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MORPHOLOGICAL DEVELOPMENTS AND COASTAL ZONE MANAGEMENT IN THE NETHERLANDS.

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1. INTRODUCTION

The Netherlands are situated on the delta of three of Europe's biggest rivers: the Rhine, the Meuse and the Scheldt, at the border of a shallow regional sea : the North Sea (see Fig. 1). Without dikes more than half of the country would be flooded (see Fig.2). The area is threatened from one side by storms which can generate huge surges, due to the shallow sea and the funnel shaped geometry of the southern North Sea, and from the other side by river floods. Without flood defences much of the Netherlands would be regularly flooded as large parts lie below mean sea level.

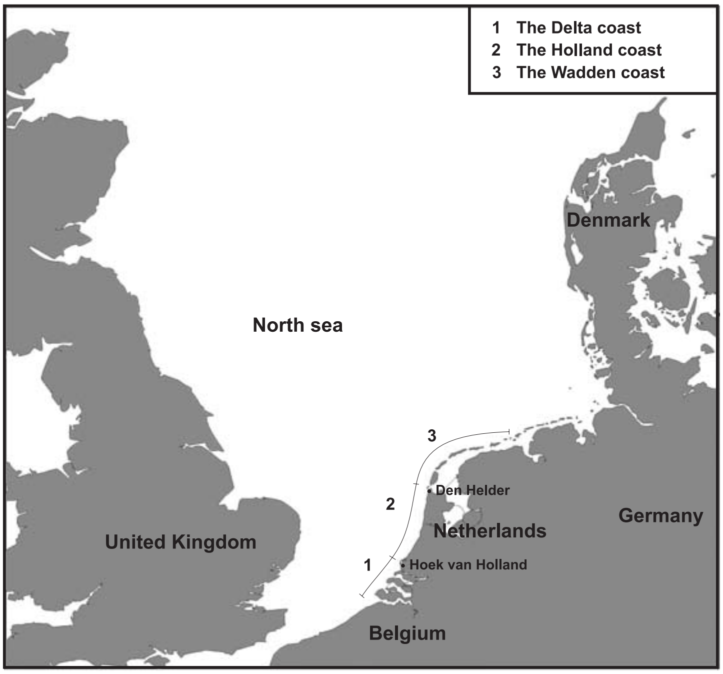

Fig. 1 Orientation of the dutch coast

In 1953 a big storm caused a flooding disaster with enormous damage and nearly 2000 deaths in the Netherlands. In 1995 a river flood caused a situation so serious that the security against flooding of various polders could no longer be guaranteed and 200,000 people together with many millions of animals were evacuated. Following these events safetystandards were developed and in 1996 a new Flood protection Bill including a 5-yearly check of all dikes and dunes was implemented.

Ongoing erosion of the sandy coast and its impact on safety and nature caused a change of policy in 1990. From than on the policy of "Dynamic preservation" has been followed where further erosion has been counteracted by sand nourishments involving 6 M m^3 sand per year. Following ongoing research and especially taking into account the sustainability of the deeper shore, it was concluded that a higher amount is needed. From 2001 onwards, the Netherlands has raised the total nourishment volume in it's coastal system from an average of 6 to an average of 12 M m^3 per year. The nourishment budget has been raised from 27 to 41 million Dollar per year.

Fig. 2 Area flooded without dikes

2. HISTORY

In geological terms much of what is now the Netherlands was created during the last Ice Age but one (circa 180,000 – 130,000 years ago). In the central Netherlands moraines of up to 100 meters above mean sea level were left, and in the north of the country vast amounts of glacial material were laid down. In the south of the country the influence of the major rivers was dominant. The Rhine and Meuse laid down thick layers of sand and gravel. After this period the land supported little vegetation such that the winds were able to blow away large quantities of soil to other locations. In the last Ice Age (circa 65,000 – 10,000 years ago) in which the ice cap did not reach the Netherlands, cover sands were laid down on a large scale.

Approximately 10,000 years ago the last Ice Age ended and the warmer Holocene period started. As a result of the rising sea level an increasingly large part of the west and north of the country came under the influence of the sea. Dunes rose parallel to the coast behind which clay and peat deposits were formed. From approximately 5,000 years ago the coastline of the Netherlands looked broadly as it does now.

From approximately 1,000 A.D. the coast underwent an important change. The shore face cross section took on its current relatively steep form caused by the displacement of large quantities of sand in the direction of land. In this period the so-called Younger Dunes were formed that now dominate the character of the Dutch coastline and in many places represent a natural barrier to the sea.

During this period the river trajectories were relatively stable. The Rhine and Meuse flowed to the sea in wide, relatively shallow channels with many sandbanks. As a result of reasonably regular drainage from the upper reaches of the area, water levels of the rivers varied little.

Discharge was also divided over a large number of river branches. Nevertheless flooding in this period did occur [Van de Ven, 1993]. The flooding of the river over its normal banks was however, rarely seen as a disaster. People lived primarily on the higher ground (mainly the banks and river dunes and flood depths were low.

In the Roman era (circa 2,000 years ago) local people started to drain the low lying peat and clay areas to give access to more agricultural land. The dewatering of the marshes also resulted in a lowering of the ground level by which again damage from flooding rose. From the twelfth century farmers also started building dikes to protect their land. Drainage of the low lying land could then no longer take place in a natural manner. Drainage ditches and sluice systems were built. Later windmills were used to raise the water into the drain system from low lying polders . This again resulted in further lowering of the ground level. Since the early Middle Ages ground levels dropped several metres as a consequence of drainage, oxidation and settlement.

In the following centuries the building of dikes was continued to respond to the needs of an increasing population and make greater use of the low lying polder areas. The dike-ring areas (those areas enclosed by primary dikes), which still exist in many parts of the country today, were created in this period by building dikes along the rivers. Land reclamation in the west of the country completed this picture, in which the difference between the falling land levels and the rising external water levels – as a result of rising sea level and higher water flows, only continued to rise [Van de Ven, 1993].

3. MANAGEMENT AND ORGANIZATION

The history of the Netherlands is closely interwoven with the countries fight against flooding. This is also to be seen in the structuring of the national water management organization. For more than a thousand years sayings such as To live by water, manage that water , Pump or drown , and Dike or depart have been the main guidelines in protection against flooding. Concern for the dikes and control of water levels are firstly handled at the local level, later at a regional level. From the 13th century the water boards received the responsibility for the maintenance of the dike system and the water levels. These water boards are in fact the oldest democratic institutions in the Netherlands. The contribution that each citizen has to pay to a water board was, and is today, a function of the value of their property. The water boards also regulate the water levels in the polders. The number of polders in the Netherlands increased drastically over time and in parallel with this the number of water boards. In the first half of the 20th century there was a total of more than 2,500. Over the last decades the number of water boards has been strongly reduced. There are currently some 85 water boards left. A further reduction is likely in the context of efforts to create strong all-in local authorities.

The water boards are now the foundation for the national management organization for flood defence and water management. Every Dutch resident pays taxes to his or her water board and can participate in the elections for the management of the organization. The chairperson of the water board is appointed by the crown.

Some 200 years ago, in 1798, the institution Rijkswaterstaat was founded to give a national guidance to the water management as some aspects could be better addressed at a national level. Rijkswaterstaat (currently employing some 9,500 staff) is the executive organ of the national Ministry of Transport, Public Works and Water Management.

In spite of the considerable power of Rijkswaterstaat, the water boards have always retained a significant role in the management organization. The management of water and the flood defences in the Netherlands are strongly decentralised. Water boards are responsible for the management and maintenance of defences and the quality and quantity of the local and regional water supplies. The Provinces are supervisors and the national authorities (through

Rijkswaterstaat) have final control. The Minister of Transport, Public Works and Water Management is responsible to Parliament (States General) for all aspects of flood defence and water management.

The twelve provinces form the national middle management structure. They represent the link between the national government and the local authorities (water boards and municipalities) with important tasks in the domain of spatial planning and regional adaptation of national plans in the area of the environment, traffic and transport, and integrated water management.

The different roles and responsibilities of central government, provinces and water boards are clearly visible in the challenge of maintaining and reinforcing dikes. The standards which the flood defences must satisfy are laid down by Parliament. The plans for reinforcement programmes are set up by the water boards. The provinces must approve these while taking into careful consideration other factors such as spatial planning, nature, landscape and historical culture. The water boards then provide supervision for the actual defence strengthening work. The role of national government is restricted to supervision and specialist support if this is required. The national government does, in fact, still directly manage some flood defences, such as the enclosure dams of the IJssellake and the enclosure dams of the former tidal inlets in Zeeland.

Management relationships are also clearly visible in the event of high water conditions; wherever possible the responsibilities are laid at the feet of local authorities. Water boards judge the strength of the defences, municipalities carry responsibilities for the safety of citizens and provide information. If necessary the regional coordination is handled by the Province. Only in very special situations coordination is transferred to a national level.

4. SAFETY STANDARDS AND FLOOD PROTECTION BILL

The implementation of safety standards started after the big flooding in 1953. During the night of 31 January to 1 February 1953, a severe north-westerly storm drove the sea-water up against the Dutch coast. At Hook of Holland the water reached a level of 3.85 m above mean sea level: 57 cm higher than the previous record. This is a level expected to occur approximately once in every 250 years. The storm surge led to severe flooding. A total of 136,000 ha of land was inundated and 1835 people were drowned. The economic damage was approximately 14 % of the gross national product. Almost immediately the Minister of Transport, Public Works and Water Management appointed a special Delta committee to consider urgently what action should be taken to prevent any future recurrence of such a major disaster. This resulted in the Delta-Plan (Deltacommissie, 1960) and the closure of many of the tidal inlets in the southern part of the Netherlands. In 1986 the last tidal inlet, the eastern Scheldt, was closed with a storm surge barrier with 62 openings and a total width of 2800 metres. At the same time this committee studied the required safety standards for the coastal areas of the Netherlands. The outcome of an economic study (Deltacommissie, 1960) was that a safety standard of 10^{-5} to 10^{-6} against flooding should be applied to the central part of the Netherlands. Currently the total invested capital behind the dutch flood defences is estimated at 4,000 billion guilders or 2,400 billion US Dollars (Resource Analysis, et al., 1992).

Finally these results were implemented in the following safety standards against flooding. For the central part of the Netherlands (see Fig. 3) the safety standard and the design criteria were set to 10^{-4} (so a chance of 1/10,000 per year), whereby the construction should be designed so that under these conditions the construction will not fail with a high degree of security (Ronde, et al., 1995a). In practice this would lead to a safety against flooding as mentioned in the economical study. For other parts of the coast different safety standards were applied due to what was called an economic reduction. In areas with an economically lower value, the safety standard should be lower resulting in values of 1/2000 per year for the small Wadden Islands and 1/4000 per year for the other coastal areas (see Fig. 3).

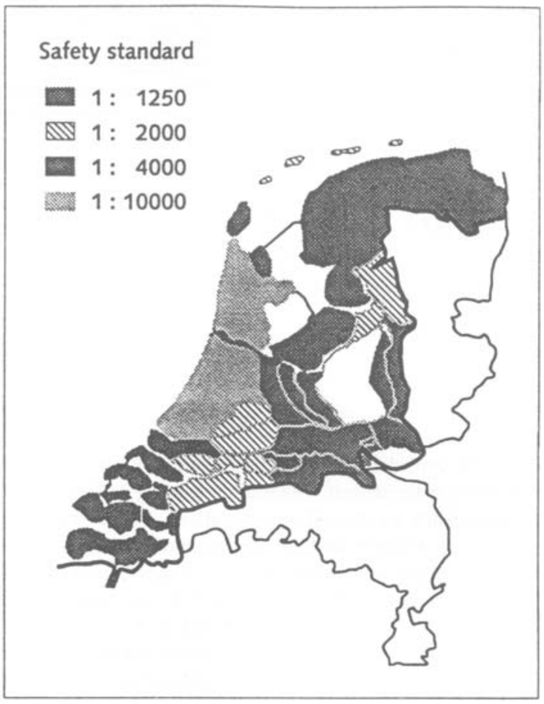

Fig. 3 Different safety standards per area

- the flood protection bill

To have a safe and strengthened flood protection is not enough. This safety must also be ensured for the future. Water defences must be maintained and regularly checked, the relative height can diminish by subsidence of the subsoil or by shrinkage of the body of the dike itself. Also sea level rise or changing hydraulic design conditions may impact safety of a construction.

To maintain safety against flooding at the required level the flood protection bill of 1996 (MinV&W, 1990) demands a 5-yearly check of all water defences in the Netherlands, not only along the coast, but also along the rivers and main lakes.

To make this 5-yearly check possible, the government (Rijkswaterstaat) has to provide updated hydraulic design conditions every 5-years (Ronde de et.al., 1995) taking into account sea level rise, soil subsidence, changes of storminess, changes in geometry etc, etc. After that the local authorities responsible for the water defences (in most cases the water boards) have a time period of 5 years to test their defences. The rules, how to perform these tests are provided by the government (Rijkswaterstaat). At the end of the period the local authorities have to report the conditions of the water defences to the provinces together with any necessary plans for strengthening defences. The provinces in their turn have to inform the Minister of Transport, Public Works and Water Management.

- the future, a risk based method.

The calculation of the probability of floods is a first step in moving towards a risk-based method. In the long run the Ministry of Transport, Public Works and Water Management plan to use a risk based method, where both the probability and the consequences of a flood are considered. Then decisions on measures to take to increase safety can be balanced. The following information will play a role (Vrijling, 1998):

- the cost of measures

Costs are not only the direct costs of the measure, but also societal costs. By taking measures, damage can be caused to (historical) landscape, nature, cultural values or individuals. Measures may be technical measures, measures in spatial planning or emergency services.

- the benefits of measures

Safety is the ultimate topic; measures will lead to more safety, if not in the area involved directly, then in areas where economic activities and population is concentrated. Safety cannot be expressed by economic value only. One should also consider the psychological effect.

- the evaluation of societal and individual risk

Societal risk is the risk on which the population does not have much influence. Individual risk is considered to be the risk an individual chooses to take by voluntary action. The acceptance of consequences (damage or casualties) of an individual risk is larger than that of a societal risk. Models have been defined by the Technical Advisory Committee on flood defence works. The results will be made available in the coming years. In a technical sense, this will give insight into weak spots in our flood defence system. It will also give the opportunity to increase safety in an effective way, taking into account not only technical measures, but also measures in terms of e.g. spatial planning or evacuation. But application of the new method will also point out knowledge deficits. Answering one question, will lead to many new questions. Research will continue.

It is expected that a discussion on flood risk and the desired level of protection will start. The current safety guidelines originated in the past century. Population, economic value, economic productivity, but also pressure on space are all changing rapidly. On the other hand, techniques are also developing: early warning systems, new telecommunication techniques, evacuation materials, etc. The discussion will be an emotional one. The outcome of it will largely depend on the perception of the flood risk by the population and politicians. However, the results provided by using this method will stimulate this discussion.

5. SAFETY AND PRESERVATION OF THE DUNE COAST

The Dutch coastline including all estuaries has a length of about 1000 km. The part positioned directly along the North Sea is about 350 km long of which 75% consists of dune areas of varying widths, ranging from less than 100 meters up to a width of several kilometers. The primary function of the coast is to protect the low-lying hinterland from flooding. The sandy coast, however, represents important values to other functions as well: e.g. ecological values, drinking water supply, recreation, residential and industrial functions. Coastal erosion, dominant along half of the Dutch coast, is endangering these functions.

Large sections of the Dutch coast were eroding, at some locations resulting in a retreat of 5 km in four centuries. Only an ad-hoc policy against coastal erosion was followed: measures were only taken when the safety of polder land was at stake or when special values in the dune area - e.g. drinking water areas, nature reserves, camping places – were threatened. If no measures were taken against ongoing coastal erosion tens of kilometres of coast would become unsafe and hundreds of hectares of valuable dune area would be lost every decade. An accelerated rise in sea level will enhance this problem even further.

Discussion on a new policy for coastal defence of dune coasts started in the 1980's (Hillen et al., 1995). In 1990 Parliament decided to adopt a new policy called “Dynamic Preservation of the coast line” in order to stop further retreat of the coast, meaning that the entire coastline will be maintained at its 1990 position. Further erosion will be counteracted by sand nourishments. Sand nourishment has been a common measure to combat coastal erosion in the Netherlands since the end of the 1970's. When a nourishment project is carried out, sand excavated from the bottom of the North Sea (outside the -20 m depth contour), is added to the near shore zone.

The implementation of this policy has been guided by the specication of 4 steps (Koningsveld M. van, and J.P.M. Mulder, 2003), defining:

A : a quantitative concept of the actual state of the system;

B : procedures for objective bench marking;

C : procedures for preferred interventions; and

D : procedures for evaluation.

The strategic and operational objectives, together with the decision recipe, constitute what in this paper is referred to as the operational "frame of reference" for the Dynamic Preservation Policy.

A : QUANTITATIVE STATE CONCEPT: THE MOMENTARY COASTLINE

The first element of the decision recipe for coastline management is an objective assessment of the state of the system. For this purpose the concept of the Momentary Coastline (MCL) has been developed. To objectively determine this MCL in any given cross-shore profile, a methodology has been developed based on the area (or volume per unit length) of sand between two horizontal planes (Min V&W, 1991). This area is to be divided by the difference in height of the upper and lower boundaries. Roughly generalised the method schematises the coastal profile as a triangle with a certain area that can be determined. The horizontal position of the MCL can be found at the center of the base of this triangle. The upper and lower boundaries are each located at a distance 'H' from the mean low water level (MLWL). This vertical distance 'H',denotes the vertical difference between the dune foot and the mean low water level (see Fig. 4).

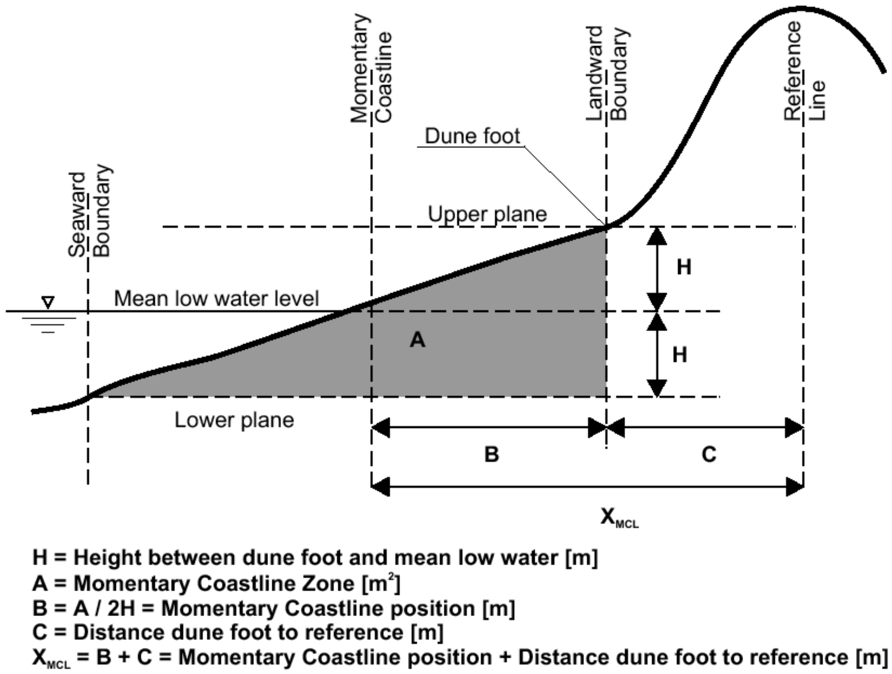

Fig. 4 Calculation of momentary coastline (MCL) (Source: (Min V&W, 1991))

The 'actual' calculation of the MCL is based on data from the Dutch yearly coastal monitoring program (JARKUS), which has been operational since 1963. JARKUS measures coastal depth profiles from the first dunes up to 1 km in a seaward direction, at alongshore intervals of 250m.

B : BENCHMARKING PROCEDURE

Next, a benchmarking procedure was developed, with the MCL as the basic quantitative building block.

● The Basal Coastline

For problem detection the observed or predicted system state needs to be described and compared with a predefined reference state. The operational objective to maintain the coastline at it's 1990 position, implies a reference state related to the 1990 coast-line. As such the Basal Coastline (BCL) has been defined as the estimated position of the coastline on January 1 st of 1990. This estimated position is derived from an extrapolation of the linear trend that can be determined from the positions of the 10 MCL-points in the years 1980 to 1989 (Fig. 5). The choice for an estimation based on a 10 year linear trend extrapolation, was inspired by the objective to counter structural,rather than incidental erosion.

● The Testing Coastline

To provide a crude prediction of the future state of the system, a so-called Testing Coastline (TCL) has been defined. The position of the TCL is determined, in a similar way as the BCL, by linearly extrapolating the trend of coastline positions (MCL) often previous years. Thus the position of the TCL in the year T can be determined by linearly extrapolating on the calculated MCL positions in the years (T-10) until (T-1) (Fig. 5).

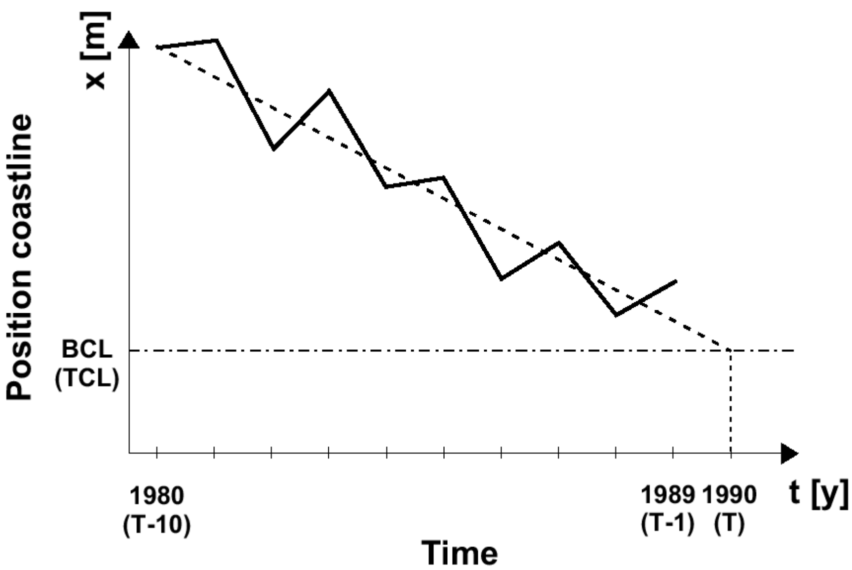

Fig. 5 Procedure to define the BCL (resp. TCL)

The state of the system can now be compared with the reference state, by comparing the TCL position with the BCL position. This comparison provides an indication for the expected coastal state in the year T. A TCL that moves landward of the BCL represents a signal to the responsible coastal authority to consider intervention.

C : INTERVENTION PROCEDURE: SAND NOURISHMENT

In the 1990's yearly a total of some 6 Mm 3 of sand, on the average, has been nourished to the beaches in the Netherlands (see Fig. 6). Implicitly it is assumed that a sufficient volume of sand in the BCL layer warrants a good condition of the other coastal state indicators like dune volume (protection against flooding) and beach width (recreation). Furthermore, an optimum design lifetime of some 5 years for beach nourishments was found. Still it was felt that shoreface nourishing instead of beach nourishment might provide a further means for optimizing coastline maintenance. Following the promising result of a first Dutch, experimental, shoreface nourishment (1993), carried out at Terschelling , since 1997 more than 10 new shoreface nourishments have been performed (Spanhoff et al. 2003). They replace the beach nourishments that otherwise would have been performed (see Fig. 7).

Usually, the maximum gain in the MCL layer will only be a fraction of the nourished volume, thus at least twice as much sand (per lineal meter) is nourished as would have been done in a beach nourishment. The price per m^3 sand of a shoreface nourishment is (less than) half of that of a beach nourishment, so the total costs for both options are of the same order. Shoreface nourishments so far have shore-parallel lengths of order 2-4 km, total volumes of order 1-2 M m^3, and amount typically circa 300-600 m^3/m.

The effects of these shoreface nourishments are positive so that shoreface nourishments nowadays are the standard. Beach nourishments are only carried out in special cases, e.g. when safety against flooding is at stake or when no cost effective results are anticipated. Every year, some 3-5 shoreface nourishments are carried out.

When effective, shoreface nourishments provide an attractive alternative for beach nourishments since they avoid hindrance for recreation and since twice or triple the amount of sand, for the same amount of money, is brought in the coastal system.

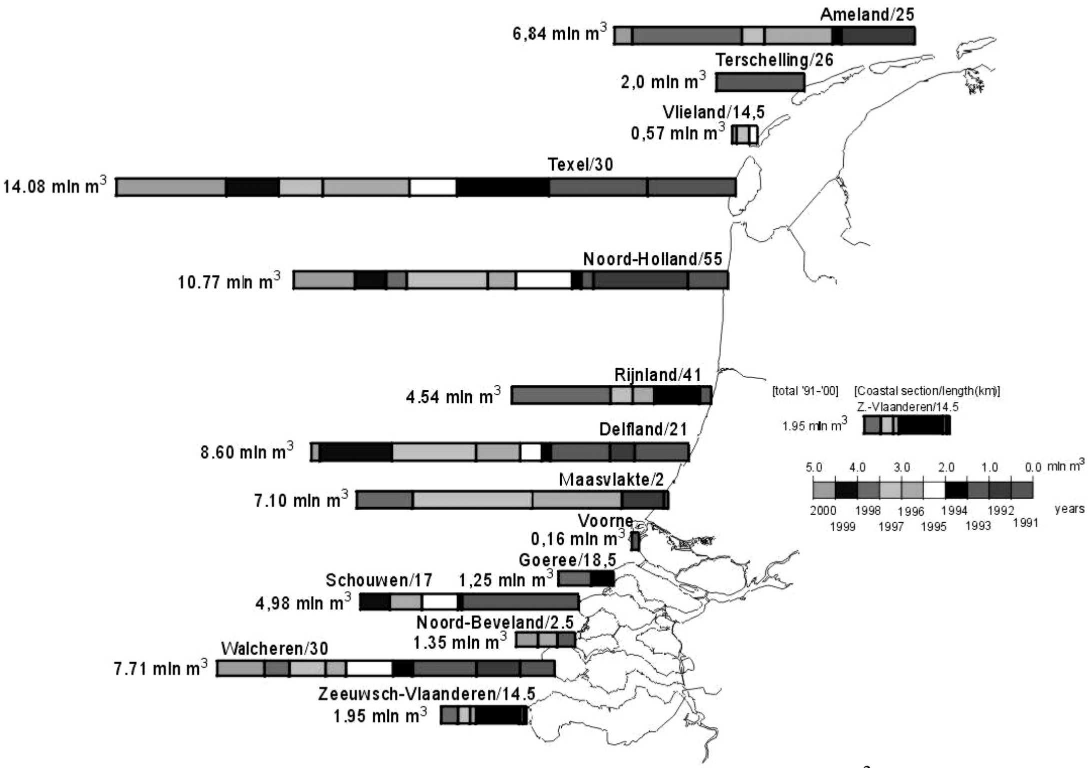

Fig. 6 Sand suppletions during the period 1991-2000 (6 Mm^3 per year).

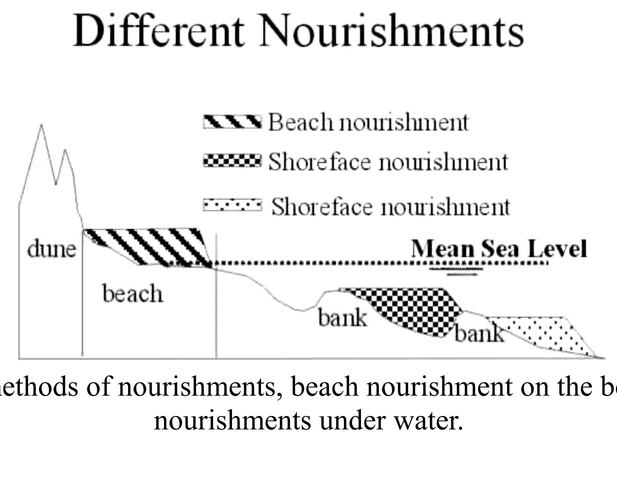

Fig. 7 Different methods of nourishments, beach nourishment on the beach and shoreface nourishments under water.

D : EVALUATION OF POLICY EFFECTIVENESS

Periodic evaluation of policy effectiveness is recommended. The Flood protection Bill (MinV&W, 1990) prescribes a 5 year interval for evaluation.

Since 1990, several evaluations, of single nourishment events (Roelse and Hillen,1993) and the coastline policy as a whole(de Ruig, 1998), have been presented. Considering the operational objective to preserve the coastline at it's 1990 position,a quantitative evaluation leads to a clear conclusion: "Dynamic Preservation" has been successful over the period of 1991 – 2000. With a yearly average of 6 M m3 of sand nourishments over the last decade, Roelse (2002) states that there is no more coastal retreat and the number of transects exceeding the BCL is decreasing yearly.

With respect to the strategic objectives, viz. to guarantee a sustainable safety level and sustainable preservation of values and functions in the dune area, a quantitative evaluation is hampered by the lacking of guidelines for bench marking of effectiveness.

However, indications are positive. Roelse (2002) reports over the period 1991 – 2000, an improvement of safety levels and shows an increase of the total dune area and a slight increase of the widths of recreational beaches. Whether the latter is representative for the development of all values and functions in the dune area, is questionable. Such conclusion would require a further specification of the values and functions included in the strategic objective.

The same accounts for the element of the strategic objective dealing with sustainability. Discussing sustainability requires making time- and space scales explicit. Larger time scales, likewise must imply larger space scales. Hinton (2000) clearly indicates a time dependency of the depth of closure. Based on an analysis of the JARKUS database covering the Dutch coast to a depth of -8 to -12 m, a continuous closure depth could not be established in the data applying a time frame of 32 years. Thus, considering a time frame of 30 – 50 years a closure depth of -20 m seems a (safe and) justified assumption for the Dutch coastal system. On this basis Mulder (2000) derived a long term sand balance of the coastal system from available sounding data. Over the period 1965 – 1995 the Dutch coastal system shows a negative sand balance of 4 to 10 M m^3 per year. Extrapolating the long term trends and compensating for the effect of a sealevel rise of 20 cm per century, Mulder (2000) estimated a negative sand balance of 12 to 16 M m^3 per year for the coming decennia. Comparing these long term figures with the average yearly nourishment volume of 6 M m^3 per year during the last decade, led to the following conclusions:

- the present nourishment design procedure does NOT deliver representative estimates of sand volume changes in the total coastal system;
- the present policy of Dynamic Preservation is NOT sustainable at larger scale.

The conclusions of this evaluation, have led to a redefinition of the Dynamic Preservation policy into a sustainable coastal policy based on a small and a large scale approach (MinV&W, 2000).

Considering preservation of the potential of various values and functions as the first basic condition for sustainability, a logical first operational objective of a redefined sustainable coastal policy is:

1. "Preservation of the total sand volume in the coastal system ...".

Basically this implies a large scale approach.

The actual status of values and functions in the coastal zone, is determined by the actual distribution of sand on smaller time scales. Preservation of values and functions on a time scale of 1 to 10 years, has proven to be quite effective using the BCL approach of Dynamic Preservation (Roelse, 2002). Thus, a logical second operational objective of a redefined sustainable coastal policy remains:

2. "... maintaining the coast line at it's position in the year 1990".

This small scale approach, supplemented by the large scale approach, characterizes the redefined sustainable coastal policy in the Netherlands, as implemented in 2001 (MinV&W, 2000). From 2001, the Netherlands has raised the total nourishment volume in it's coastal system from an average of 6 to an average of 12 M m^3 per year. The nourishment budget has been raised from 27 to 41 million Dollar per year.

REFERENCES

Deltacommissie, Eindverslag en interimadviezen, Deel I, Staatsdrukkerij- en uitgeverijbedrijf, s-Gravenhage, 1960 (in dutch).

Hillen, H., Roelse, P., Dynamic preservation of the coastline in the Netherlands, Journal of Coastal Conservation 1: 17–28, 1995.

Hinton, C., 2000. "Decadal Morphodynamic Behaviour of the Holland Shoreface". PhD Thesis, Flood Hazard Research Centre, Middlesex University.

Koningsveld M. van, and J.P.M. Mulder, 2003 . Sustainable Coastal Policy Developments in the Netherlands. A Systematic Approach Revealed. Submitted to Journal of Coastal Research

Min V&W 1990. "Coastal defence after 1990, a policy choice for coastal protection". 1 st Coastal Policy Document, Ministry of Transport, Public Works and Watermanagement, The Hague NL.

Min V&W 1991. "De basiskustlijn, een technisch / morfologische uitwerking" (in Dutch).

Min V&W 2000. "Tradition, Trends and Tomorrow". 3 rd Coastal Policy Document,

Ministry of Transport, Public Works and Watermanagement, The Hague NL.

Mulder, J.P.M., 2000. "Zandverliezen in het Nederlandse kustysteem; Advies voor Dynamisch Handhaven in de 21 e eeuw" (In Dutch). Report RIKZ-2000.36, National Institute for Marine and Coastal Management (RIKZ), The Hague, NL.

Resource Analysis, Delft Hydraulics and Ministry of Transport, Public Works and Water Management-Tidal Waters Division (1992). Analysis of vulnerability to the impacts of a rise in sea level. Report DGW-93.034.

Roelse, P. and R. Hillen, 1993. "Evaluatie van zandsuppleties, een morfologische beschouwing" (In Dutch). Interim report DGW-93054.

Roelse, P., 2002, "Water en Zand in Balans. Evaluatie zandsuppleties na 1990; een morfologische beschouwing" (In Dutch). Report RIKZ-2002.003. ISBN 90-36-369-3426-5.

Ronde, J.G. de, Dillingh, D., Philippart, M.E., Design criteria along the dutch coast, Hydrocoast 95, International workshop on water related problems in low-lying coastal areas, 1995.

Ruig, J.H.M. de, 1998. "Coastline Management in The Netherlands: Human use versus natural Dynamics". Journal of Coastal Conservation 4 :127–134.

Ven, G.P. van de, (1993) Leefbaar laagland, geschiedenis van de waterbeheersing en landaanwinning in Nederland (Man-made Lowlands, a history of water control and land reclamation in the Netherlands). International Commission on Irrigation and Drainage (ICID) and the Royal Institute of Engineers (KIVI), Utrecht.

Vrijling, J.K., Hengel, W. van, Houben, R.J., 1998: Acceptable risk as a basis for design, Reliability Engineering and System Safety 1998 – Volume 59 – issue 1 – page 1411–50.

Spanhoff, R. , Biegel, E.J. ,Burger, M. and Dunsbergen, D.W. (2003), Shoreface nourishments in the Netherlands, Proceedings Coastal Sediments "03, The fifth International Symposium on Coastal Engineering and Science of Coastal Sediment Processes, May18–23, 2003.