

# Design and Execution of Beach Nourishments in Belgium

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## Abstract

*When a severe coastal erosion problem has to be solved, two kinds of remedial/coastal protection works are usually taken in view: the first one, most often used in the past, requires the construction of structures such as groynes and breakwaters; the second one aims at providing a coastal protection solution by restoring or modifying the beach profile. Factors to be considered when evaluating the possible solutions are environmental conditions and sediment transport mechanisms.*

*In fact, engineering design methods and human concern, are evolving, which leads to a new concept of coastal defence works.*

*This trend is illustrated by case studies of projects carried out along the Belgian coast.*

## Introduction

The Belgian coastline is characterized by a 65 km long stretch of sandy beach/dune barrier. The coastal barrier is a dynamic system in balance with the prevailing hydrometeorological conditions (sea-level, waves, tides, winds) and is thus subjected to fluctuations in location and height of the beaches and dunes (fig. 1).

Since the early 1900's several constructions along this coastline have been built aimed at providing coastal protection for the polder hinterland or at allowing tourist resorts and urban developments.

These infrastructures for coastal protection or coastline fixation are essentially combinations of sloped sea-walls, groyne-fields and beach profiling/replenishment works.

The growing urban development and touristic exploitation of the coastal area, together with the assessment of eroding coastal sections, create the need for integrated and flexible coastal protection actions. Therefore several beach nourishment projects have been designed and/or executed during the last 15 years.

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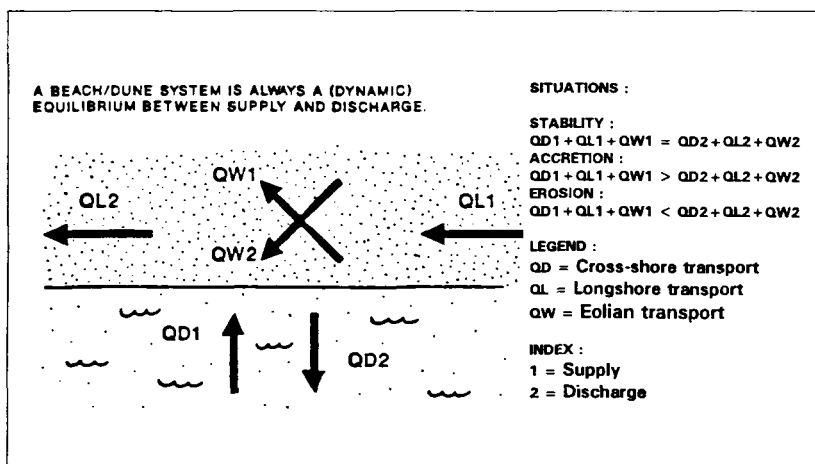


Figure 1 : Equilibrium mechanisms governing the stability of a beach/dune system.

### Coastal defence works

Common shore defence systems include hard structures such as groynes, detached breakwaters and sea walls.

Groynes aim to reduce the longshore sediment transport in a given coastal area. Detached breakwaters are build in order to reduce the wave action on the coastline.

Sea walls are build to prevent the coastline from further regression and have sloped masonry structures to achieve a progressive wave breaking.

Beach restoration/replenishment works aim at restoring the deficient sand balance of the system and at restoring a natural flexible coastal protection. In some cases projects combine sand suppletion with construction of hard defence structures.

In lowlands such as Belgium and the Netherlands, many beach/dune systems act as the ultimate coastal protection. These sandy beach/dune systems locally suffer from erosion. This erosion is a result of a disequilibrium between sand supply and sand-discharge by longshore, cross-shore and/or eolian transport. A deficit in sand-supply causes erosion of the beach/dune system. This deficit may originate from natural causes (e.g. regional, sedimentological variations, sea-level changes) or man-made causes (e.g. coastal structures, sand-excavations, dredging).

Groynes and breakwaters will only affect the wave regime and sediment transport in the immediate area. They do not create solutions for the adjacent coastal areas where the sediment transport capacities are unchanged. On the contrary, they may cause a spectacular increase in sediment transport on the lee-side of the structure causing renewed coastal erosion. In fact, the problem has merely been moved from one area to another.

### Knokke-Heist project (1977-1979)

The winter storms of 1976 left a seriously eroded 9 km long beach in front of the seawall and groyne field of the Knokke-Heist municipality. Predicted sand losses and coastline regressions were compared, which corresponded to different alternatives including sand suppletion and groynes. In fact, total capital and maintenance costs of beach nourishment, with or without groynes, were not significantly different.

According to the design, coastal protection works were executed consisting of a beach replenishment scheme, whereby ca. 8,5 million m<sup>3</sup> of a selected sand-type was landfilled on the existing eroded beach-profile. A cross-section of the beach replenishment realized by means of hydraulic pumping is shown in figure 2.

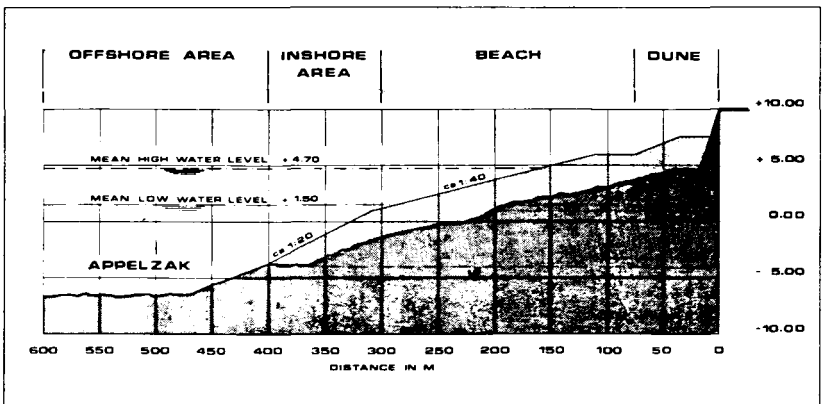


Figure 2: Design of beach nourishment at Knokke-Heist, Belgium (beach profile before and after nourishment).

The sand was trailed/dredged in sea (access channels, sandbanks) and dumped in a borrow pit in the Zeebrugge harbour, where a cutter suction dredger excavated it to pump it as a hydraulic mixture via a 800 mm beach pipeline with booster stations (max. 5) down to the fill area. The works started in 1977 and ended in 1979; a fill density along the 9 km coast of ca. 1000 m<sup>3</sup> of sand per running metre was realized.

The monitoring of this beach nourishment project shows clearly that material is eroded by waves, tides and winds from the dry and tidal beach area and displaced to the nearshore area (below the LW-line by cross-shore transport) and the dune area (by eolian transport). The net erosion of this coastal section however seems to be linked to the presence and the evolution of a nearshore flood tidal gully, the "Appelzak" (Kerckaert et al., 1985; De Wolf et al., 1993).

Due to the local strong erosion, an additional beach replenishment of appr. 1 million m<sup>3</sup> of sand was executed in 1986. This beach replenishment volume has now (1993) almost been completely eroded from the dry beach.

**Koksijde project**

The beach at Koksijde suffers from regular and very local erosion due to the presence of a tidal gully "Potje" close to the coastline. This coastline is naturally sheltered from strong wave-attack by shallow sand-banks. Despite a groyne-field the erosion continues.

The area around Koksijde is characterized by an active flood channel, whose shallow North flank (i.e. the Broersbank) plays a large part in influencing the wave height at the beach, and apparently reduces it. At the flood channel head, sand transport occurs from a SW - NNW wave sector.

Due to the orientation of the flood channel, currents are forced to group together between the flood channel and the coast. This narrow band of currents is obviously the reason for the locally severe erosion.

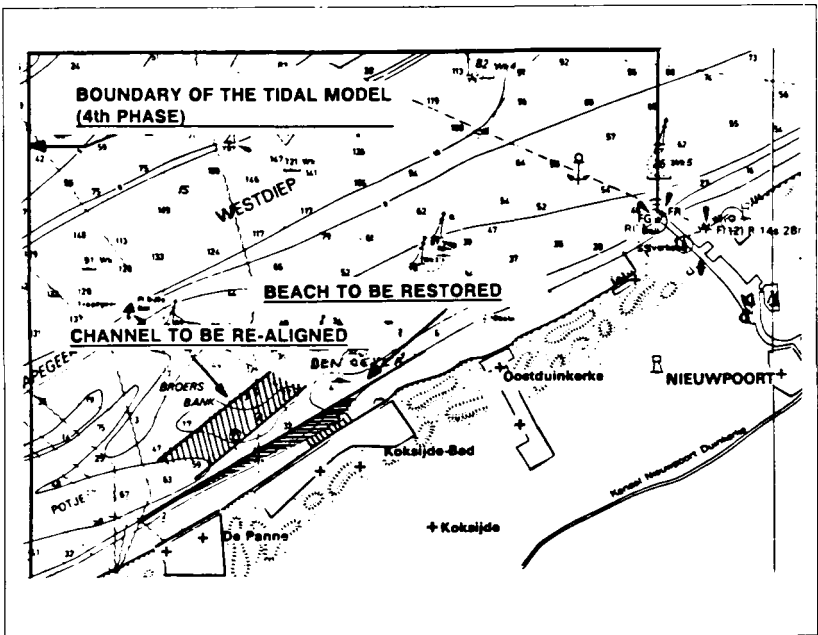


Figure 3: Situation plan Belgian West Coast  
Description of retained compensation dredging.

Five possible solutions were investigated :

- A. Rectification of the flood channel by means of excavation and nourishment techniques (compensation dredging): a. excavation of the northern slope of the channel head and b. pumping this dredged sand back into the beach whilst maintaining the classic, hydraulic cross-section of the beach. The head of a flood channel is usually made up of coarser sand so that the solution with combined excavation and nourishment back at the beach is usually the most attractive (fig. 3).

- B. Rectification of the flood channel by excavation and beach nourishment, including disposal of coarser sand (Kwinte Bank) as a protective cover layer.
- C. A connecting channel to be cut from the secondary flood channel north of the Broersbank.
- D. Extension of the existing beach groynes.
- E. Construction or installation of underwater groynes and beach nourishment.

An attempt was made to expose each possible solution to a multi-criteria analysis. The following criteria were used to weigh each solution :

1. Efficiency (coastal defence in the long-term).
2. Direct or indirect effects on coastal protection.
3. Hydraulic influence.
4. Technical feasibility.
5. Cost of execution.

This multi-criteria analysis isolated alternatives A and C as being most suitable for further investigation. The two alternatives were built into a mathematical tide model and the rate of decrease of the longshore current was calculated.

Solution A gave a sizable reduction in current velocities (up to 20 % at spring tide) near the major erosion areas. The influence of a possible connecting channel (solution C) gave only a slight velocity reduction in the extreme west of the problem area. The design study resulted in a solution of compensation dredging with subsequent beach nourishment and lengthening of existing groynes.

According to the design, the northern bank of the tidal gulley is to be excavated to deviate the strong flood currents in offshore direction. The sand to be excavated by a seagoing cutter suction dredger equipped with a floating discharge pipe ( $l = 2000\text{m}$ ) will be re-used for the beach nourishment in Koksijde. Thus a total length of 3000m of beach could be restored with a fill-density of ca.  $450 \text{ m}^3/\text{m}$ . At present, these works have not yet been started.

### **Ostend project**

Since the end of the 19th century the beaches at Ostend, Belgium have been popular holiday resorts. However, steady erosion has occurred, especially on the beach section between the Casino-Kursaal and the harbour entrance (fig. 4). Indeed, the beach front promenade was constructed along the line of the 17th century fortifications of the city, which protrude into the sea beyond the natural coastline over ca. 150 m. A system of huge perpendicular groynes, ca. 200 m long could only reduce the erosion. A flood protection improvement programme, realized after the dramatic storm surge of February 1953 and extended after the winter storms of January 1976, resulted in a small storm surge barrier wall on top of the seawall up to level +10.20 m and an associated storm surge sewer system. As this programme could have some results only on the short term, a long-term solution had to be proposed.

The requirements to be taken into account are as follows:

- reduction of wave overtopping of the existing sea wall;
- prevention of the existing port access channel from higher sedimentation due to the coastal defence works;

- consideration of future recreational beach activities ;
- limitation of the project within the existing groyne structure extension.

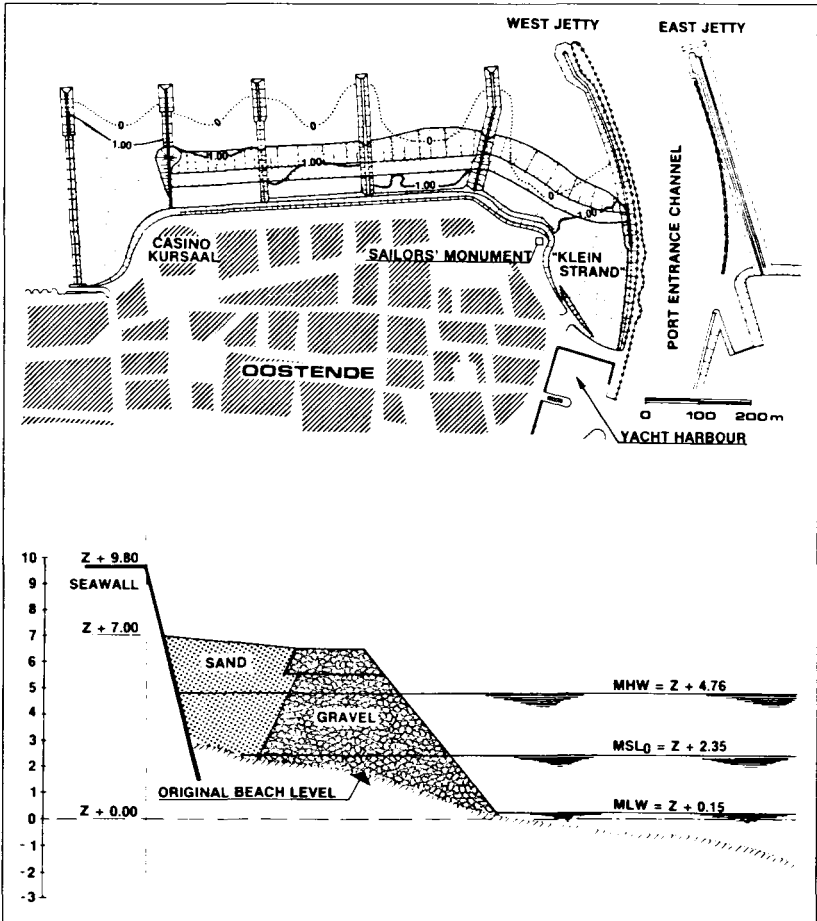


Figure 4: The gravel beach concept for Ostend

After coastal engineering studies and model testing, a gravel beach supported by a sandfill core has proven to be a feasible and cost-effective beach restoration and flood protection alternative (Simoen *et al.*, 1988). The gravel beach concept is integrated in the existing coastal protection infrastructure, i.e. a sloped seawall with groyne-field. To execute the design illustrated on figure 4, a gravel/sand fill density of ca. 600 m<sup>3</sup>/m over a length of 850 m is required. At present, these works have not yet been started.

Some additional results could also be achieved with this flexible solution:

- new beach recreational facilities in safe conditions for the public;
- the economic incentive for the much needed re-development of this part of downtown Ostend and the beach front;
- the conservation to a large extent of the present sea-view from the sea promenade.

### De Haan project (1990-1992)

The Belgian North Sea Coast at De Haan was seriously hit by the storm of 28.02.90 - 01.03.90 causing an intense erosion of the upper-beach/dune system. Due to the coastal protection function of this coastal barrier for the polder lowlands, the Administration of Waterways decided to execute coastal protection works.

The coastal protection study showed that the major coast-erosion mechanism is an intense cross-shore redistribution of sand in a ridge- and runnel beach system. The L.W.-bar is hereby acting as a buffer in which sand is accumulated in storm periods and from which sand is remobilized in onshore direction during calmer weather periods.

The same study showed that the most appropriate and cost-effective coastal protection system relies on the combination of a profile nourishment with a feeder berm on the L.W.-bar (fig. 5).

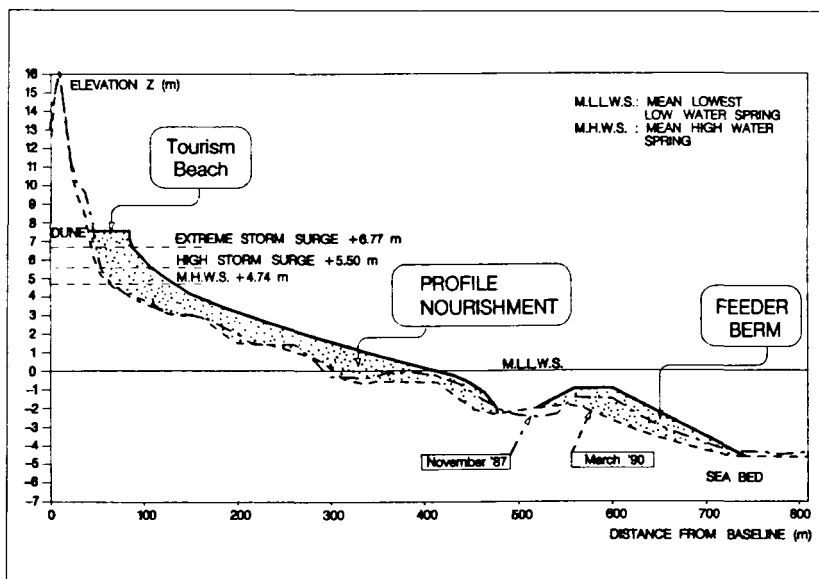


Figure 5: Typical cross-sectional view of the dune/beach system at De Haan (Belgium). Illustration of a design with profile nourishment and feeder berm at the L.W.-bar.

This selection was done after a careful multi-criteria analysis of different solutions. The original concept of this beach protection/restoration system - first application in Europe - relies on the knowledge of the natural sediment transport and distribution mechanism.

Both structures, profile nourishment and feeder berm, aim at a restoration of the cross-shore sand budget maintaining the original beach slope (Malherbe B., 1989). The coastal protection system involves the nourishment of ca. 1.300.000 m<sup>3</sup> of sand (fill density : ca. 750 m<sup>3</sup>/m) and is designed to use exclusively natural North Sea sediments excavated for the deepening of access channels and by the use of appropriate dredging equipment. The works were executed according to a Quality Assurance Plan. The shoreface nourishment works (1000 - 2000 m<sup>3</sup> split hopper dredgers) for the 2,200 km long feeder berm started in February 1991 and ended in March 1992. The profile nourishment works were executed by 2 self-pumping hopper dredgers, a sinker pipeline (1500 m long), a booster with 2 discharges pipelines and bulldozers for beach profiling; the works started in April 1992 and ended in May 1992 (fig. 6).

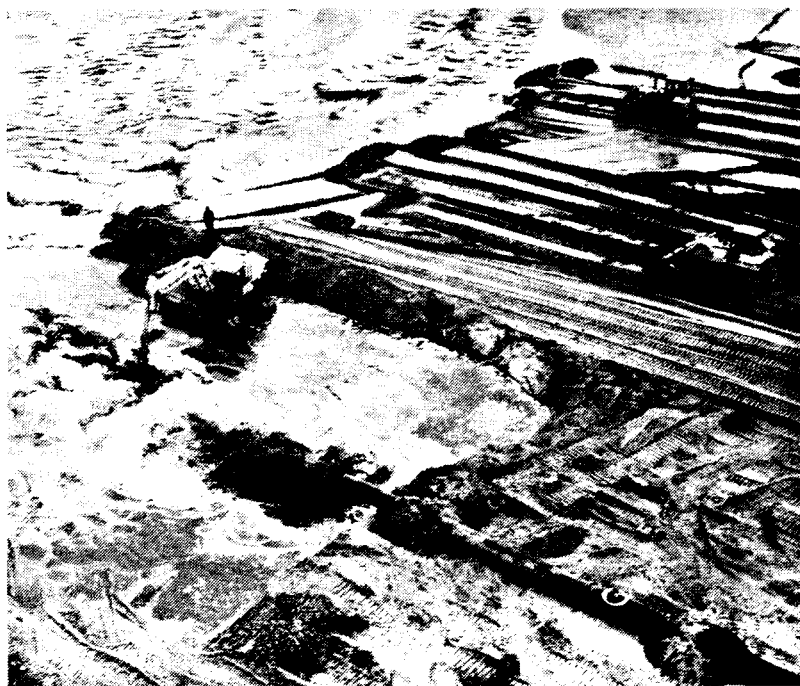


Figure 6: Profile nourishment works at De Haan (Belgium)

The results of the monitoring of the project area (by terrestrial levelling and nearshore echosounding) during the first year indicate that the feeder berm progressively feeds the upper beach up till L.W. + 1 m.

Eolian transport is quite significant. Therefore the design has foreseen the building of a wind-screen network on the dry-beach. This seems to be most effective after the first W-NW-storms of November 1992.

After these storms the natural beach evolution indicated a strong cross-shore redistribution of sand in a ridge and runnel system whereby the natural (and predicted) beach slope is obtained.

Despite the particularly windy period in the North Sea in October/November 1992 no significant sand losses could be measured. An exact project-evaluation will be done aftersome years of monitoring.

### References

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