

Vulnerability of the Belgian Coastal Lowlands to Future Sea-level Rise

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3.1 INTRODUCTION

The coast of Belgium is characterized by a low-lying plain which is situated at about mean sea level and protected from the sea by dikes and dunes. The plain, with an average width of 15 km, borders the southern North Sea coast and extends over a total length of 65 km. An important extension occurs in the western part along the river Yser. The topographical level of the plain ranges from 4 to 2 m TWA, which in reality means at mean sea-level to +2 m (the Belgian reference zero represents mean low water level at spring tide, which is 2.03 m below NAP) (figure 3.1).

Only two reclaimed areas situated below mean sea-level occur; one of them, called De Moeren, is located in the far west and lies 1 to 3 m below mean sea-level; the other, called De Lage Moere, near Brugges in the eastern part of the plain, is at a level of 1 m below mean sea-level. The general topography dips southwards from the sea into the hinterland, thus causing great difficulties for drainage.

The river Yser is the only river in the coastal plain. Its mouth is located at the town of Nieuwpoort where an important sluice complex controls the drainage of a great part of the plain. In history, and not at least during the First World War, these sluices played an important role in the artificial inundation of the area.

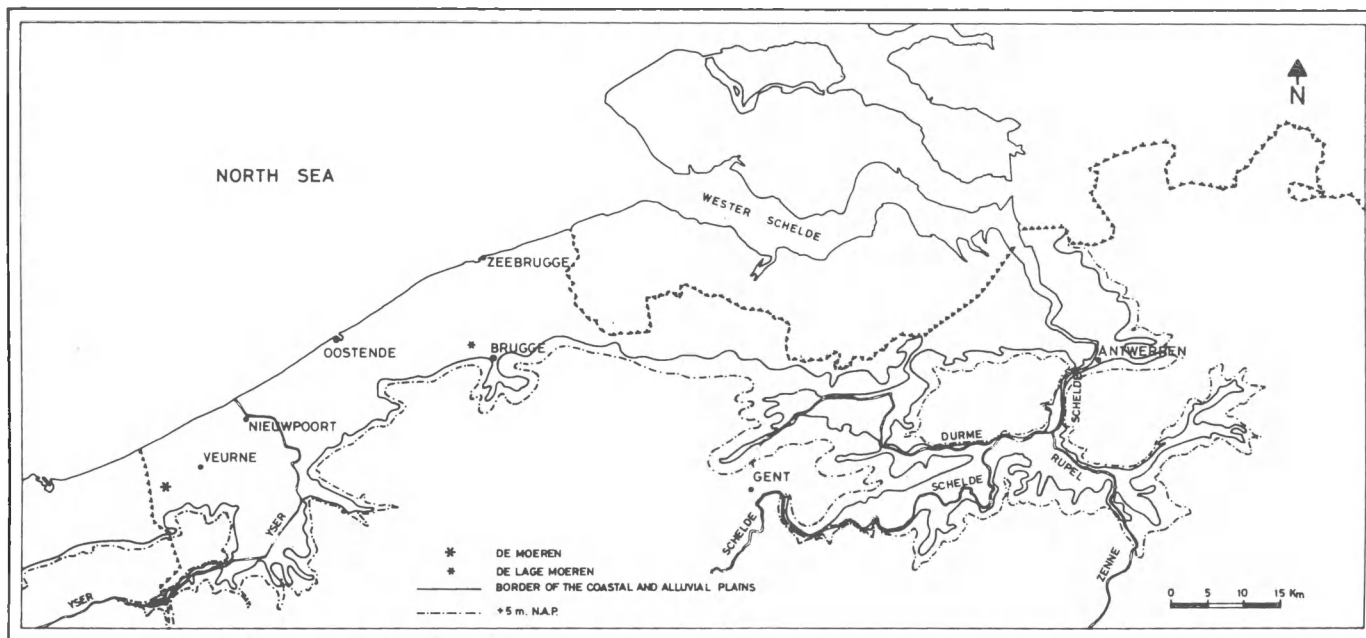


Figure 3.1 Location of the lowlands along the Belgian coast and the Scheldt estuary. The area below the +5m (NAP) contour line is considered to be a potentially hazardous region with a sea-level rise of one metre

The only two remaining natural areas not protected from the sea by man are the Zwin, a sandy salt marsh behind the dunes in the far east of the Belgian coast, and a very restricted tidal mudflat with salt marsh on the east side of the Yser mouth in Nieuwpoort.

3.2 THE SHORE AND DUNE BELT

The Belgian shoreline is a mesotidal, wind-dominated clastic shoreline with a tidal range between 4 and 5 m. The shore shows a typical runnel and ridge beach. As on the Dutch coast, wave action is generated by the prevailing westerly winds, and the coast is periodically subject to storm surges from the south-west, west and north-west. The north-westerly storms especially cause extreme high tides and high energy waves.

There is a dune belt all along the shoreline. In the western part the belt is 1.5 to 2 km wide and is very well developed, reaching elevations up to 10 to 20 m in general. The highest dune, located at Koksijde, reaches an altitude of 30 m. In the central and eastern part of the coast, the dune belt is alarmingly narrow (50 m to 800 m), although it is fairly high (ranging between 10 and 25 m, with extreme heights of about 50 m). In the far east near the Dutch border the dunes reach a height of only 5 to 10 m and are in general 1.5 km wide.

Beach erosion has been observed at different parts of the coast. De Moor (1979) described several places where severe erosion of the beach and the foredune is occurring, despite extension of defence structures and beach nourishment. The author discusses in more detail the erosion of the beach between Bredene and De Haan, where in the period between 1970 and 1979 a residual retreat of the dunefoot of about 40 m was observed. The defence structure, aiming to create an artificial beach by sand nourishment, failed completely. A survey of beach profiling during three consecutive years yielded that the main erosion consists of the following phenomena: a long-run residual lowering of the beach; a back-cutting of the back beach; a direct spring tide wave attack on the dunefoot; and a retreat of the dunefoot itself in the zones without a seawall (De Moor 1979). According to the author, the erosion is a natural phenomenon and consists of the erosional phase of coastal megaprotuberances.

The highest waterlevels ever recorded are (in m TAW, i.e. 2.03 m below mean sea-level):

along the coast:

Nieuwpoort	6.73 m (1953)
Ostend	6.66 m (1953)
Zeebrugge	6.69 m (1953)

along the Schelde:

Terneuzen	7.29 m (1953)
Doel	7.76 m (1953)
Antwerp	7.77 m (1953)
Temse	7.34 m (1976)
Dendermonde	6.94 m (1976)
Melle	6.45 m (1980)

The human impact on the shore and dune belt

In many locations, the coastline is directly bordered by high apartment buildings, thus forming an almost continuous concrete wall, sometimes called the new Atlantic Wall (plate 6). These buildings are protected from the sea by a seawall. Actually 83 per cent of the shoreline is protected by a sea defence structure.

The logic or usefulness of all these defence structures still remains an open question, as some particular situations can be observed. Seawalls are usefully constructed as a protection in areas where erosion occurs and when men and resources from the upland become endangered by inundation and erosion. But west of De Panne, for example, a 3 km-long seawall was built in front of a dune belt which is nearly 2 km wide and where neither property nor human life can be endangered, as the area is protected as a nature reserve. It is true the foredunes are subject to erosion, but it seems that the meaning of protection has been interpreted somewhat too widely, as the erosion occurs mainly in wintertime (Depuydt 1967), which is the usual situation.

It would be very interesting to leave this (restricted) erosional phenomenon to nature and observe and quantify the response of the beach and foredune to possible increased storminess and sea-level rise. Moreover due to this erosion (which is not a severe threat to this dune belt) sand would be added in the littoral system and deposited on other sand-deficient beaches.

Another special situation with respect to the planning of sea defence structures can be observed at Oostduinkerke. Large houses and apartment buildings, representing great investments, have recently been built on the foredune, about 300 m from the high water mark, without any protection at

all. The private view of the beach is first-rate; the question however is for how long.

The dune belt has also been used as a zone for residential building, except for a few localities. A great number of houses and apartment blocks are built, requiring a dense road infrastructure. At Oostduinkerke a car park has been built in front of the foredune. Moreover an important part of the central dunebelt is used as a golf course. To what extent this considerable human impact on the shore and the dunes is detrimental is still to be quantified.

While there is broad agreement that seawalls are detrimental to adjacent beaches and that they are passively responsible for narrowing the beaches in front of them, controversy still remains over the question of whether seawalls play an active role in beach degradation (Pilkey and Wright 1988). Kraus (1988) in a review of the subject concluded that the majority of quantitative-type field studies indicate that seawalls do not accelerate long-term erosion of beaches if there is ample sediment or a wide surf zone exists. But if beaches are deficient in sediment or if sea-level is rising, erosion is more likely to occur on armoured beaches compared to unarmoured beaches. De Moor (1979) concluded for the Belgian coast that the classical defence structures have proved to be useful by only impeding further retreat of the dunefoot. Lowering of the beach itself still continues.

3.3 SYNOPSIS OF THE TIDAL OBSERVATIONS ALONG THE COAST: CONSIDERATIONS WITH RESPECT TO SEA-LEVEL CHANGES

In Ostend tidal observations, i.e. high water (HW) and low water (LW) records, started in 1820 (van Cauwenberghe 1977, 1985). They were established on a tide gauge near a lock in the harbour. Unfortunately, for the period 1820–34 all data are lost; it is only for 1835–52 that monthly mean values of HW and LW are found in a manuscript of Henrionet (1876). At that time, the tide gauge was linked to a reliable benchmark which was incorporated on top of a quay in the vicinity.

As only monthly mean values of HW and LW are available, mean tide level (i.e. mean HW and LW) can be calculated. The difference between this level and mean sea-level (MSL) along the coastline is fairly constant (e.g. 0.063 m + 0.006 for the period 1949–88). So, knowing the mean tide levels, it is possible to determine the MSL values for each year for the period concerned.

The tidal records of the period 1866–71 were observed by a mechanical tide gauge; however, they were lost, and those of 1878–1914 have been

subject to many interruptions in the observations, so that they cannot be used for further consideration.

From 1927 until now, reliable and continued records for Ostend are available in the Coastal Hydrographic Office (the years 1940, 1942 and 1944 are very disrupted owing to the circumstances of the Second World War). For the observation sites at Nieuwpoort and Zeebrugge valuable records are available since 1967 and 1964, respectively, but they cover too short a time span for any conclusive interpretation with respect to sea-level changes.

Best-fit curve calculations on the Ostend records for the entire period, i.e. from 1835 to 1852 and from 1927 to 1988, indicate a linear increase of 0.01 m per decade for HW, LW and MSL. So far no indication of an acceleration in the increase has been shown on the moving averages of the MSL or on the graphs of the annual values.

Tidal observations are of course relative measurements. Whether the tidal observations are an indication of a rising sea-level or a record of the subsidence of the land is still to be established.

3.4 EFFECTS OF A FUTURE SEA-LEVEL RISE ON THE COASTAL PLAIN

In general the major impacts of a future sea-level rise in coastal lowlands are permanent inundation, loss of protective beaches, increased flooding and salt water intrusion (Titus 1986).

However, a rise in sea-level would seriously threaten a large portion of the coastal lowlands. The most obvious impact is that nearly the entire coastal plain of Belgium would be permanently inundated. In the case of a series of heavy storms the actual sea dikes will certainly not be high enough, and storm waves may overtop the sea walls. On the other hand, areas that are below or at sea-level have their unique characteristics of low elevations and high ground water tables which require drainage by pumping.

The impact of a rising sea-level on the coastal area is influenced to a great extent by its Holocene geological setting.

Geological setting of the Belgian coastal area

The coastal deposits represent the major infilling of the area under marine, fresh water and terrestrial conditions during the Holocene. The deposits reach their greatest thickness of about 30 m in the seaward region and wedge out towards the Pleistocene hinterland.

The western plain shows a different Holocene geological history from the eastern coastal plain, resulting from the altitude of the Pleistocene subcrop. In the eastern part the subcrop occurs at a considerably higher elevation, so that the influence of the Holocene sea-level rise started much later. The western part of the coastal plain is considerably enlarged by an important southern extension along the River Yser. As a consequence the western part contains a greater record of geological events both in time and in space (Baeteman 1981).

In the western part, the unconsolidated deposits are characterized by lateral zonation. In the seaward region, only marine and brackish clastic sediments are present overlying a basal peat layer in some places. In the central part of the western plain, the deposits consist in general of an alternation of brackish-marine sediments and peat layers. Towards the Pleistocene hinterland, the deposits are formed by only a basal peat layer overlaid by a cover of clastic brackish-marine sediments, while at the border of the outcropping Pleistocene area, the cover of brackish-marine sediments form the entire Holocene sequence (figure 3.2).

The sequence of coastal deposits is a result of the Holocene sea-level rise which initially was very rapid. During the last glacial age, sea-level was at least 100 m lower, and 9,000 years ago it was about 45 m lower than at present. On land, the very first evidence of a rising sea-level is reflected in the development of a basal peat. However, the continuous and rapid rise of

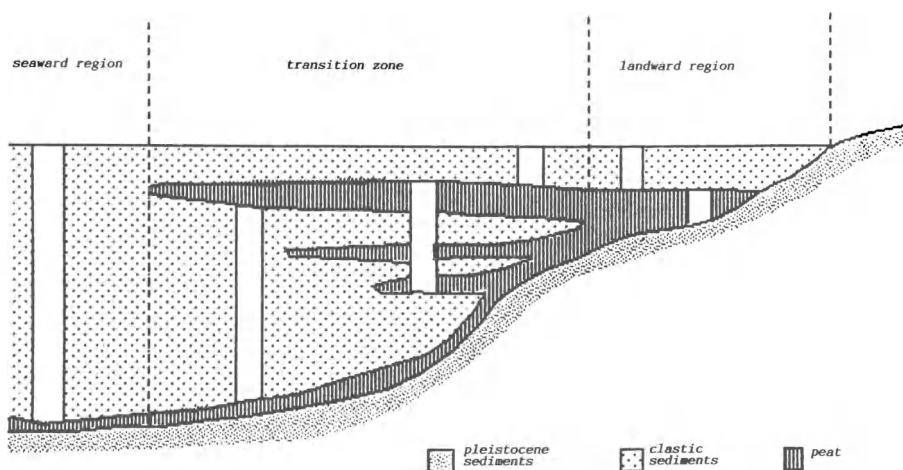


Figure 3.2 Schematic cross-section of the Holocene deposits in the western part of the coastal plain

the sea-level ultimately resulted in the deposition of sediments in the lower parts of the area.

The oldest known onset of the marine sedimentation, observed at an altitude of -16.60 m, occurred at 8440 ± 130 years BP (Baeteman 1989). From then onwards a tidal flat, and more particularly sandflats and associated tidal gullies, started to develop, characterized by a continuous deposition of clastic sediments. At the same time, the marine influence shifted landward and upward causing the end of the basal peat growth in these areas (figure 3.3).

From 7000 years BP a significant change in the general tendency took place as the rate of sea-level rise decreased (Baeteman 1987 a,b, 1989). In the residual valleys, previously infilled with sandflat deposits and fluvial deposits in the southern areas, peat growth started while in the rest of the (contemporary) plain, mudflat and salt marshes developed. From 6400 years BP, however, general peat growth is observed over nearly the entire (contemporary) plain, showing an important landward extension in both western and eastern parts (figure 3.3).

This peat layer represents the onset of what is usually called the typical cyclic formation of coastal deposits where peat repeatedly came into being alternating with the deposition of tidal sediments. The cyclic formation with the intercalated peat layers, indicating temporary regressive tendencies, generally came to an end in the time interval of 2700–2200 years BP, and in more landward areas, between 1900 and 1600 years BP.

In the eastern part, this typical cyclic formation is not so well developed. In general the Holocene sequence consists of only a basal peat that developed from 5600 years BP till 2500 years BP, overlaid by a clastic cover a few metres thick (Mostaert 1985, 1987).

The seaward extension of the coastal plain could not be established yet. Most of the evidence is situated offshore. Moreover the beach and possible dune deposits have been reworked continuously since the beginning of the Holocene. Indeed the potential for preservation of these sedimentary environments is very low in the case of a transgressive coast.

In the western part of the coastal areas, more particularly west of Nieuwpoort, older dune systems were preserved, however. An old dune group, called the Adinkerke-Ghyvelde dunes, occurs in an isolated position in the coastal plain near the French border (figure 3.4). The dunes are believed to be older than 4300 years BP (de Ceunynck 1985, 1987; Depuydt 1967). (This last remnant of older dunes is now threatened by the construction of a new highway.) From 3,000 years ago the coast (at least the western part) was characterized by progradation and a new dune system, called the Old Dunes of De Panne, developed seaward from the Adinkerke-

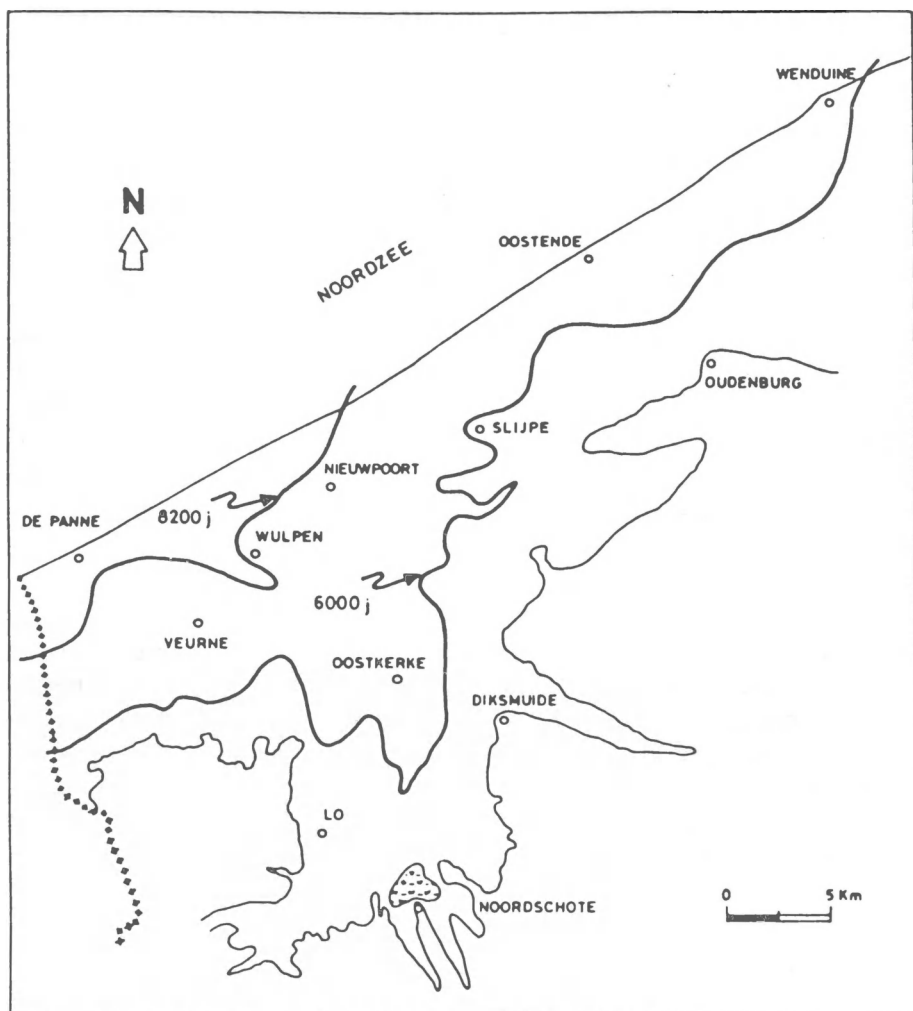


Figure 3.3 Landward extension of the coastal plain at 8200 years BP and 6000 years BP

Source: (After Baeteman 1989).

Ghyvelde dunes (de Ceunynck 1987). All evidence, and not least from archaeology, points out that the Old Dunes of De Panne were on the coast until the Roman period (de Ceunynck and Thoen 1981).

After the Roman period significant changes at the coast occurred. Severe transgression(s) took place eroding, amongst other things most of the Older Dunes of De Panne. Only from the eleventh century AD the formation of a new dune system (the Younger Dunes) was observed, which started

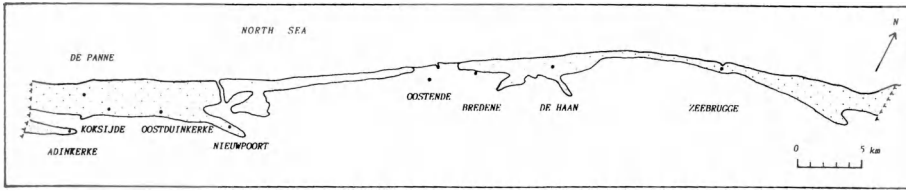


Figure 3.4 Location of the dune belt along the coast and the Old Dunes of Adinkerke-Ghyvelde. The dune belt is alarmingly narrow in the central part, and well developed only in the western part of Belgium.

probably as a result of increased storminess. From the end of the fourteenth century large parabolic dunes developed. Their formation was probably related to an increased erosion along the coast, yielding more sand to the littoral system (de Ceunynck 1985).

The vulnerability of the clay/peat area of the coastal plain

Those areas where the deposits are characterized by the alternation of peat and clay are very vulnerable. They are situated approximately at mean sea-level and the ground water table nearly reaches the surface. Hence these areas have very bad natural drainage. At present the evacuation of superfluous water is a great problem and in rainy seasons most of these areas are regularly flooded, in particular those along the River Yser. This critical situation is enhanced by the fact that the clay and peat sediments are very sensitive to compaction and as a consequence the area is subject to considerable land subsidence. In this case pumping is out of the question. Artificial drainage based on pumping certainly will lower the ground water table, but will simultaneously lower the land surface; thus the initial problem is not solved but the risk for flooding is increased. Besides the problem of land subsidence, pumping also brings the risk of intruding brackish or salt water into the upper part of the phreatic ground water.

It is obvious that (better) management for drainage is to be considered critically in the near future, if complete flooding of the area is to be avoided. It is true that general flooding of a coastal lowland and consequently the deposition of new sediments are not the result of one single storm surge only. Much more important – and critical – is the situation of the area itself with respect to the water control. In well-drained areas, superfluous water from temporary floods will be relatively quickly under control. On the other hand, in areas with deficient drainage it is clear that the evacuation of the superfluous water will become impossible. This can

lead to continuous flooding from the invading sea attended with erosional incisions, resulting in considerable damage.

Proper management of the drainage system will require careful maintenance of the numerous ditches and canals and their dikes. At present many of these dikes are certainly not high enough and in too bad condition to ensure optimal evacuation of a sudden excess of water and sufficient protection.

The vulnerability of the dunes and beaches

A coastal dune belt pre-eminently forms the natural coastal defence against storm surges. But more than half of the dune belt is much too narrow to resist a period of storms. The dunes will be eroded, partly or even entirely during a heavy forty-eight-hour storm.

A rise in sea level will cause the shoreline to retreat. Beaches follow a characteristic profile. If sea level rises, the entire profile must rise by an equivalent amount. The sand necessary to raise the profile will generally be supplied by the upper part of the beach, thus resulting in a landward shift of the entire beach profile (Bruun 1962. See figure 5.14).

However in many places the first line of dunes facing the beach has been replaced by apartment buildings, hotels and concrete seawalls. Consequently there is no possibility any more for a natural sediment exchange between foreshore, beach and dunes, and during periods of high energy waves and storms there will be no sediment supply from the first dune ridge to the beach. As most of the beaches fronting the seawall are narrow, the recovery process may be absent (Kraus 1988). This lack of sediment supply can accelerate beach erosion, and the undermining of the seawall protecting the buildings is not inconceivable.

Inherent in the process of infilling of a coastal plain is the occurrence of numerous former gullies at different depths. When the gullies are post-Roman in age, they are filled with loosely packed sand saturated with water. These sandbodies are easily subject to liquefaction (quick sand flow) when the pressure on them suddenly is reduced. This situation might occur where such a former gully intersects the actual shoreline and if the pressure, formed by the fresh water pocket in the dunes, decreases considerably in the case of erosion of the dunes. This very vulnerable situation exists in particular where the dune belt is narrow, i.e. in the central part of the coast.

Last but not least, the dune belt is the only natural fresh water reserve besides rivers for the coastal plain and represents the resource for drinking water for the coastal region. The broader and higher the dunebelt is

activity the coastal zone is the most important region of the country. In 1982, 20.4 per cent of all vacations (at least four nights) of the Belgian population took place on the Belgian coast (68 per cent of the vacations of Belgians were taken abroad). In 1985 tourists (Belgians and foreigners) spent 15.3 million nights on the Belgian coast, representing 49 per cent of all (registered) tourist nights in Belgium. Fifty-one per cent of all day trips in 1982 had the coastal zone as a destination. All these activities take place along a coastline only 65 km long, so that congestion is the main problem on peak days (Boerjan 1985; Vanhove 1973).

Tourist activity on the Belgian coast has been growing for more than 100 years. The influence of Leopold II (Belgium's second king) was important; he compared the Belgian coast to a gold mine waiting to be exploited. After the Second World War the evolution in the tourist activity grew very rapidly. The increase of free time and income in the 1950s and 1960s and growing motorization brought about an explosion in demand for tourism. The demand for accommodation causes a rapid increase of land prices, which makes it easy to understand that many hotels and houses are replaced by apartment buildings. Apartment tourism soon becomes the dominant type of accommodation. A building boom took place especially after 1955. Project-developers were on the hunt for decayed hotels and houses and for new building sites (often located on land of great value from an ecological point of view). *Belle époque* houses were replaced by monotonous high-rise buildings which formed a new Atlantic Wall. Seaside resorts are losing their identity and are expanding towards each other, leaving few open coastal spaces and natural dune areas. Holiday villages and new camping grounds are built in the polders. Camping tourism expanded considerably and also consumed much of valuable space in the dunes and polders. Many camping grounds are concentrated along the littoral fringe, in particular in those localities where the dune belt is alarmingly narrow. The type of accommodation on camping grounds changed from tents to caravans and solid constructions. Camping sites became overcrowded and disorderly and sometimes lacked basic amenities. The infrastructure for recreation (swimming pools, tennis courts etc.) took additional space.

The explanation of the destruction of the natural landscape of the coast resides in the objectives of the tourist sector, which are purely economically oriented. The tourist supply is simply determined by its demand. The coast is considered as a 'tourist product' that has to be sold. Real estate agents invite the public to buy an apartment as an excellent investment. The ecological value of dunes and polders gets little attention unless as an element of the tourist product. Even in the seventies a buffer zone around the beautiful nature reserve of De Panne was sacrificed to an upper-class

residential development. The Belgian coast lost about 300 ha of dunes between 1965 and 1985 mainly through the extension of residential areas.

The government continues to invest heavily in tourism. Many harbours for sailing yachts have been enlarged or newly built; Nieuwpoort for example is becoming one of the largest in north-west Europe. Recently numerous breakwaters were built along the shore in an attempt to offer tourists broader beaches.

3.6 THE ALLUVIAL PLAIN ALONG THE SCHEDT ESTUARY

The polders and low wetlands along the Rivers Scheldt, Rupel and Durme are situated at a level of -0.5 to 3 m TAW and belong to the lowermost regions of Belgium. The main problem of these areas is the discharge of superfluous water.

The tidal range in the estuary increases from about 4 m at the mouth of the Scheldt to more than 5 m at the mouth of the Rupel. In periods of heavy rain and high tides, discharge of surface water becomes impossible and several times already this situation has given rise to extensive flooding of the alluvial plains. The highest tide ever recorded reached 7.77 m in 1953 in Antwerp.

A serious improvement of the drainage system, a precise water level control and a maintenance and elevation of the dikes will be essential. However, intensive drainage and pumping is increasing the salt water intrusion in the aquifers, which is already occurring in some parts of these polders.

The planning of navigation and port facilities will have to take rising sea-level into account. The sea-level rise will gradually decrease clearance under bridges, requiring drawbridges to be opened more frequently.

The Scheldt estuary is characterized by the dominant position of the industry of the harbour of Antwerp. The harbour of Antwerp forms the most important industrial centre of Belgium (chemical, petrochemical sector, petroleum refinery, motor industry, electricity production). A nuclear plant is located along the Wester Scheldt at a short distance from Antwerp. The harbour itself is spread over a $13,800$ ha area; docks and quays reach a length of about 80 km. Yearly 85 to 90 million tons of merchandise are exchanged and $16,000$ to $17,000$ units of the merchant service arrive at the port. Tremendous private investments have been applied to industry; nearly 70 per cent of investments were realized by foreign firms and joint ventures. About $75,000$ persons are involved in the

harbour activities (industry included), which means that (with their families) no less than 200,000 Belgians are dependent on it.

3.7 FINAL CONSIDERATION

The coastal and alluvial low-lying wetlands are important areas for the country as an industrial and recreational zone. The areas are characterized by a dense population, and great investments have been made to develop industry and tourism.

However these areas are very vulnerable. Already nowadays flooding is occurring regularly and an eventual sea-level rise in the near future will severely damage these entire plains. The drainage system is insufficient and in a bad condition. The dikes along the canals must be elevated, and discharge feasibilities must be reconsidered as well as the increasing salt water intrusion. The coastal dune strip is for its greatest part far too small to act as a natural defence against the power of the sea, and the huge human impact on that environment makes its situation even more vulnerable.

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