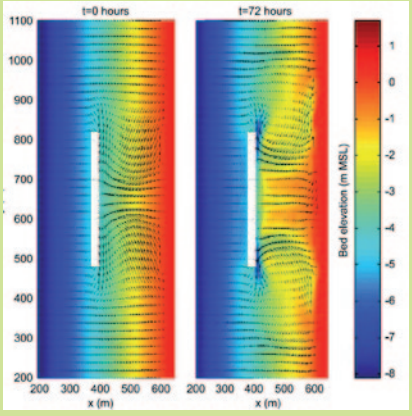
In-house developed modelling software (such as Delft3D, XBeach and Unibest-CL+) is often applied to support the coastal analysis and predictions, and to design coastal protection or beach development schemes. For each study the most suitable model is selected, based on our judgement of the dominant physical processes and the complexity of the situation. Worldwide these models are acknowledged

## Study approach – examples




*In-house developed shoreline modelling software (Unibest-CL+) is often applied to analyse transport gradients and erosion-accretion patterns along a coast. Such models are also used to predict the effect of human interference with the coast, and of measures to mitigate such effects. The presented example shows an application for a strongly curved coast in the south of the Netherlands.*

*Our in-house developed models are used by various consultancy firms worldwide. Our coastal engineers can organize training courses for optimal use of the models and interpretation of the results.*




*Complex transport patterns around structures and resulting bed level changes can be analysed and predicted with our in-house developed state-of-the-art modelling software Delft3D. The example shows the initial bathymetry and transport pattern (left) and an intermediate result (right) around an offshore breakwater.*

*In our laboratory test facilities we enhance our insight into complex physical processes by means of scale model tests. Physical model tests are also often carried out to support the design of coastal structures. The picture shows large-scale model tests on dune erosion.*

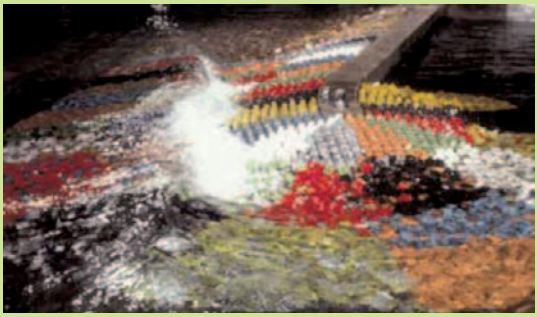
as state-of-the-art software and ample attention is given to model validation. Since the software has been developed by Deltares, our specialists have maximum insight into the possibilities and limitations of the models, and they can interpret the results accordingly.

In general, the studies start with the modelling of currents and waves, since these are the driving forces for sediment transport. These hydrodynamic conditions are then used as input for modelling of the sediment transport and coastal changes in the baseline (existing) situation. Model verification – and if required model calibration – is an important step in our modelling sequence. Subsequently the model is used to predict the coastal response to interventions and to optimise designs of measures. Our open source Delft3D software package is commonly used to model detailed short to mid-term morphological changes, particularly for complex situations near structures. Our Unibest-CL+ model is particularly suitable to assess long-term, large-scale shoreline changes. The XBeach model is used to examine storm deformation of beaches and sand bars. Combined model approaches are commonly used to assess the morphological changes over different spatial and temporal scales and to include long-term aspects like climate change.

### Physical modelling (scale models)

In cases involving beach retaining structures or complex hydrodynamics, physical modelling is used to support our advice. Sometimes a so-called 'hybrid approach' is followed, in which the strong points of numerical and physical modelling are combined. Deltares has state-of-the-art laboratory facilities (wave basins and flumes which also accommodate the generation of flow to include wave-flow interaction) in which physical scale model tests can be carried out by experienced staff.

## Study approach – examples



*In our test facilities the structural design of coastal defence structures such as groynes, breakwaters, revetments, dikes or seawalls can be optimised. Typical parameters for optimisation are the weight of the armour rock and the structure crest height, width and layout. In a movable bed model also scour at the toe of the structure can be investigated.*

*Creation of beaches on a new land reclamation: 'Logo Island' near the Palm Jumeirah in Dubai*

## Solutions

Depending on the local problem and situation, different solutions may be advised to mitigate erosion or to optimise a beach design. An important principle in our evaluation of suitable sustainable measures is that we will always try to 'build with nature'. After the most suitable concept has been selected in consultation with the Client, we can make the functional design of the selected scheme and optimise beach layouts and dimensions of coastal protection works. Deltares can also contribute to a detailed design of schemes, if required. Solutions may consist of 'soft measures' (sand), 'hard measures' (structures) or a combination of soft and hard measures.

### Coastal protection - soft measures

In many cases restoration of the sand balance by means of beach or foreshore nourishment is found to be the optimal solution. Other examples of soft measures are artificial sand bypass (by pumping sand around obstructions) or re-circulation of sand within a coastal cell (by pumping sand from accreting areas to nearby eroding areas). Soft measures are particularly suitable for situations where the use of structures would result in a shift of the erosion problem further down the coast due to lee-side erosion caused by the scheme. The feasibility of this option depends on the availability of suitable sand sources near the study site. Deltares can contribute to the design and optimisation of beach nourishments or other soft solutions.

### Coastal protection - hard measures

In some cases schemes including structures such as groynes, revetments or detached breakwaters are designed to locally mitigate coastal erosion. Sometimes the decision for hard measures is based on the lack of suitable economically recoverable sand in the offshore region or inland. For hard measures, often a delicate balance has to be found between designing an effective coastal protection scheme and avoiding or minimising adverse effects on the downdrift coast, since in many situations such schemes tend to shift the coastal erosion problem further down the coast. Combinations of soft and hard measures can be applied in a way that

## Measures – examples

*In a complex area with a strongly fluctuating beach width due to passing sand waves, Deltares was requested to design a scheme that would protect valuable hotel assets during erosive periods of the sand wave cycle and that would leave sufficient beach width for recreation during such periods. An effective scheme of a sand nourishment protected by groynes was designed which reduces the shoreline fluctuations and thus provides a minimum beach width at all times (Gambia).*

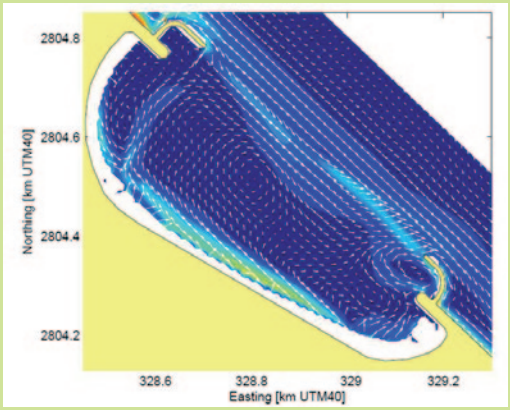
*Traditionally the Dutch coast is maintained by regular sand nourishments. Deltares has investigated the effectiveness of an innovative plan for non-uniform placement of the nourishment sand along the coast. The picture shows the work in progress.*

structures are included in the design to improve the efficiency of a nourishment.

Since conditions vary strongly from place to place, a coastal protection design is always site-specific. Deltares has ample experience in making functional designs in which all design criteria and requirements are considered and optimised. In addition to their effectiveness in mitigating the erosion and their lee-side effects, other aspects are included in the design of such schemes, such as aesthetics and swimming safety.

## Beach design – examples


*Due to large-scale coastal erosion, high value property along the Dubai coast was jeopardized. Anticipating future changes in nearshore conditions in this rapidly developing coastal environment, Deltares was requested to design low-maintenance new beaches with sufficient robustness to remain effective for several defined nearshore wave climate scenarios. Using our knowledge of the area and processes, and with the support of our models Delft3D and Unibest-CL+, this challenge was met.*




*On a large land reclamation in Dubai a new beach was planned. Given the large local water depth the perched beach concept was applied. For this complex scheme extensive numerical modeling was carried out. The figure shows a computed flow pattern which forms the basis for the assessment of swimming safety and sediment transport along the beach.*

### Beach design

For the design of new beaches, the slope and orientation of the beach are important parameters for the minimisation of future beach maintenance (re-nourishment). To minimise alongshore sand loss, structures are often applied to enclose the beach at both sides. If a new beach is placed in deep water (for example at a land reclamation) the perched beach concept (beach toe supported by a submerged detached breakwater) can be applied to minimise the initial sand requirement and the sand loss. Given the various fields of expertise within Deltares, issues related to water quality, ecology and structural stability can be integrated in the design process, to obtain an optimal solution for all stakeholders.

Generally, if a new beach is created, maintenance should be anticipated since some loss of sand due to the action of the waves, currents and wind is inevitable. Deltares predicts the required beach maintenance and gives recommendations for beach monitoring. We can also support the setup of sophisticated continuous monitoring systems (for example by means of the "Argus" camera system). Deltares can also be of service in the interpretation of monitoring results and in fine-tuning of nourishment schedules on the basis of these results.

**For more information:** info-hye@deltares.nl

Deltares

PO Box 177
2600 MH Delft, The Netherlands
T +31 (0)88 335 82 73
info@deltares.nl
www.deltares.nl

*Deltares is a leading, independent, Dutch-based research institute and specialist consultancy for matters relating to water, soil and the subsurface. We apply our advanced expertise worldwide, to help people live safely and sustainably in delta areas, coastal zones and river basins.*