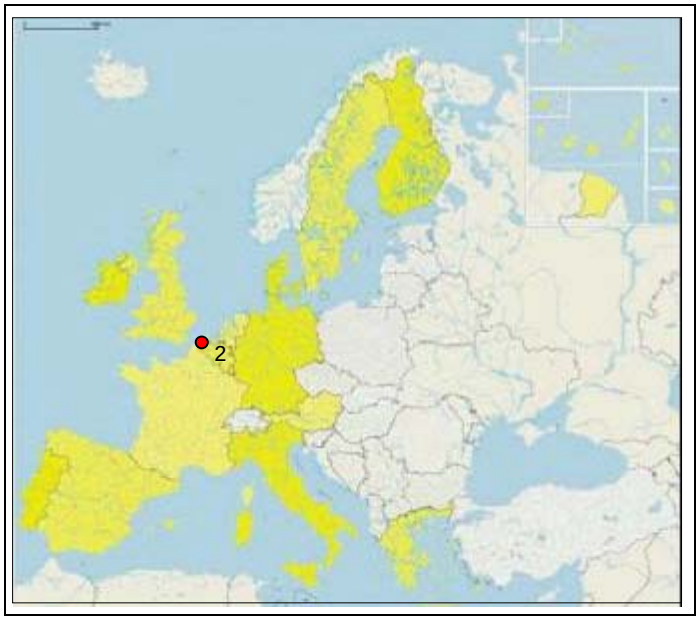
ZEEBRUGGE – KNOKKE HEIST (BELGIUM)



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1. GENERAL DESCRIPTION OF THE AREA

1.1 Physical process level

1.1.1 Classification

Fig. 1: Location of the case area.

The case area Zeebrugge is located in Belgium (see Figure 1). The coast of Belgium is about 65 km long and forms part of the sandy and rectilinear Southern North Sea coastline that stretches from Cap Blanc Nez (north of France) in the west to the Schelde estuary (the Netherlands) in the east.

The Belgian coast is a macro tidal coast with sandy beaches and the classification conform the scoping study therefore is:

3a. Tide-dominated sediment. Plains.
Barrier dune coasts

The coastal zone of this type of coast comprises three main units: a very gently sloping and fine sandy beach, a dune ridge and a coastal plain. In Belgium, from west to east the beach slope tends to increase, the grain size distinctly increases and the width of the beach distinctly decreases. Parallel to the Belgium coast, the long-stretched Flemish Banks are located in the North Sea.

1.1.2 Geology

A few thousand years before Christ the coastal plain of Belgium existed of flats cut of from sea by a very long dune ridge. Transgressions and regressions of the flats have influenced the development of the coast greatly. After the Dunkerquian transgressions, the building of dikes prevented further flooding of the flats. The coastal flats were reclaimed as land and the present coastal zone was developed.

The mean grain size diameter of sand on the Belgian continental shelf ranges from 0,150 mm to 0,300 mm.

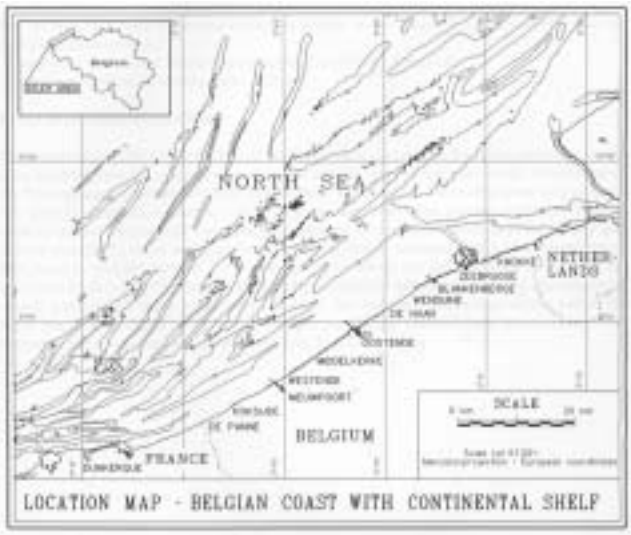


Fig. 2: Overview of Belgian Coast.

1.1.3 Morphology

The morphology of the Belgian North Sea coast is characterized by large sand banks alternating with shoals and tidal flats along the coastline. Parallel to the Belgium coast, the long-stretched Flemish Banks are located in the North Sea. The dunes are 60 to 600 m wide in most parts, only at the Dutch and French border the dunes they are 2 - 3 km wide.

An important morphological feature at this case area is the tidal gully “Appelzak” (Figure 3). The tidal channel has developed to a depth of 8 m below low-water and has shifted dangerously close to the coast. The Paardenmarkt is a shallow flat fronting the coast of Knokke.

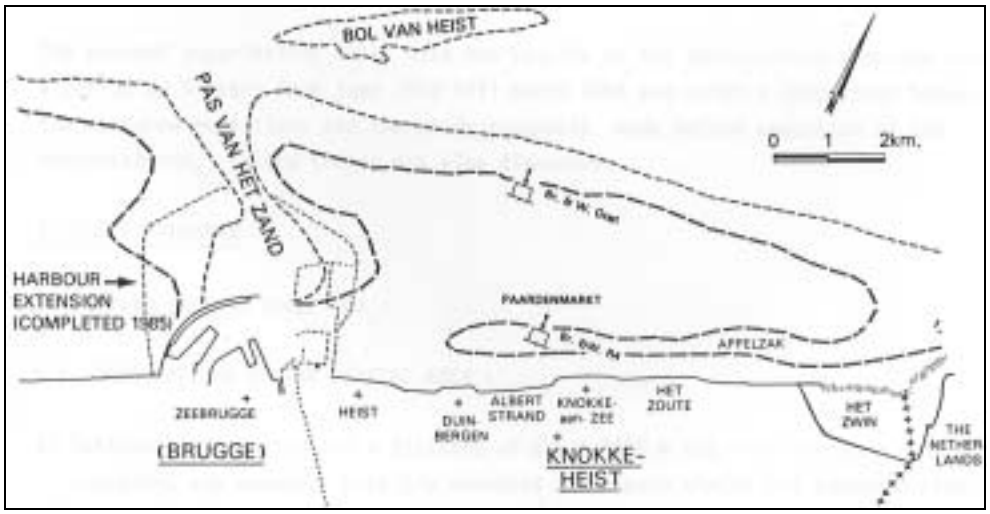


Fig. 3: Morphology of the coast at Knokke-Heist.

1.1.4 Physical processes

Tide

The tide is bidiurnal with a small asymmetry. Tidal range is typically between 3,5 m and 5 m. This important tidal range is linked to quite significant tidal currents, which exceed generally 1,5 knots in the nearshore areas.

Waves

Because of the shallow seas and the short fetch, waves are typically short crested at the Belgian coast.

Currents

The Gulf Stream passes the Belgium coast in a northern direction. This causes a net long shore current in northeasterly direction along the entire Belgium coast.

Storm events

Storm events can cause severe erosion at the case area, especially in combination with the tidal current in the tidal gully “Appelzak”.

Wind

Wind set-up can generate water elevation at the coast of more than 2 m.

1.1.5 Erosion

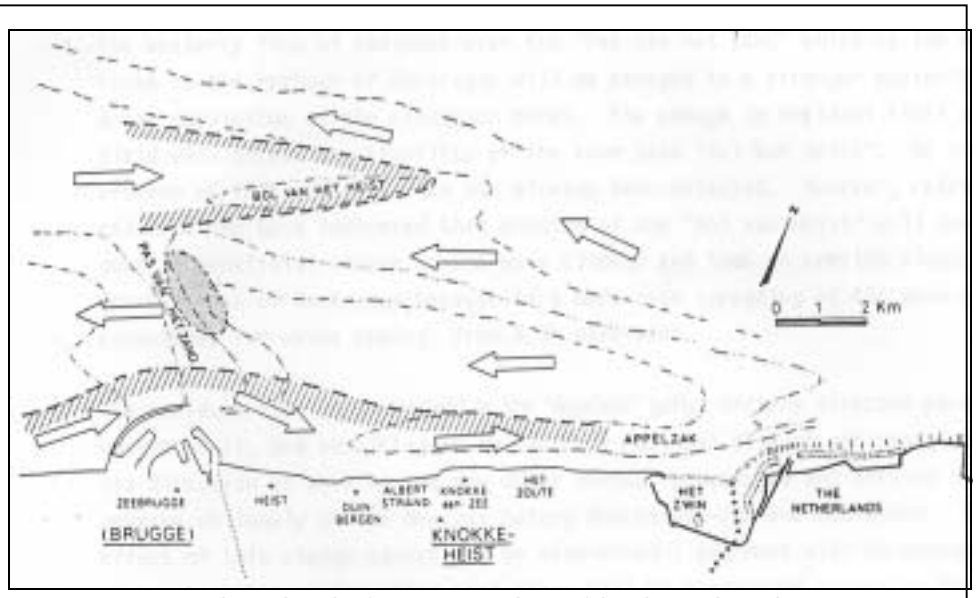
Structural erosion

Along the entire Flemish East coast persistent regression of the coastline forms an acute threat. Due to the combination of wave-induced on- and offshore transport with the longshore tidal drift, structural erosion of the Flemish East coast occurs.

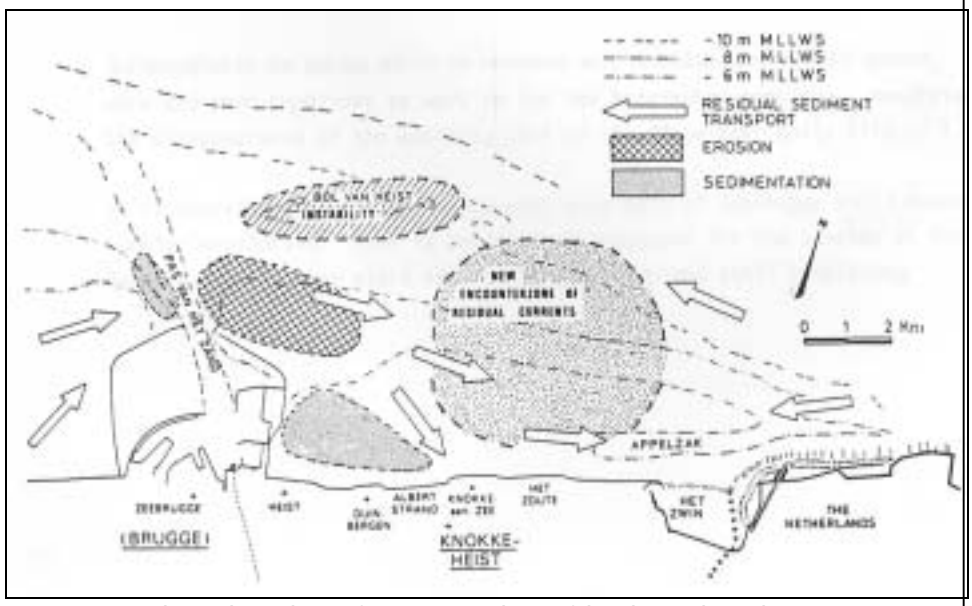
The seaward extension (to a distance of 3,5 km from the coast) of the harbour of Zeebrugge in 1970’s intersected the easterly longshore tidal flow (see Figure 4) and locally disturbed the morphological equilibrium. As a result, the local tidal trench called “Appelzak” shifted ground and re-established itself just in front of the groins before the coast of Knokke. Breaking storm waves transport the beach material offshore tot the seaward limit of the foreshore, into the tidal gully “Appelzak” from where it is carried away by the predomininantly northeasterly-flowing tidal current. In this way a structural erosion problem of the Knokke-Zoute beaches is induced. In Figure 4 the changing situation due to the extension of the harbour is shown.

Acute erosion

Storm events, such as in the storm of 1976 for example, can cause severe erosion at the coast east of Zeebrugge.



a. Situation before extension of harbour breakwaters



b. Situation after extension of harbour breakwaters

Fig. 4: Changing of current, sedimentation and erosion pattern due to extension of harbour breakwaters.

1.2 Socio-economic aspects

1.2.1 Population rate

The population of Knokke-Heist counts about 30,000 people. The average population density in Belgium is around 400 persons/km^2, at the coastal area however this population density is even higher.

1.2.2 Major functions of the coastal zone

- **Fisheries and aquacultures:** In Zeebrugge, the fishery is also very important. More than one hundred of the 205 boats that compose the Belgian fishing fleet have their home port in Zeebrugge.

- **Industry, transport and energy:** Zeebrugge has become a real world port. The main advantage of this sea resort is the outer harbour, allowing the biggest tankers and ocean steamers to moor here.

- **Tourism and recreation:** Several popular seaside resorts are located along the influenced coastal stretch east of Zeebrugge.

- **Nature conservation:** The nature reserve, The Zwin, is tucked between Knokke and the Dutch border. It is the silted-up former estuary that used to give access to the ports of Sluis, Damme and Brugge.

- **Urbanisation (safety of people and investments)**

1.2.3 Land use

The coastal area at Zeebrugge is mostly a built up inhabited area. The function of the inhabited area is mostly tourism at the Knokke-Heist beaches and industry at Zeebrugge. The nature reserve, where the dune area is untouched, is located north of Knokke.

1.2.4 Assessment of capital at risk

Because of the development of tourism, the coastal area has become densely populated and densely built in Belgium. According to Bryant [1995], the entire Belgian coast is at high risk because of the dense population, infrastructure and buildings in the coastal area.

High risk: city or major port or > 150 persons/km2 or >150 m road/km2 or > 10 m pipeline/km2
Moderate risk: 150 < persons/km2 > 75 and 150 < m road/km2 > 100 and 10 < m pipeline/km2 > 0
Low risk: persons/km2 < 75 and m road/km2 < 100 and no pipelines

The beach region is of high importance (touristical, ecological, economical and social) and with the high population density the coast of Zeebrugge, Knokke-Heist must be considered as being at high risk.

2. PROBLEM DESCRIPTION

2.1 Eroding sites

Zeebrugge has had a small port since about 1900. Before the seaward extension of the harbour in the 1970's groins and a seawall were already present at the Knokke-Zoute beaches to protect the hinterland from flooding and the beach from eroding.
At that time there rather narrow beaches had already developed due to the harbour breakwaters intersecting the longshore transport. Notwithstanding the protection provided by the groins, erosion of the beaches continued; the Appelzak tidal gully already played an important role in the erosion process. At high tide the beach disappeared, leaving the seawall exposed to attack by storms.

The winter storm of 1976 left a seriously eroded 9 km long beach in front of the seawall and groins field of the Knokke-Heist municipality. Storm waves damaged the seawall on several occasions so that coastal protection works became very urgent.

Fig. 5: Groins at Knokke-Heist.

In 1976 the Belgian government decided to enlarge the harbour breakwaters at Zeebrugge (3,5 km into the sea). As a result of the Zeebrugge port extension (1979-1986), a more intensified beach degradation appeared in the area together with a dramatic silting up of the entrance gully to the highly valuable "Zwin" nature reserve further downstream.

2.2 Impacts

Erosion at the Knokke-Zoute beaches has great impact on the tourism and recreation functions of this area. Furthermore the occurring erosion seriously threatens the safety of the hinterland. Due to the erosion, the seawall, that protects the hinterland from flooding in combination with the dune belt, is under wave attack and can be damaged.

3. SOLUTIONS / MEASURES

3.1 Policy options

No further retreat of the coastline can be allowed in the coast sections where safety against inundation must be guaranteed by dunes. The policy option is hold the line at these sections (also at Zeebrugge and Knokke-Zoute beaches).

3.2 Strategy

After the harbour at Zeebrugge was built (1900), the first coastal protection works at the coast of this area existed of hard measures (groins and seawall). The groins could not be kept-up under German occupation during the Second World War, and in the 1950's and 1960's the area of dry sand on many beaches was either reduced at high tide to a few square meters (Knokke) or was just non-existent (Heist). When it was decided to extend the harbour breakwater 3, 5 km into the sea in 1976 it was also decided to execute protection works for the beaches situated at Knokke-Heist east of Zeebrugge.

A rehabilitation of the natural sea-land environment, new technical potentialities and political accents have made that since the seventies preference is given to "soft", eco-friendly measures, i.e. beach nourishment, taking into account the natural dynamics of the shore profile. After a comprehensive morphological study, it was decided to improve the east of Zeebrugge beaches with artificial beach nourishment too. The first nourishment was executed in 1977-1979.

Following completion of the beach nourishment works, the whole area has been surveyed regularly by echo-sounding below low water and by aerial photogrammetic and terrestrial surveys above low water since the first nourishment.

3.3 Technical measures

3.3.1 Historic measures

- Seawall
- Groins
- Harbour breakwaters

The harbour breakwaters after extension and before extension and the groins at the Knokke-Zoute beaches are shown in Figure 6.

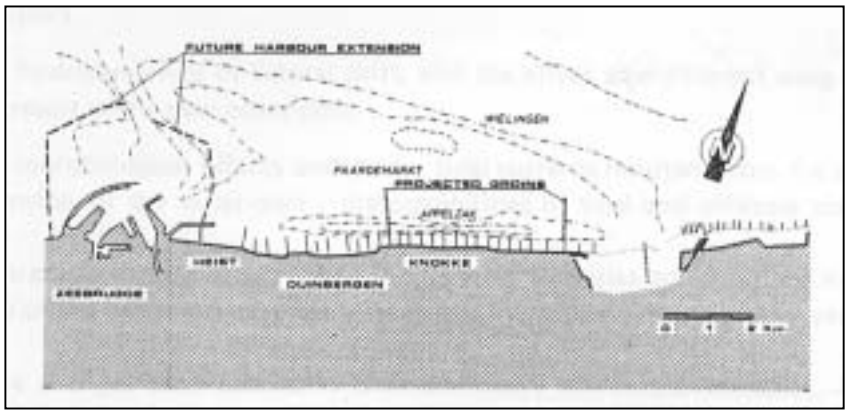


Fig. 6: Historic measures at Knokke-Zoute beaches.

3.3.2 Type

- **Artificial nourishment**

The first beach replenishment was executed in 1977. The second nourishment was necessary in 1986, at that time the harbour extension had just been finished.

3.3.3 Technical details

- **Artificial nourishment**

For the first beach nourishment, executed over a 8 km stretch in 1977, some 8,5 million m^3 of sand was required. As a result of the nourishment a new beach with a width of about 100 m at high tide was created. The nourishment was executed in two phases, in the first phase 2,6 million m^3 was pumped over a 5 km length of beach at a rate of 520 m^3 of sand per running metre on the most eroded beaches. Thereafter, during the second phase, 5,8 million m^3 was evenly-distributed over some 8 km of coast, at a rate of about 725 m^3 / m^1.

The second nourishment was an additional beach replenishment of approx. 1 million m^3 of sand over a 2,9 km reach in 1986. The present groins were for a great part covered by the sand of the renourishment.

The hopper dredgers dumped their load in a special dumping pit. From there, working continuously, a powerful cutter suction dredger and the necessary booster stations pumped sand along the beach. Some nourishment sand was dredged from the entrance channel tot the port of Zeebrugge which was to be deepened as part of the total project. An 11 km long pipeline was used to reach the most remote dumping areas.

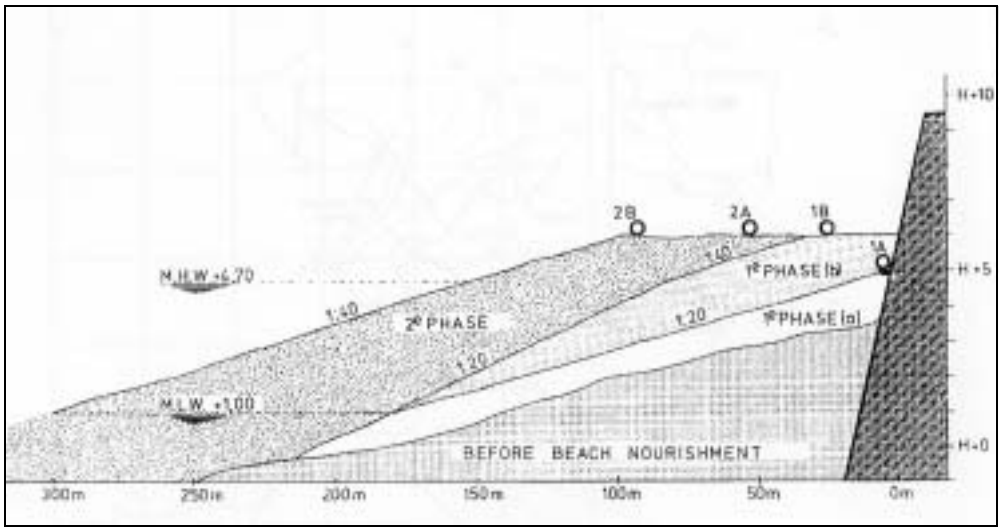


Fig. 7: Cross section of nourished beach at Knokke-Heist.

3.3.4 Costs

No information was found on the costs of the nourishments at Knokke-Heist.

4. EFFECTS AND LESSONS LEARNT

4.1 Effects related to erosion

- **Survey after the first nourishment 1979-1981**

An overall increase in dune growth occurred due to the increasing aeolian sand-transport because of the enlarged area of dry sand (beach nourishment). In contrast, on the beach the erosion predominates. The average beach erosion is about 50 m^3 /m^1 in the two first years after suppletion. Maximum erosion occurs on the beaches of Knokke-aan-Zee and Het Zoute (section 4 and 5): 150 m^3/m^1 after two initial years. The erosion is strongest in the foreshore area. The tidal gully "Appelzak" has shifted eastward and reduced significantly. In a period of two years, about 470,000 m^3 of sand has been lost from the beaches.

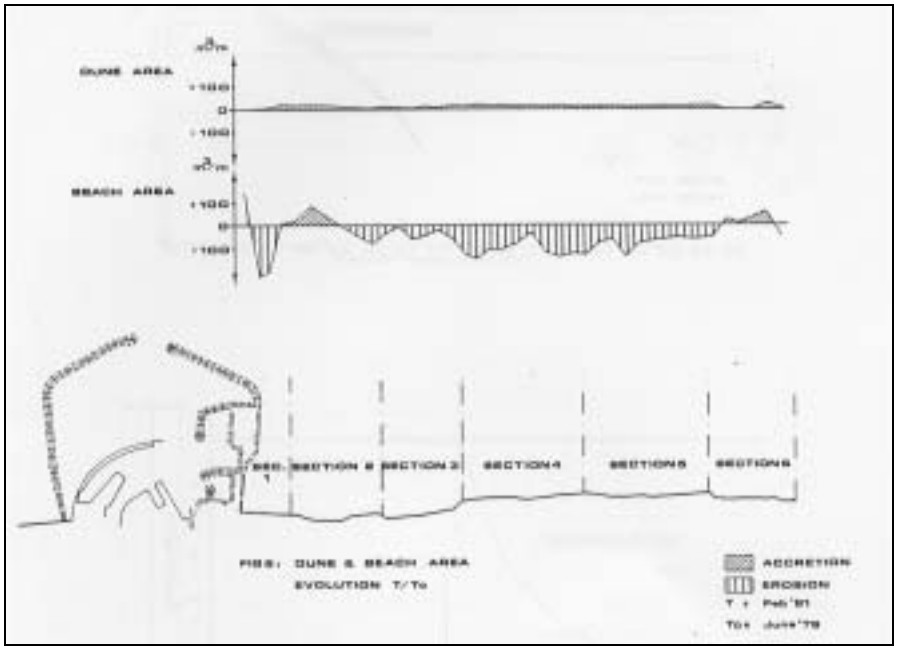


Fig. 8: Erosion and accretion after the first nourishment.

In winter there is erosion on almost all the beaches. In summer erosion is mostly limited to the beaches of Knokke-aan-Zee and Het Zoute (section 4 and 5), on the other beaches there is accretion or stabilisation. The sand lost in winter is thus partly recuperated in summer.

- **Survey after the second nourishment 1986**

After the second nourishment, intense local erosion at the beach of Knokke-Zoute transported the total sand volume out of the region in a period of only 5 years. Initially an erosion rate of 100 m^3/m^1/year was noticed, while a mean value of 40 m^3/m^1/year over the last 13 years is calculated. After five years, due to the sand deficit at the beach, even the foreshore started eroding. The erosion has increased at section 4 and 5 due to the presence of the extended harbour in 1986 (which was not present jet at the first beach nourishment). This can be explained by the changed current pattern (see Figure 8).

The nourishments do not stop the erosion, but they do prevent the coastline from receding further and further. Because of the net longshore transport gradient, the nourishments have to be repeated with a certain frequency.

4.2 Effects related to socio-economic aspects

The taken measures have created a wider beach at Knokke-Heist (function tourism and recreation). Furthermore the wider beaches and thereby the protection of the seawall assure the safety of the people and investments in the hinterland of the coast. In the current situation however, locally (Knokke-Heist and Het Zoute) the coastal protection system has weakened significantly since the last nourishment of 1986. New measures are needed to protect the safety of the hinterland and restore the beaches for recreational purposes.

4.3 Effects in neighbouring regions

No effects in neighbouring regions were notices from the executed nourishments.

4.4 Relation with ICZM

Only 20% of the dune area is managed as a nature reserve. A major problem for the conservation of natural values in the coastal zone is the fact that most of the remaining dune areas are still private property. In 1995 an “ecosysteemvisie” (dune ecosystem perspective) was needed to “correct” human activities. The perspective will be used for consultation between nature conservation and the different economic and utilitarian sectors that are active: coastal protection, water production, recreation and tourism. The ecosystem perspective presents target landscape types *(nearly natural units, multifunctional units, semi-natural units and controlled natural units)* and target habitat types *(EU Habitats directive)*.

In the past dunes were stabilised by placing fences and planting marram grass. Also marine erosion was prevented by building dykes in front of the dune belt. Fore dunes are now allowed to follow natural dynamics again with maintenance of the present shoreline. The main task is to restore herbaceous habitats. Therefore scrub has been removed followed by grazing with horse and cattle (pattern - oriented management). Also part of restoration is spontaneous woodland development by removal of exotic tree-species and grazing by donkeys (process - oriented management). By diminishing the extraction of groundwater and drainage in the polders, and allowing some sand drift a natural dune fringe landscape with calcareous marshland and wet meadows is expected to develop.

Fig. 9: Nourishment directly downstream of harbour breakwater.

4.5 Conclusions

Effectiveness

The nourishments are effective in preventing the coastline from receding. However at heavy storm surges a lot of erosion can occur in a small time at the Knokke-Zoute beaches. Though the nourishments are expensive and do not stop the erosion, an advantage is that no negative effects are induced in neighbouring areas (as is the case with hard measures such as groins).

The nourishments are not a permanent solution; they have to be repeated after a certain period when the beach becomes too narrow again.

Possible undesirable effects

No undesirable effects of the nourishment were experienced.

Gaps in information

No information was found on the costs of the nourishments.

5. REFERENCES

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Figures:

Figure 1: http://www.icm.noaa.gov/country/belgium.html
Figure 2: HAECON, New developments on coastal protection along Belgian Coast
Figure 3: HEACON, Beach nourishment: a "soft" method for coastal protection
Figure 4: HEACON, Beach nourishment: a "soft" method for coastal protection
Figure 5: ???????
Figure 6: HAECON, Artificial beach re-nourishment on the Belgian coast
Figure 7: European coasts, an introductory survey
Figure 8: HAECON, Artificial beach re-nourishment on the Belgian coast
Figure 9: European coasts, an introductory survey.