

ministry of transport and public works

rijkswaterstaat



**A new coastal
defence policy for
the Netherlands**

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defence policy for
the Netherlands**

December, 1990

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Foreword

Over half of the Netherlands lies below sea level. If it were not for the dykes and the dunes, the western part of the country would have disappeared into the North Sea long ago. The situation calls for constant vigilance.

After the disastrous floods of 1953, the dykes and dunes along the North Sea were raised to "Delta height". In meeting this standard as specified by law, the safety of the polders is ensured.

However, the Dutch sea defences must also remain safe in the coming decades. This can only be achieved if the Dutch coast is carefully guarded and timely measures are taken should sea defences become weakened as a result of erosion.

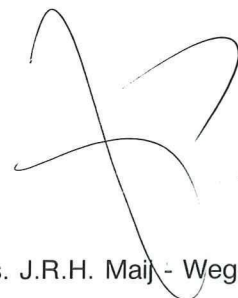
In May 1989, the Minister of Transport and Public Works presented the Discussion Document "Kustverdediging na 1990" (Coastal Defence after 1990). This Document, together with 20 supporting technical studies, formed the basis for a discussion on long-term coastal defence policy in the Netherlands. In the Document four policy alternatives were presented:

1. Retreat: coastal recession will only be counteracted at those locations where erosion threatens the safety of the polders;
2. Selective Preservation: intervention would not only be pertinent to those locations where the safety of the polders is threatened, but also where major interests in the dunes or on the beach may be lost;
3. Preservation: the entire coastline would be maintained on the basis of its location in 1990;
4. Expansion Seaward: At points of marked erosion, artificial defences extending into the sea would be built, bringing coastal recession to a standstill. Elsewhere along the coast, the present coastline would be preserved.

In June 1990, the Government of the Netherlands announced its chosen alternative: the option of Preservation. The Government did make a subtle distinction however: if safety was not imperiled and major values in the dunes were not under threat, some allowance should be made for the "natural" movement of the coastline, inherent to a dune area. The Government therefore defined its choice as "Dynamic Preservation".

The Discussion Document, the Policy Choice Document and the supporting technical reports have all been written in Dutch. As issues of coastal management and coastal policy are enjoying the international limelight at present, it was decided to publish the Discussion Document together with the policy choice of the Government in the English language. The present report "A new coastal defence policy for the Netherlands" offers an outline of national policy with respect to coastal defence in the Netherlands.

The Minister of Transport and Public Works



Mrs. J.R.H. Maij - Weggen

The North Sea coast as considered in this report measures 353 km in total, 75% of which are dunes. The dunes offer protection from the sea and harbour economic interests and natural values. The forces of nature such as waves, tides and the wind keep the dune coast in a constant state of flux: accretion at one point, erosion at the other.

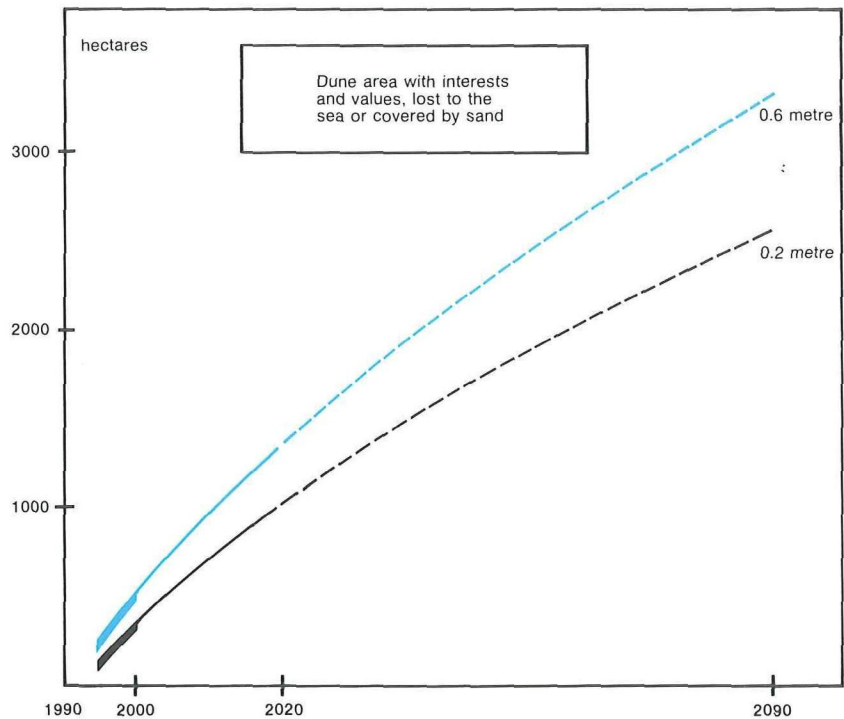
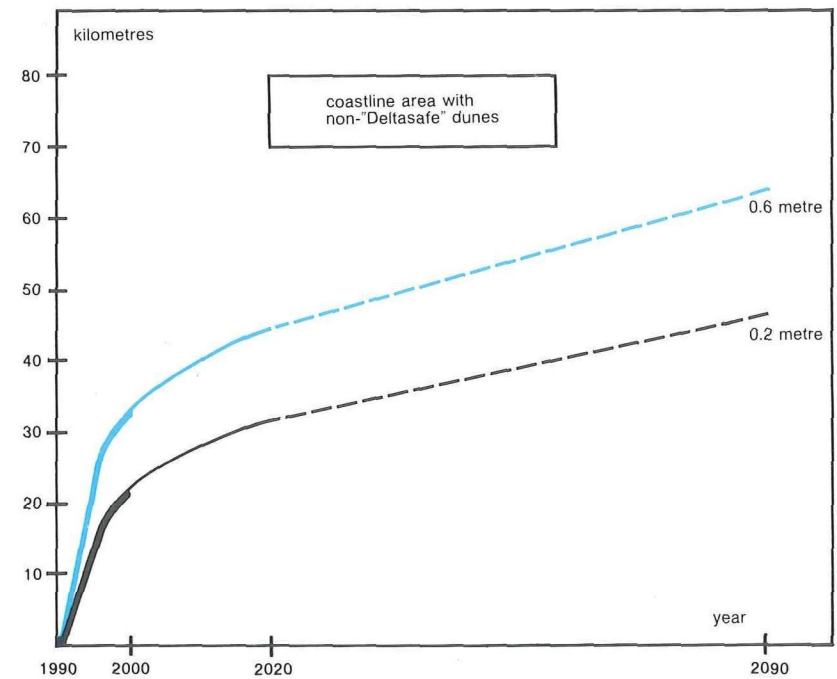
The bars indicate where the dune coast is receding following erosion at the beginning of the 1990s.



The problem addressed by this report: gradual recession of the coast. Coastal erosion causes land to be steadily relinquished to the sea. During the Second World War, this bunker near Voorne was located in the dunes.



The problem of the dune coast if erosion is not counteracted: tens of kilometres of hazardous dunes; interests and values lost to the sea or covered by sand. This loss is shown on the basis of two rates for a rise in sea level: 0.2 metre per century (the current rate) and 0.6 metre per century (the anticipated rate).



Summary

The coast

The Dutch North Sea coast is made up of dunes, dykes and other structures offering a barrier to the sea. Together they protect the lowlands of the Netherlands, the polders, against the onslaught of wind and water. The dunes represent about 75% of this line of defence, varying in width from one hundred metres to several kilometres. The dunes, together with the beach and the shoreface, represent a natural, sandy defence to the sea. The forces of nature cause this barrier to be in a constant state of flux, advancing at one point (coastal accretion) while receding at another (coastal erosion).

The dunes lend the Netherlands its characteristic landscape and harbour unique natural values for the north-west of Europe. They also represent an economic value: drinking water supply, recreation, industry and residential.

The problem: coastal recession

In 1990 - almost forty years after the disastrous floods of 1953 - the North Sea coast is "Delta safe". This means it can withstand extreme storms and the associated water levels and waves. Of course, this level of safety must be upheld. Constant effort is demanded, because ongoing coastal erosion causes almost half of the coastline to recede, slowly but relentlessly. As a result, the capacity of the dunes to offer a barrier against the sea is weakened and sea dykes and other artificial constructions are undermined. If nothing is done, tens of kilometres of dunes will be damaged to such an extent that the safety of the polders can no longer be guaranteed by the turn of the century. Aside from safety, user functions and natural values in the dune area are threatened by coastal erosion over tens of kilometres of coastline. A more rapid rise in sea level will only enhance these problems and bring forward their onset by many years. These problems are encountered all along the coast and are of a structural nature.

Present coastal defence is based on a problem-solving policy. For large parts of the coastline, recession is tolerated: dunes undergo "controlled retreat" through intensive maintenance measures.

Supporting studies

- TR-0 Overview of technical studies supporting the Discussion Document on Coastal Defence summary and conclusions of the projects conducted.
- TR-1 Sand system of the coast a morphological characterisation.
- TR-2 Situation of the coast in 1990 coast typology and situation.
- TR-3 Coastal maintenance costs of basic maintenance.
- TR-4 *Inventory of dune functions*
- TR-5 Coastal prognosis prognosis for the development of the coastline 1990-2090.
- TR-6 Rise in sea level hydro-meteo scenarios.
- TR-7 Dunes as water barriers *influence of coastal changes on safety.*
- TR-8 Dune functions *influence of coastal changes on dune functions.*
- TR-9 Inventory of functions of the shoreface *interaction with coastal defence.*
- TR-10 Extraction of sea sand *influence on coastal morphology; an exploratory study.*
- TR-11 Beach and dune nourishment effectiveness and costs.
- TR-12 Groynes and pile groynes *evaluation of their effect.*
- TR-13 Large civil works *influence on coastal morphology.*
- TR-14 Shoreface nourishment *an alternative coastal protection method.*
- TR-15 *Monitoring the coast* *current situation and future perspectives.*
- TR-16 Hard coastal defence works *the function of dykes, harbour areas and beach esplanades as water barriers.*
- TR-17 Policy analysis model *description of a computer model.*
- TR-18 Calculation results of policy alternatives *detailed results of the computer model.*
- TR-19 Coastal defence innovation *making use of the natural coastal system.*
- TR-20 Seaward coastal defence *a preliminary analysis of several possibilities.*

To indicate the four policy scenarios the Dutch abbreviations (T, S, H and Z) are used in the figures and tables of this report. In scientific papers the alternative translations are sometimes used to describe the four policy scenarios.

Dutch	English (alternative translation)
T Terugtrekken	Retreat
S Selectief handhaven	Selective Preservation (Selective erosion control)
H Handhaven	Preservation (Full erosion control)
Z Zeewaarts	Expansion Seaward (Seaward expansion)

Where the safety of the polders is endangered, further recession is brought to a standstill. In recent years, recession of the coastline has affected the interests and natural values in the dune area to an increasing extent. Furthermore, sea dykes and other hard barriers come to protrude like bulwarks into the sea.

As no other solutions were available, policy to date was limited to solving only the most pressing problems.

National coastal defence policy: a necessity

Coastal erosion is evident along the entire coastline. A more rapid rise in sea level will be felt everywhere. Not one function of the coast will be left untouched. This problem requires a reconsideration of current policy. Clear choices on major issues are demanded: which interests and values in the dunes must be protected against the consequences of coastal recession, and what budget can be set aside for this purpose. That is why a new policy for coastal defence is being developed, one that looks towards a long-term solution.

This Document focuses attention on the concept of coastal defence: it asks to what extent existing interests and values in the coastal area should be preserved. Creating opportunities for generating new values and interests by reclaiming land from the sea is not considered part of the coastal defence task. Therefore, this report will not consider such an approach. For the same reason, attention is focused on eroding coastal areas, as areas of coastal accretion do not demand special defence efforts.

Policy alternatives

Upholding the safety of the polders is an absolute prerequisite. The Water Defence Bill is based on the safety standards of the Delta Commission. However, the degree to which interests and values in the dunes should be protected against coastal recession is not subject to specified standards; here, a choice has to be made. The options vary from no protection to full protection of all interests and values.

Policy aims and technical realisation for the four coast types. Various defence alternatives are feasible for the 254 km of dune coast. For the 34 km of sea dykes, the 38 km of beach flats and the 27 km of other hard sea defences, continuation of existing policy is the only realistic option.

coast type	aim	measures maintenance	combating erosion
dune coast	- maintain polder safety - a choice with respect to interests and values in the dune area	- continue present maintenance	- sand nourishment - local hard measures
sea dykes	- maintain	- continue present maintenance	- stone revetment + nourishment
beach flats	- natural development	- limited maintenance	- none
"remaining"	- maintain present maintenance	- continue sand nourishment	- incidental

Policy alternatives for the defence of the dune coast

RETREAT	Only where the safety of the land behind the dunes (polders) is threatened will coastal recession be fought; elsewhere along the coast a "controlled retreat" policy applies. This represents the least active realisation of the State's legal obligation.
SELECTIVE PRESERVATION	Aside from principles of safety, the protection of special values and interests in the dune area demands that coastal recession be combated. To a certain extent, current policy may be compared to this alternative.
PRESERVATION	Coastal recession is counteracted at all locations.
EXPANSION SEAWARD	Coastal recession is fought all along the coast. At points where the dunes are very narrow or where recession is considerable, the coast will be reinforced by a seaward construction and natural sand accretion will be encouraged.

Four alternatives have been considered for the dune coast:

- I Retreat. In principle, coastal erosion is accepted. Only where erosive processes pose a threat to the safety of the polders behind the dunes will coastal recession be combated.
- II Selective Preservation. Aside from those locations where the safety of the polders is endangered, a number of locations where major interests in the dunes or on the beach are threatened will be protected against coastal recession.
- III Preservation. The coastline is maintained everywhere at its current position.
- IV Expansion Seaward. At some markedly eroded and relatively weak locations, constructions extending into the sea will be built. This should reverse the receding movement of the coast at that location, allowing it to advance. Elsewhere, the coast is maintained at its current position.

Measures

To realise the policy aims, measures must be taken. A distinction is made between maintenance and combating erosion. This differentiation is based on the distribution of tasks between the Water Boards and the State.

The basic assumption of this Document is: to maintain the sea barriers along the entire North Sea coast at a level comparable to the past 10 to 20 years.

Depending on the policy alternative chosen, the eroding parts of the coast will require additional measures to combat erosion. In this Document the current policy of sand nourishments has been chosen as the primary national approach towards combating erosion.

At weak locations along the dune coast, supplementary hard barriers may be introduced to improve protection. Stone revetment is used for sea dykes. Beach flats do not need measures to counter erosion.

The major points for comparison of the policy alternatives.

A	<p>Number of km where coastal recession is counteracted.</p> <p>The benefits of the policy alternatives relate to the degree of protection they offer the coastal dunes against gradual erosion of the coast. A first impression is gained by the length of coastline over which coastal erosion is counteracted to uphold the safety of the polder or protect the interests and values in the dune area.</p>
B	<p>Number of km with minimal dune reserves.</p> <p>Where coastal recession is not counteracted, the damming capacity of the coastal dunes is diminished. A figure which offers an insight is the number of kilometres with minimal dune reserves: if the coast recedes by over 10 metres, problems of safety will arise.</p>
C	<p>Area losses of interests or values.</p> <p>Where coastal recession is not counteracted, interests or values are lost. Such losses are expressed in hectares of dune area relinquished to the sea or covered beneath the sand of the seaward range of dunes. These figures indicate the degree of protection: the smaller the loss, the greater the protection offered. The losses are presented separately for each interest or value.</p>
D	<p>The costs of coastal maintenance and combating erosion.</p> <p>The costs are presented as the average annual costs. The overall costs relate to both maintenance and combating erosion for the entire coast-line, 353 km in length. The costs of combating erosion are presented separately.</p> <p>The Expansion Seaward alternative requires investment to realise the phased building of seaward constructions. These costs are calculated on the basis of a 50-year repayment plan.</p>

Overview of the major benefits and costs for the four coastal defence alternatives for the year 2000, at a 20 cm rise in sea level per century.

		POLICY ALTERNATIVES			
		T	S	H	Z
A	number of kilometres to maintain	20	60	140	140
C	loss of area with interests and values	350	150	-	-
D	total costs of coastal defence (M Dfl/year)	35	45	60	80
D	costs of combating erosion (M Dfl/year)	10	20	40	60

Results

The benefits and costs of the policy alternatives Retreat, Selective Preservation and Preservation are calculated for the period 1990-2090 and for three scenarios of a rise in sea level. The alternative Expansion Seaward has only been elaborated on a preliminary basis. The benefits and costs are expressed with respect to various factors: the length of coastline over which protective measures must be introduced, the number of kilometres with minimal dune reserves, losses of interests and values and the costs of coastal defence. The benefits and costs are expressed in different units, relevant to each aspect. The analysis is based on a geographical information system for the coastal area and on technical studies that offer new methods for the prognosis of coastal morphology. These studies were conducted as a joint project between the Public Works Department and research institutes and universities in the field of hydraulic engineering and earth sciences (the Coastal Genesis project).




The most important aspects offering an insight into the benefits and costs of the policy alternatives are presented on the next page as a series of figures. They relate to three points in time in the next 100 years. The bars in the figures reflect the margins of uncertainty of predicting the position of the coastline. In the long term, estimation of these margins becomes uncertain. This is indicated by presenting the results as a broken line. The results for the period after 2000 attempt to offer an indication of the consequences of policy choices in the long term.

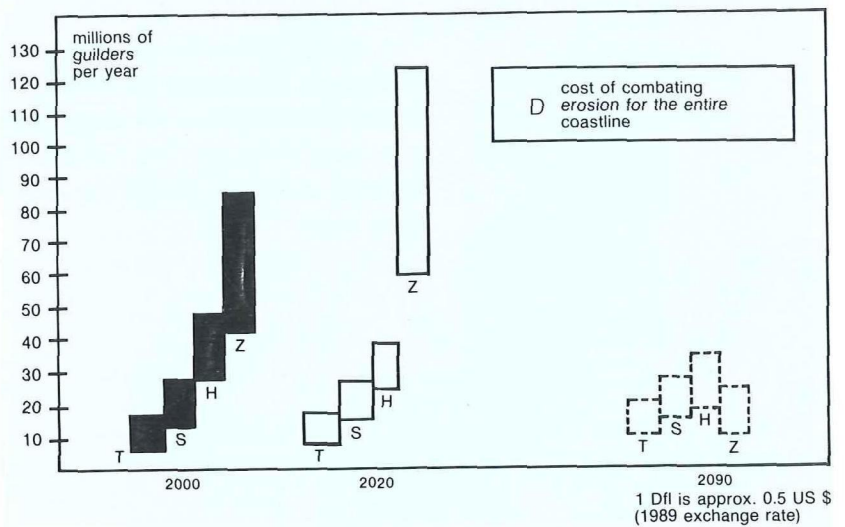
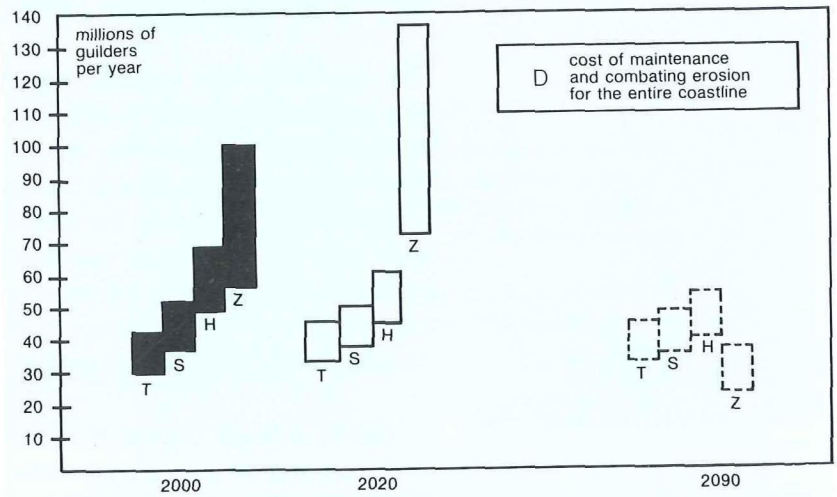
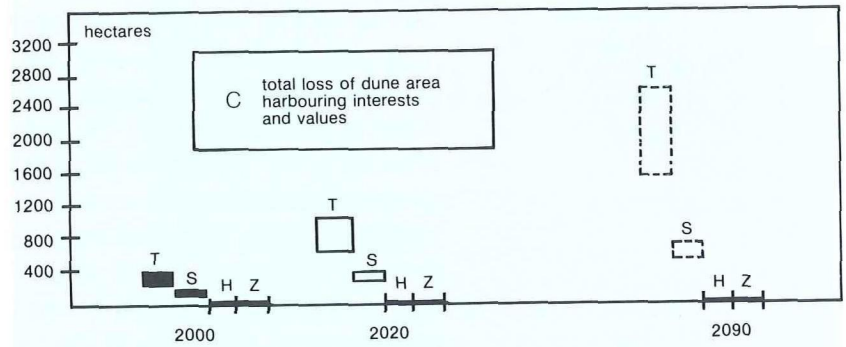
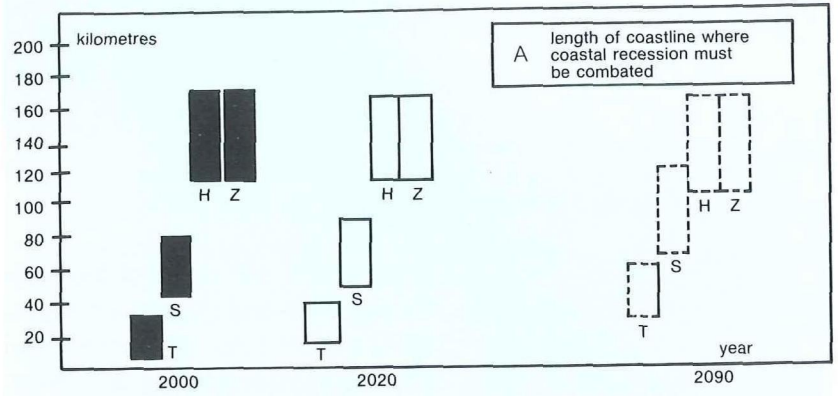
In making a policy choice, the estimation of the benefits and costs in the coming decade are of particular importance. They are summarised for the year 2000 in the table opposite.

The figures show the general picture anticipated: moving from Retreat to Expansion Seaward, the length of coastline over which protective measures are taken increases and, as a result, the costs of coastal defence. The number of kilometres with minimal dune reserves declines, as will the loss of interests and values in the dune area.

Benefits and costs of the four policy alternatives, i.e. Retreat (T), Selective Preservation (S), Preservation (H) and Expansion Seaward (Z) as calculated for the scenario of the present rate in the rise in sea level, i.e. 0.2 metres per century.

Bar interpretation:

-  unfavourable prognosis
-  anticipated value
-  favourable prognosis



Safety of the polders

With all policy alternatives, the safety of the polders is ensured. With the alternatives Retreat and Selective Preservation, the reserves the dune coast can offer against recession will gradually become less.

Already in 1990, the reserves along about 40 km of the dune coast are too small to cope with a coastal recession of only 10 metres. At the end of the next century, that figure will rise by 40% to 50% for the Retreat option. With Selective Preservation, this increase measures about 25%. The Preservation alternative will keep all reserves present in 1990 intact, while Expansion Seaward will permanently reinforce about 60% of presently weak locations.

Interests and values in the dune area

The losses associated with Retreat run from several hundreds of hectares in the year 2000 to over 2000 hectares in 2090. About half of this figure affects ecologically valuable nature areas. To a lesser extent, drinking water supply areas will be affected: several tens of hectares in the year 2000, increasing to several hundred towards the end of the next century. Until 2000, losses of residential and recreational areas will remain limited to a few hectares. However, in the long term some tens of hectares could be affected.

With Selective Preservation, the losses associated with Retreat are cut back by 50 to 70%: the most valuable interests and natural values are protected.

With Preservation and Expansion Seaward, no losses will be suffered in the dune area, while with Expansion Seaward, hundreds of hectares of land will be gained.

Costs of coastal maintenance and combating erosion

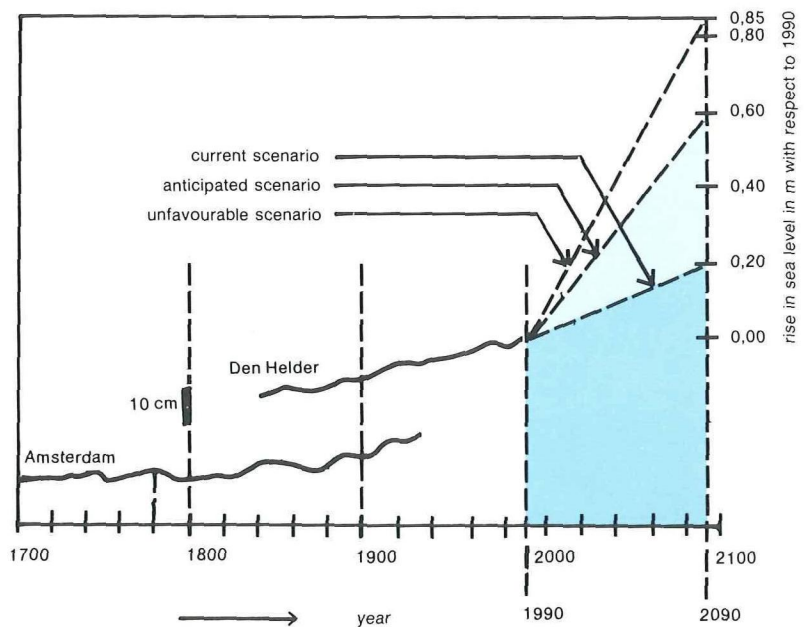
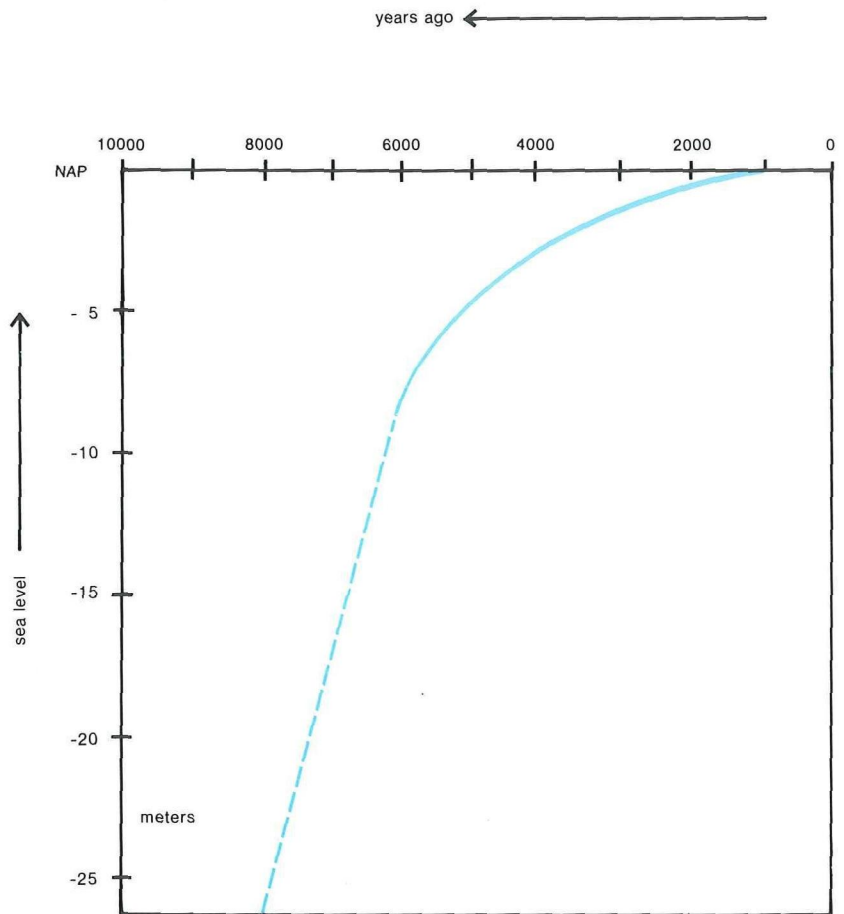
Upholding the safety of the polders (Retreat) will demand about 35 million guilders a year in the short term. Protection of special interests and natural values in the dune area against coastal erosion (Selective Preservation) will cost about 45 million guilders a year, an increase of 10 million. Full maintenance of the 1990 coastline will cost 60 million guilders, while additional reinforcement of the weak locations will cost, with a phased approach, about 80 million guilders in the next 10 years.

In the long term, when the works have depreciated, a saving in annual defence costs can be anticipated: Expansion Seaward will then become more economical than Retreat.

As the Expansion Seaward alternative has not been worked out in detail, this result should be supported by further research.

The rise in sea level: past, present and future.

Melting ice caps and a sinking sea floor have caused the relative sea level to rise by approx. 100 metres since the last Ice Age, approx. 10,000 years ago. Over the last 100 years, a rise of approx. 20 centimetres per century has been measured - the present scenario. The "greenhouse effect" may boost this rate. The latest estimation is 60 cm in the next century - the anticipated scenario. However, a faster rate is also a probability - the unfavourable scenario.



Costs of combating erosion

The annual costs required to combat erosion in the year 2000 will be 10 million guilders for Retreat, 20 million guilders for Selective Preservation and 40 million guilders for Preservation. In time, Retreat and Selective Preservation will require measures to be taken at an increasing number of locations, leading to an increase in defence costs. Current insights expect a more favourable coastal morphology for Texel island, Vorne, Goeree and Schouwen in the next century, as a consequence of landward migrating sand bars. The costs of combating erosion may therefore become less with the Preservation alternative. A comparison between, for example, Retreat and Preservation, shows that the costs for combating erosion in 2000 will differ by a factor of 4; in 2090 this difference will be less than a factor of 2. Eventually, the costs for Retreat and Selective Preservation will draw level with those for Preservation.

Effects of a more rapid rise in sea level

When choosing a national coastal defence policy, the probability of a more rapid rise in sea level as a consequence of a change in climate must be taken into account (the "Greenhouse effect"). If the anticipated rise of 0.6 m per century does indeed prove to be true, the coast will recede at more locations. Furthermore, the rate of recession will increase.

Therefore, countermeasures will need to be taken sooner and at more locations. The costs of combating erosion will increase by about 25% for all policy alternatives. Maintenance costs will be subject to a less marked increase. Major upkeep of sea dykes and other hard sea defences will need to take place 10 to 20 years sooner. Further raising of the crests will be necessary, resulting in a cost increase in the order of tens of millions of guilders.

Climatic changes can also result in a change in the wave patterns on the North Sea. Even a minor change in mean wave height and the angle at which waves attack the shore seem to influence the rate of erosion and the costs of combating erosion to a much greater extent than a rise in sea level alone. This aspect of climatic change demands further study.

Sand nourishment.

Until now, the best response the Netherlands could offer to coastal erosion and the rising sea level has been sand nourishment. The country has at its disposal a sophisticated range of equipment to deposit sand at any location along the coast, for example on the beach. In this way, coastal recession can be brought to a standstill, although nourishments must be repeated on a regular basis. This coastal defence method is attractive from a financial-economic standpoint and is ecologically sound.



Policy choice

Based on a number of considerations, recommendations and discussions, the Government has come to the conclusion that coastal recession must be brought to a standstill. It has decided to choose for enduring safety and for sustainable preservation of the functions and values in the dunes. This choice for the Preservation alternative implies that the coastline will be preserved at its 1990 position at least.

Where the coast is protected by dykes, "Preservation" will always require maintenance at the current position. Preservation of the dune coast demands a more subtle distinction, however. It may be that by shifting a section of the coastline locally, the coast can be maintained with less effort.

By nature, the coastline of a dune coast is not fixed at one single position. This is inherent to the variable forces exerted by the sea. Some allowance should be made for movements of the coastline. Where this room is available, the coast can be efficiently protected. In other words, the coastline is to be preserved within certain limits.

Considerable freedom of movement can be permitted at most extremes of the Wadden islands, with the proviso that the islands should continue to exist as a whole.

Where allowances are made for the natural movement of the coastline, the dune row will also show some movement. This could offer an important impulse to the dynamic management demanded by nature conservation groups. Permitting sand drifts at some locations or the formation of one or two "sluften" (wet dune valleys influenced by the tides) is also a possibility.

The Government of the Netherlands believes that the choice for coastal preservation contributes to the sustainable development of Dutch society. By adding a subtle distinction to the Preservation option, the Government has ensured that the dynamic charm and quality of the natural dune coast will continue for many years to come. The choice of sand nourishments as the principal method to realise this aim is entirely in line with such a coastal defence policy. As such, Preservation may be called "Dynamic Preservation".

1 Introduction

This chapter offers a description in brief of the coast of the Netherlands. In addition, the organisation of the present Document will be explained.

1.1 The Dutch coast

The North Sea coast of the Netherlands consists of dunes, dykes and other water barriers. Together they protect the low polders against the North Sea.

Threequarters of this line of defence is made up of dunes, varying in width from one hundred metres to several kilometres. The dunes form a natural, sandy barrier against the sea, together with the beach and the shoreface. Under the influence of the forces of nature, this barrier is constantly moving; advancing at one location, receding at another.

The dunes lend our coast its characteristic appearance, and has a unique natural value for north-west Europe. The dune area also represents economic interests: drinking water supply, recreation and residential and industrial functions.

The dykes and other water barriers are fixed elements in coastal defence, where the coastline cannot shift its position. Erosion does undermine the stability of these structures.

At the moment, the water barriers along virtually the entire North Sea coast are strong enough. They can even resist high water levels and waves under extreme conditions. However, continuing erosion undermines the strength of the water barriers at many locations and is threatening the continuity of the dune area. If no action is taken now, tens of kilometres of coastline will be unsafe by the end of the century, and hectares of dune area will disappear, taking their functions with them. To maintain the safety achieved so far demands permanent concern for coastal defence.

This year - almost forty years since the flood disaster of 1953 - almost the whole of the North Sea coast is safeguarded on the basis of the requirements set by the Delta standards. Formerly, the water barriers were only maintained to ensure the safety of the low polders against flooding. Only limited funds were available for the protection of other interests.

At some locations there is no more room for coastal recession. Any damage must be immediately restored in order to ensure the "Delta safety" of the dunes.



Breaking waves unleash a great deal of power. Therefore, heavy storms can compromise coastal defence. Even so, there is not necessarily a danger of flooding.



Since the 1970s, attention has increasingly focused on protection of the dune area, not only because of its function as a water barrier. As a consequence of these social developments, several works have been carried out in the dune coast in recent years, which also serve to protect - or exclusively protect - other, extremely valuable interests. For example, reinforcement of the dunes on Schouwen and sand nourishment to protect the nature area of Zwanenwater in North Holland.

Until now, policy was forced to limit itself to the most pressing problems. Current coastal defence policy only deals with the major issues. For a large part of the coast, recession is accepted: dunes undergo "controlled retreat" through intensive maintenance measures.

The Water Defence Bill, currently under discussion by Parliament, specifies that the works which the Minister of Transport and Public Works considers essential to guarantee the safety of the low polders will be realised and paid for by the State.

The Bill states that the Central Government can also carry out works which the Minister of Transport and Public Works considers essential for the general good. It acknowledges the social importance of the functions and values in the dune area, which demand that the protection of interests aside from safety should play a role in future coastal defence. Safety and the general good therefore determine the concern for the position of the coastline.

1.2 Organisation of the Document

This Document, "A new coastal defence policy for the Netherlands" is composed of the following:

Problem analysis, chapter 2

This chapter describes the situation of the coast in 1990. The characteristics of the coastal area are described and some insight is given into the processes threatening the coast.

An indication is given of which developments may be expected for the future position of the coastline.

The coast is receding at many locations. A description is given of the problems which will arise if no specific measures are taken against coastal recession.

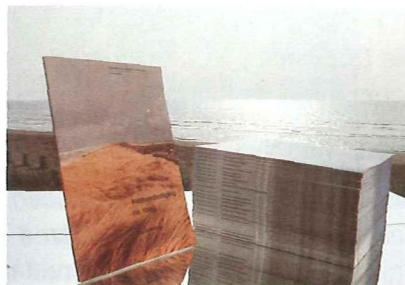
A heavy storm can lead to considerable dune erosion. This is shown on the coast by the steep slope separating the beach from the dunes.



Coastal monitoring on land and at sea each demand their own particular equipment.



The Discussion Document "Coastal defence after 1990" describes the alternatives for coastal protection and their consequences for the coast.



Policy alternatives, chapter 3

In view of the defined problems, it is essential to reconsider current coastal defence policy.

Four alternatives are presented to deal with coastal recession. A description is given of how these alternatives are realised in terms of measures, as well as the principles on which they are based.

Benefits and costs, chapter 4

The alternatives result in various benefits and costs. The benefits relate to the extent to which a loss in values and interests in the coastal area is prevented, and to the protection of reserves in the dune area that offer a buffer against coastal recession.

The costs relate to the essential maintenance of the coast and the fight against coastal recession.

Based on the present rate of a rise in sea level, a picture is sketched of the next 100 years. With the presentation of the results, emphasis is placed on the developments anticipated in the next 10 years.

Rise in sea level, chapter 5

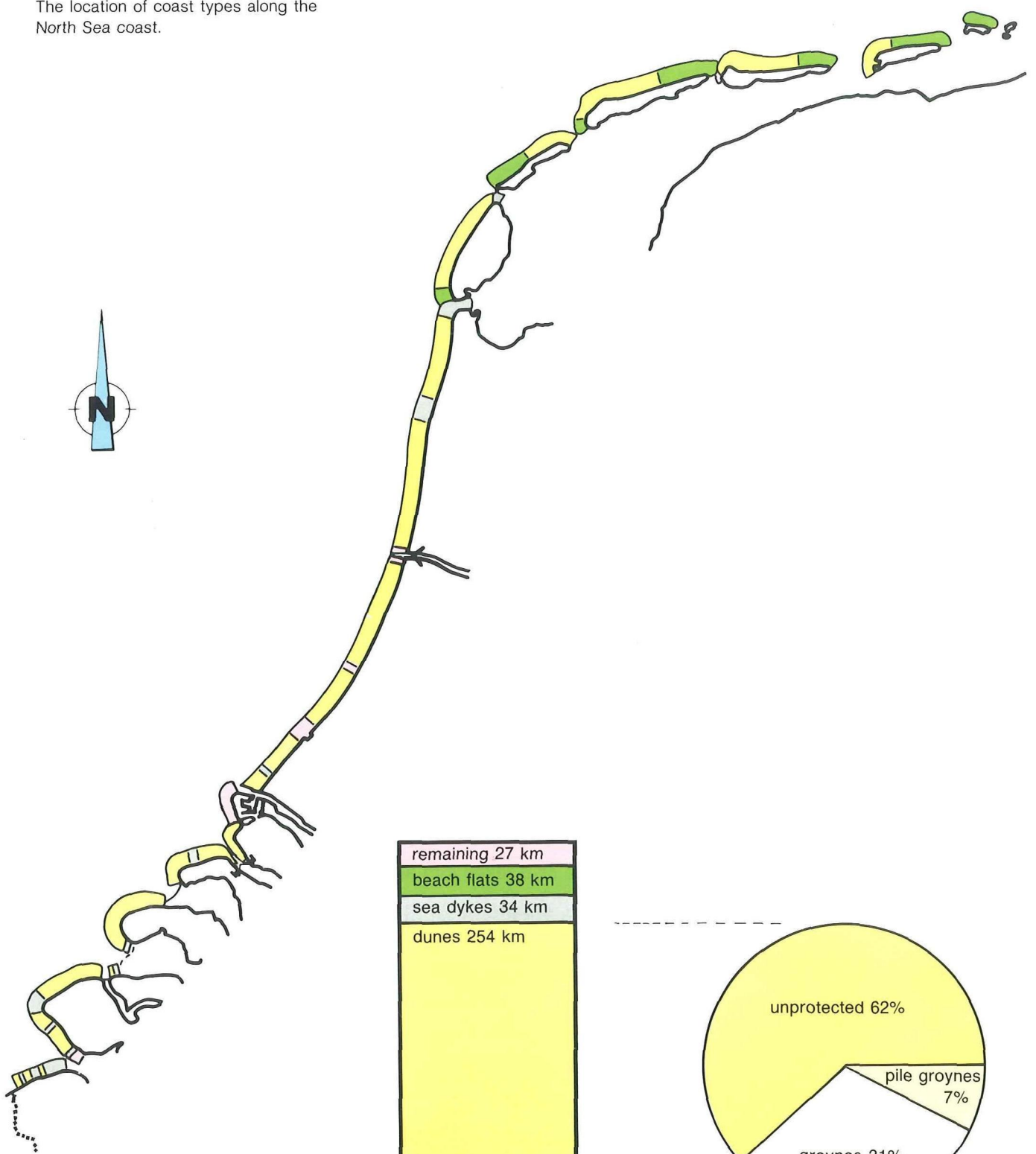
This chapter indicates the influence of climatic changes on the benefits and costs of the four policy alternatives.

The increase in the rise in sea level is calculated according to the mean anticipated value. In addition, results are shown to represent an unfavourable rise in sea level, where changes in wave and wind conditions are also taken into account.

Policy choice, chapter 6

Based on a series of considerations, recommendations and discussions, the Government of the Netherlands has come to a policy decision. The choice of the Government, as well as the considerations that form the basis of this decision, are discussed in chapter 6.

The location of coast types along the North Sea coast.



The North Sea coast subjected to investigation is subdivided into four categories. Each defends the land against the North Sea in its own characteristic way.

2 Coastal recession: analysis of the problem

This chapter analyses the causes and consequences of coastal recession. Based on recent knowledge and insights, an outline is given of why large parts of the coast are receding. The influence of erosion (affecting both the coastline and the dunes) and a rise in sea level on coastal morphology is shown. What will happen if coastal recession is not counteracted is clarified on the basis of figures as much as possible, in order to offer an insight into the nature and scope of the problem. Based on that insight, the next chapter offers alternatives towards a national approach.

2.1 The coast

The coast considered by this report runs from Zeeuws-Vlaanderen in the south-west, to Rottum, the most easterly Wadden island of the Netherlands, and measures 353 kilometres in length. The open tidal inlets and the enclosed tidal inlets will not be included in the discussion.

The largest proportion of the coast consists of dunes: the "dune coast", offering a flexible line of defence against the North Sea. About 40 percent of this coast is reinforced by additional defence works such as groynes, pile groynes and defences at the foot of the dunes.

The dunes represent an important element of the landscape. They have a unique natural value for north-west Europe, and harbour valuable interests such as drinking water supply, recreation, residential and industry.

Aside from the dunes, there are two other types of sea barrier that directly protect the low areas of the Netherlands against the North Sea: sea dykes and "remaining" structures.

The latter type includes harbour complexes, industrial areas and residential areas. The protection against the North Sea can differ markedly from one type to another, e.g. boulevards, raised streets, quays or a breakwater.

Finally, there are the beach flats. These are relatively untouched nature areas at the extremes of the Wadden islands. These do not need to protect any polders lying beyond, although they do serve to shelter the Wadden Sea and the Wadden coast to the south and the east. The beach flats are partially protected against the North Sea by small dunes and "stuifdijken", artificial dykes formed by man-induced aeolian accretion.

Scenarios for the rise in sea level

The current scenario:	0.2 metre per century. This is the rate measured at present.
The anticipated scenario:	0.6 metre per century. This is the rate expected on the basis of the most recent insights.
The unfavourable scenario:	0.85 metre per century. This scenario also takes into account unfavourable developments in wind and wave climate. The wind-force will increase by 10% and the wave height by 8%. The wind and wave direction will shift 10 degrees.

Two types of coastal recession.



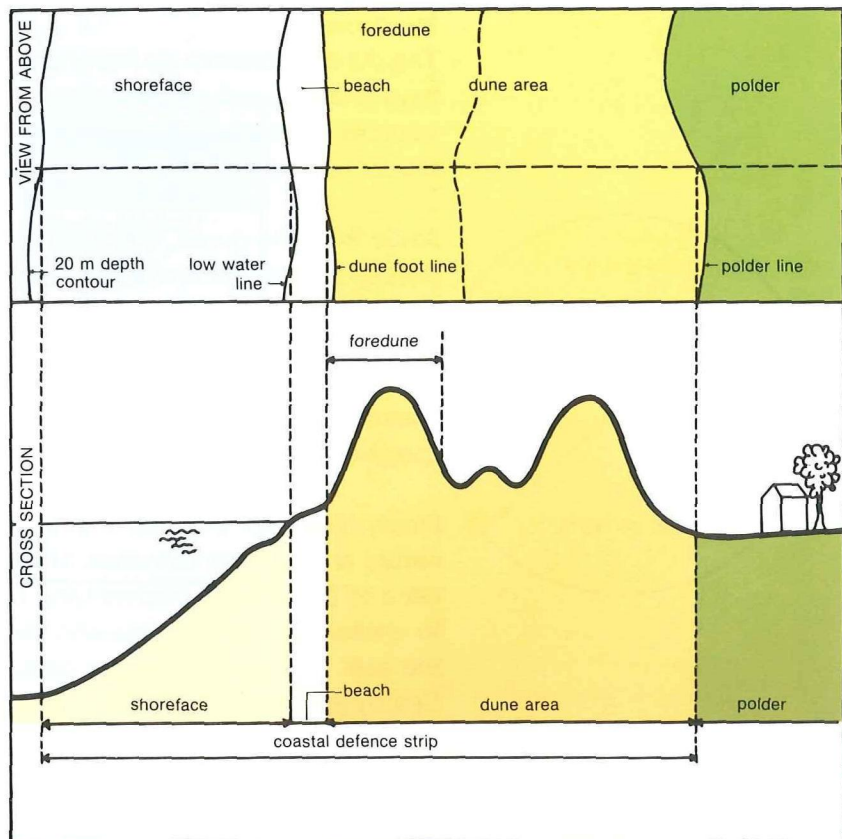
February 1989: heavy dune erosion along the coast of North Holland.



Persistent erosion has taken its toll here, near Cadzand, in Zeeuws-Vlaanderen. As the dunes needed to be reinforced, the hotel was demolished in 1980.

The coastal defence strip. The defence strip of a coastal area consists of: dunes, beach and shoreface. These three together protect the polders against flooding.

The boundary of the dune area on the landward side is the polder line. On the seaward side, the line at the foot of the dunes - the transition from dune to beach - represents the boundary. The seaward boundary of the beach is the mean low water line. The seaward boundary of the shoreface lies at a depth of about 20 metres. Beyond this point, changes are no longer considered relevant with respect to their influence on coastal development over the next 100 years, unless a deep gully runs close to coastline.



2.2 Scenarios for a rise in sea level

The rate at which the sea level will rise in the next 100 years is not certain. This Document takes into account three different scenarios: the current, the anticipated and an unfavourable scenario. The current scenario is dealt with in the greatest depth. The consequences of the other scenarios will be given in relation to this scenario.

2.3 Dune coast

2.3.1 Coastal recession

The dune coast is a flexible line of defence against the North Sea, characterised by the continuous movement of sand in the coastal defence strip. An exchange of sand takes place between the parts above and below the water. Tides and waves displace the sand on the shoreface in both a longitudinal and transverse direction. In this way, the defence strip can lose sand to neighboring coastal areas or tidal inlets lying beyond.

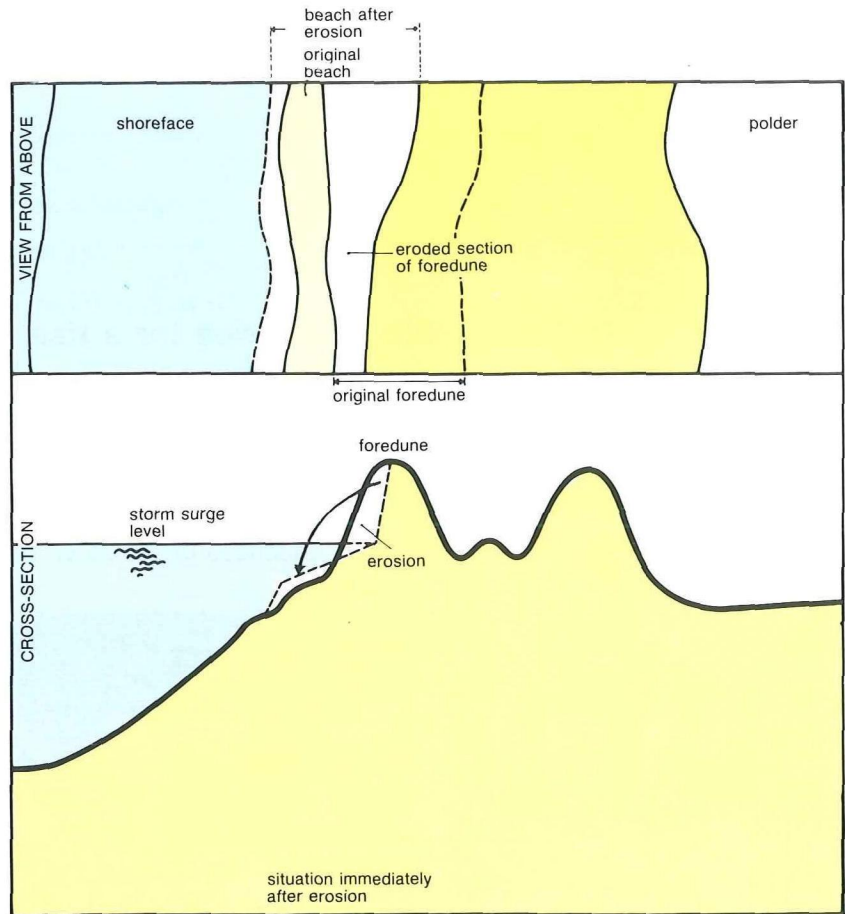
As a consequence of these processes, the landwater boundary is constantly changing. Coastal accretion and recession interchange. However, the latter almost always leads to problems.

There are two types of coastal recession.

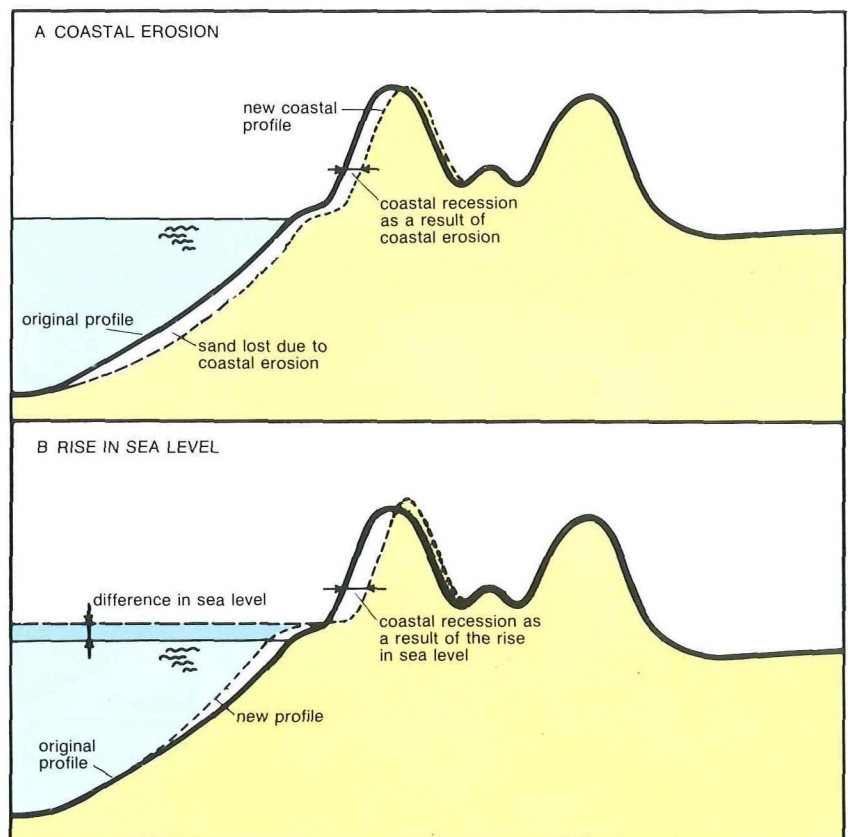
- A rapid, large recession as a consequence of dune erosion due to storms and the associated high water levels.
- A gradual, less marked recession following coastal erosion and a rise in sea level. With coastal erosion, sand leaves the coastal defence strip. The rise in sea level can add to the degree of erosion. In addition, the coastal profile adapts to the difference in sea level by moving backwards, in a landward direction.

These two types of coastal recession will now be described in greater detail.

Dune erosion caused by storms. Under normal circumstances, the beach represents the transitional area between the North Sea and the dunes. During storms, the North Sea can vent its eroding powers directly on the foredune, the most seaward row of dunes, leading to dune erosion. As a consequence, a large volume of sand is lost from the dunes locally. This sand ends up on the beach and on the shoreface. Following dune erosion, the foredune is reduced by several metres or even tens of metres, while the beach is temporarily widened.



Gradual coastal recession. Coastal erosion and a rise in sea level cause the dunes to gradually recede. With coastal erosion, this is due to the loss of sand from the coastal defence strip. Waves and tides pounding the shoreface are responsible for this effect. A rise in sea level could reinforce this erosive process: this is known as the indirect effect. The direct effect of a rise in sea level is that the coastal profile adapts to the higher sea level.



Dune erosion due to storms

Every year, tens of metres of dune are lost in a very short time during storm surges. Only at eroding coastal sectors will this loss be permanent.

The amount of dune lost during a certain storm surge at a higher water level and high waves is particularly influenced by the type of beach. Dunes with wide, high beaches are less vulnerable to storms than dunes with narrow, low beaches. At coastal sectors that do not suffer from erosion, the coast will almost always repair itself when parts have been washed away. However, at coastal sectors that do suffer from erosion, the dunes are only restored in part: they lose sand, resulting in coastal recession.

Coastal erosion

Less spectacular than dune erosion, but in the long term even more threatening, is ongoing coastal erosion. The coastal defence strip loses sand, weakening the coastal defence strip as a whole. Coastal erosion is a process that goes through a number of steps. First, the shoreface loses sand and becomes deeper. Next, the beaches lose sand, causing their level to drop. Eventually, the dunes are affected. The deepened shoreface and the lowered beach increase the dune's vulnerability to storm surges: large parts of the dunes wash away, and sand settles on the shoreface and on the beach. After such a storm, the shoreface is again raised temporarily, while the beach becomes wider and higher for a time. Only part of the sand washed away to the shoreface will return during calm weather conditions. The foredune, the outer ridge of dunes, narrows and gradually moves in a landward direction. If nothing is done, its capacity as a water barrier is reduced and interests and values in the dune area are affected.

In 1990, about 50% of the dune coast is receding; this is particularly true for parts of the Delta region in the south-west and several Wadden islands.

About half the dune coast is receding, a problem all regions have to contend with. Two well-known eroding coastal areas are shown here.

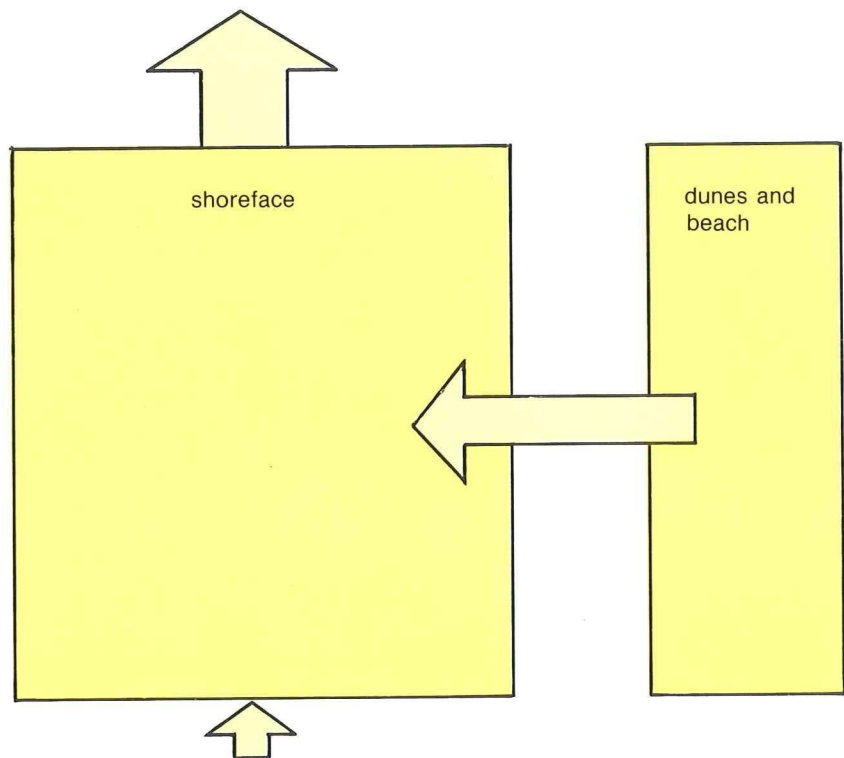


The tip of North Holland has been receding for centuries. The protruding Hondsbosche sea dyke offers evidence of this fact.



The north-west coast of Walcheren is influenced by sand waves which move along the coast from south to north. This as yet poorly understood phenomenon can lead to fluctuations of tens to hundreds of metres over a period of decades. The dip in a sand wave leads to coastal recession.

An outline of how the coastal system works. Eroding dunes are created by a disruption in the balance of sand flows: more sand leaves the coastal area than enters it. This principle, converted to a practical calculation model, was used in the Discussion Document to draw up coastal prognoses.



At some locations, coastal recession due to erosion has been going on for many centuries. One example is the tip of North Holland. There are also locations where periods of recession are interspersed with periods of accretion. This may take tens to hundreds of years. For example, the coast of Walcheren with its migrating sand waves and shifting tidal channels, and Texel island which is periodically accreting in the southwest by a landward migrating sand bar.

Causes of erosion

Tidal movement and waves cause currents on the shoreface. Large volumes of sand are transported, both along the coast and at right angles to it.

If, on average, as much sand is carried away as is washed up on a coastal sector over a number of years, that sector is said to be stable. When more is washed away than supplied, sand losses are the result: erosion. The sand of an eroding coastal sector is carried away to neighbouring coastal areas, allowing these to advance, or else the sand is transported to tidal inlets lying beyond.

Many factors can influence the "sand balance": wind force, wind direction and storms, the orientation of the coast with respect to the dominant wave direction, the tides and the sea level. Long ago, the sand balance of the coast was favourably influenced by the supply of sand brought in by the rivers. Nowadays, that supply is virtually nil. In fact, the situation has been reversed. The Wadden Sea's demand for sand has led to recession of the North Sea coast along the Wadden islands and at the tip of North Holland. In the outer deltas of the tidal inlets, migrating tidal channels and sand bars influence the morphology of bordering coastal areas.

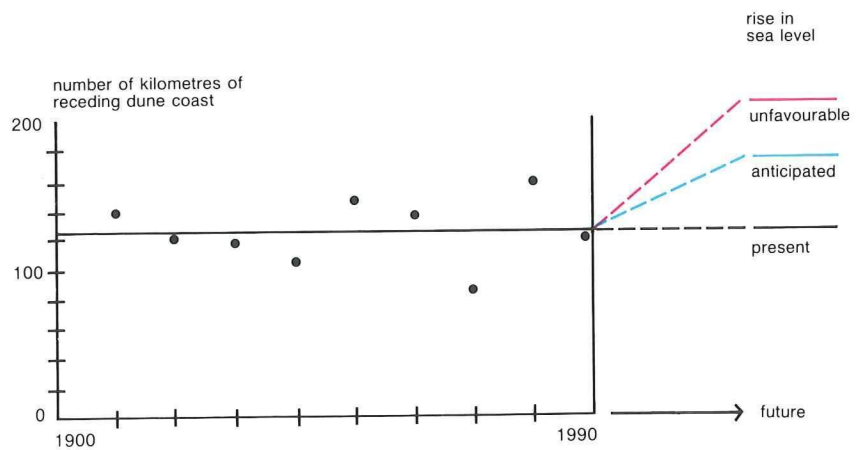
Aside from natural factors, the coast is subject to human intervention. Hydraulic engineering works change current patterns over large distances and thereby affect the "sand balance". Examples of this phenomena include the breakwaters along the coast of Holland and the closure dams in the northern part of the Delta area. The sand balance may also be unfavourably affected by sand extraction close to the coast. As a result, the coastal system is weakened locally.

Hydraulic engineering works influence the morphology of large areas. Even after many decades, their influence may still be seen.



The Brouwersdam. Its construction has stimulated the formation of banks on the outer delta, the "Voordelta".

Coastal erosion in the past and future. This century, an average of approx. 50% (120 km) of the dune coast has receded to date. On the basis of current insights, a more rapid rise in sea level could markedly increase this percentage.



Influence of a rise in sea level

Current insights predict that the rise in sea level will have two effects:

- In the first place, relative deepening of the shoreface. To compensate, the shoreface will require more sand. If this sand is not available in sufficient quantities on the nearby sea bed, sand is lost from the dunes. The foredune, the most seaward row of dunes, will become narrower and shift in a landward direction: the direct effect of a rise in sea level. This effect will be seen along the entire dune coast.

- The second effect is an enhancement of the erosive processes: the indirect effect. This relates particularly to those coastal sectors under the influence of tidal inlets. As the tidal inlets demand more sand, this sand will be derived in part from the North Sea coast.
Particularly when the rise in sea level is coupled to unfavourable wind and wave conditions, erosion can be expected to exacerbate.

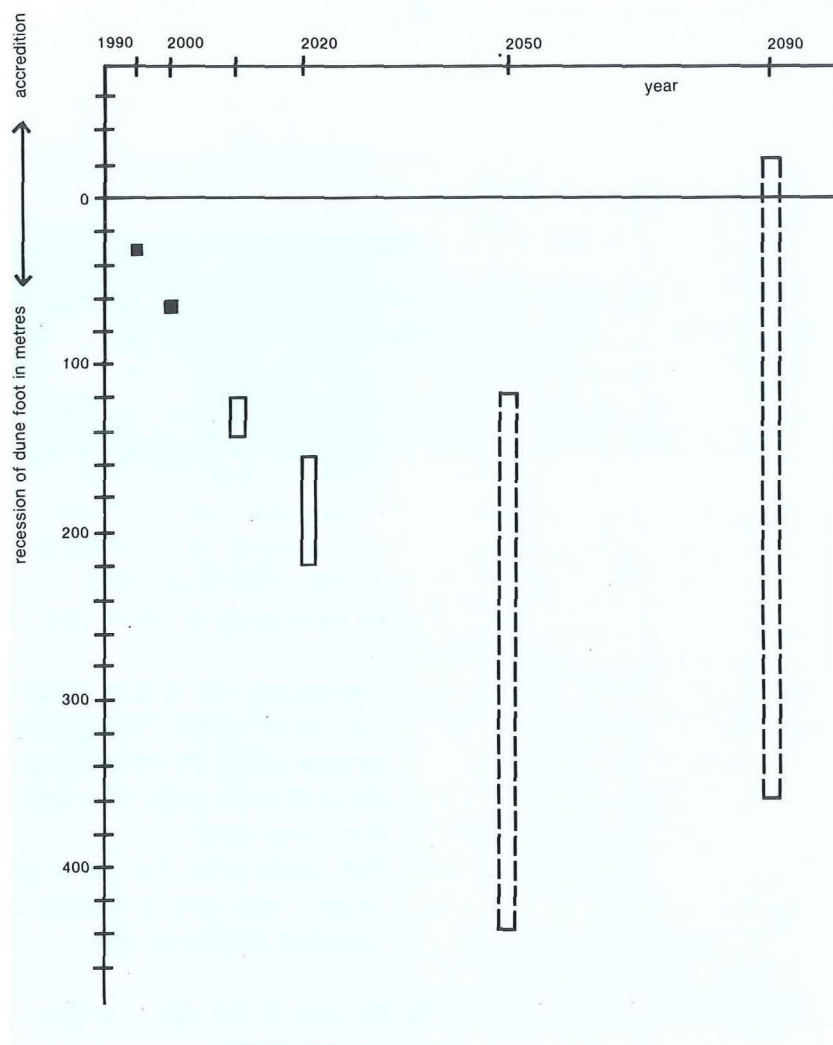
An increase in the rate of a rise in sea level will mean that a larger part of the coast will undergo erosion. The coastal sectors that are already subject to this process will erode even more rapidly.

An increase in the rate of a rise in sea level from 0.2 metres to the anticipated 0.6 metres per century will cause a state of accretion or stability to change to erosion over tens of kilometres of coastline. The rate of coastal recession will also increase. For those coastal sectors influenced by neighbouring tidal inlets, the additional recession is estimated at approx. 0.5 metres per year. For the remaining coastal areas, further recession is estimated at about 0.2 metres per year.

Coastal development near Texel island.

With coastal prognoses 10-20 years into the future, great margins for error must be taken into account, despite increased know-how gained through the Coastal Genesis project, amongst others.

The morphology of Texel island is influenced by landward migrating sand bars. In the next century, the Noorderhaaks, a sand bar which is presently located to the south-west of the island, is expected to join up with Texel island. Whether this will actually happen is not entirely certain. The margins are indicated by the broken lines.



The Noorderhaaks. On its way to Texel island?



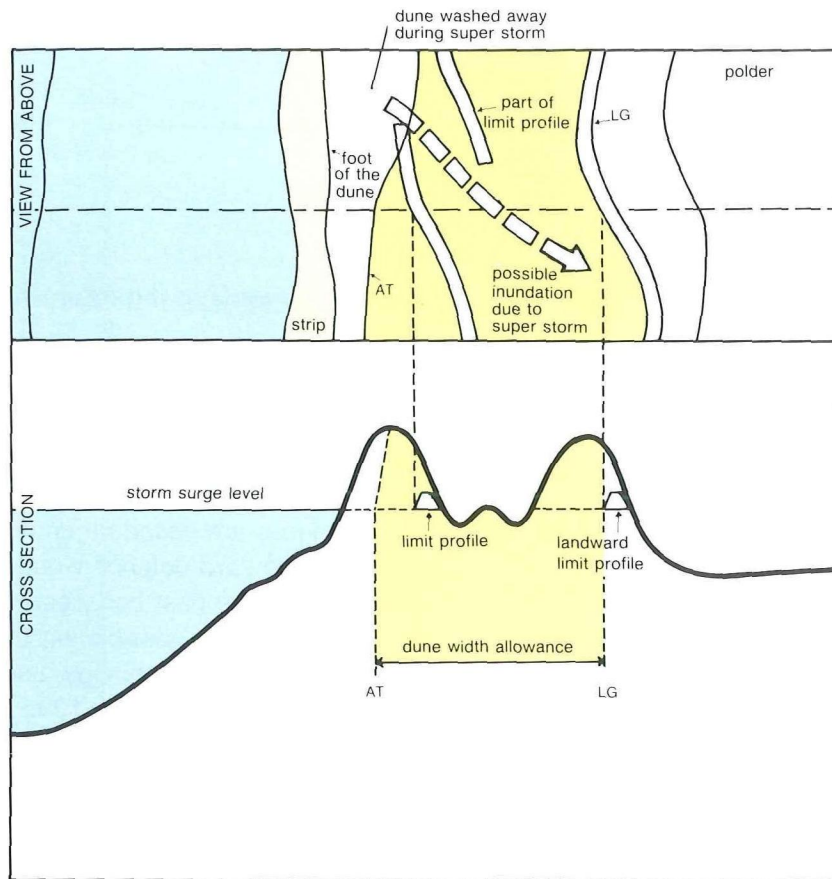
Coastal recession in the future

This Document describes the prognoses for the average position of the foot of the dunes over the period 1990 to 2090. All available coastal measurements and recent insights offered by the Coastal Genesis project relevant to the morphology of the coast have been used, with emphasis on the prognosis for coastal recession.

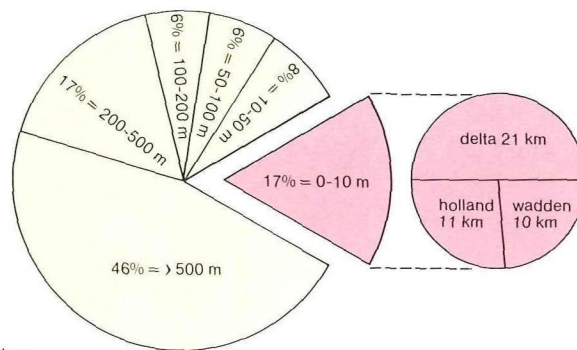
The prognoses are based on an ongoing maintenance of dunes, beach and the hard defence works they harbour, as has been carried out for the past decades. The prognosis for the position of the coastline is only possible within certain limits. Based on current insights of coastal morphology, uncertainty about the location of the coastline increases from 10 to 20 metres in the year 2000 to hundreds of metres in 2090. The greatest uncertainty is associated with the Wadden islands, followed by the Delta area. In comparison, the coast of Holland exhibits the smallest degree of uncertainty. Possible deficiencies in current insights lead to additional uncertainties with long-term prognoses.

The figures express this source of additional uncertainty by indicating long-term results as a broken line.

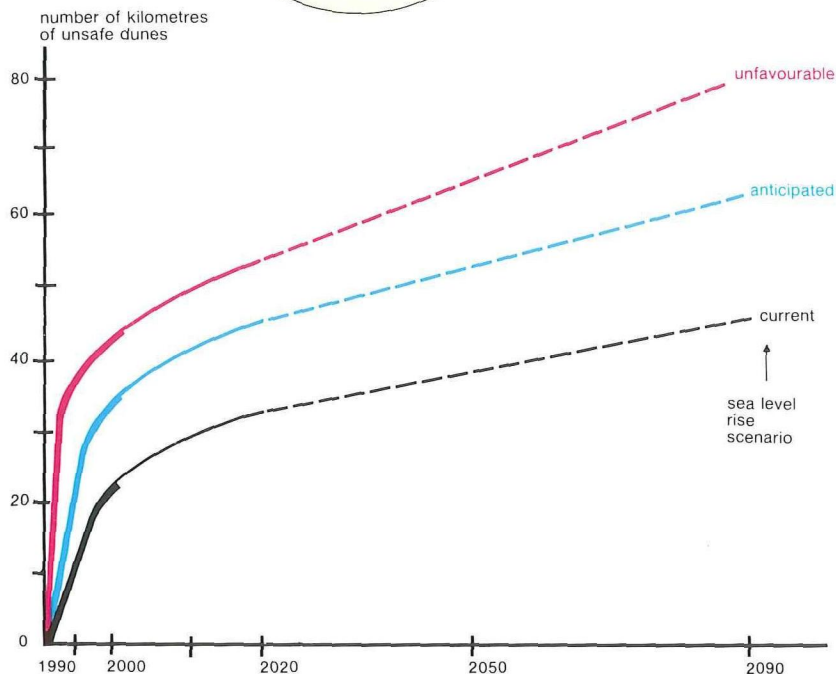
Safety of the dunes in their function as water barriers. According to the Coastal Defence Bill, the coastal defence strip must be strong enough to withstand a - rarely occurring - extremely heavy storm ('super storm'). The stretch of dune which might wash away during such a storm is called the erosion zone. This erosion zone may measure many tens to hundreds of metres. In order to prevent the polders from flooding, sufficient dune area should remain to hold back the water: the limit profile. Where the dunes are very narrow, the limit profile is situated in the foredune. At broader dune areas, limit profiles may occur at several locations. By joining up the most landward limit profiles, the landward limit profile line (LG) is found. The distance between this line and the critical erosion line (AT) is referred to as the dune width allowance. The polders are considered safe as long as this buffer is present. If this value is nought, the dune only just satisfies the norms.



The dune width allowance in 1990. At present, 17% of the dune coast has a safety margin of less than 10 metres. Here the dunes can only just withstand coastal erosion or a more rapid rise in sea level. Tens of kilometres of dunes possess virtually no reserves.



The length of coastline where the dunes are expected to become unsafe in the next 100 years if coastal recession is not prevented. A more rapid rise in sea level will exacerbate and bring forward this problem.



2.3.2 Consequences of coastal recession for the safety of the polders

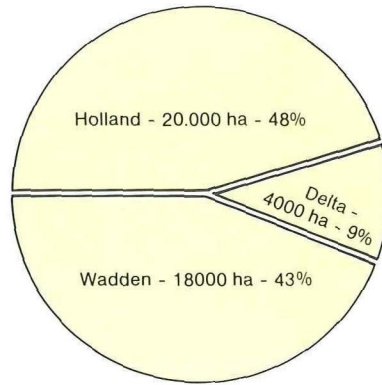
To reinforce the dunes, sand nourishments have been supplied at various locations along the coast of the Netherlands over the last decades. In 1990, the entire dune coast satisfies the standards of the Delta report, making it "Delta-safe". For example, along the coast of Holland the dunes are able to withstand a storm surge level which is exceeded only once in ten thousand years on average (i.e.: the probability of exceeding this level is one tenthousandth per year). The Delta coast and Texel island are able to withstand a storm surge level exceeded once in four thousand years, the remaining Wadden islands a storm surge level exceeded once in two thousand years, on average.

The dune width allowance represents that dune width available to provide a buffer against coastal recession, without endangering Delta safety. The distribution of the dune width allowance along the dune coast in 1990 shows that over a length of 42 kilometres this allowance is less than 10 metres.

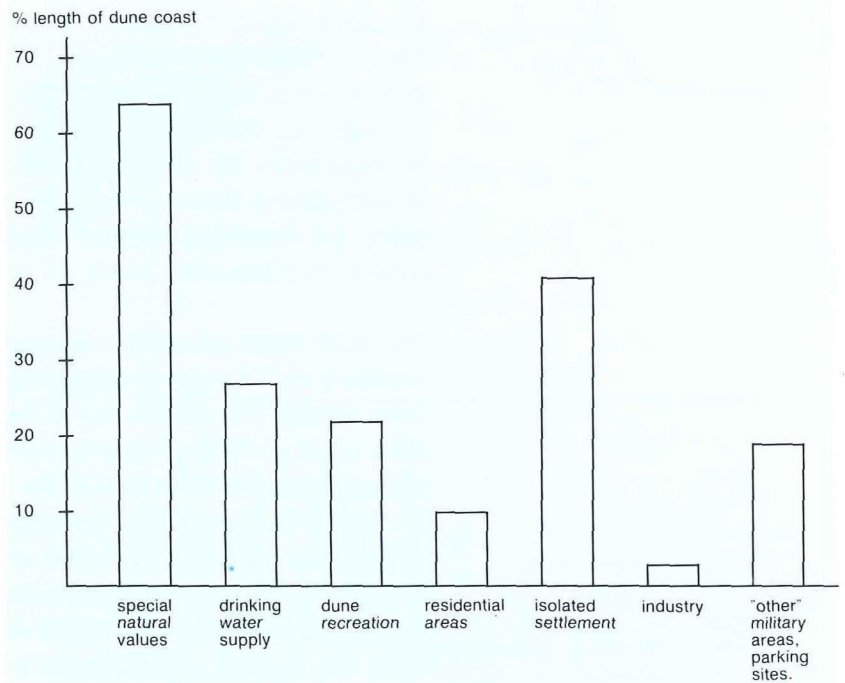
Of this 42 kilometres, the Delta coast represents half. Zeeuws-Vlaanderen, parts of Walcheren and the western extremes of Schouwen, Goeree and Vorne only have narrow dunes. In Holland, the dunes to the south of Den Helder and to the north of Hoek van Holland represent the weak spots. The Wadden islands are able to cope with a relatively large amount of coastal recession. Weak locations are found on Ameland and Vlieland.

If no measures are taken against ongoing coastal erosion, tens of kilometres of coast, particularly in the Delta area, will become unsafe within several decades. With a "super storm", the probability that the water will break through at such locations is greater than the acceptable limit. An accelerated rise in sea level will enhance this problem considerably.

Distribution of the 42,000 hectares of dune area over the regions.



The dune area harbours many interests and values. Their presence is expressed as a percentage of the total length of dune coast (254 kilometres).



Risk of erosion.

The foredune holds back the water. Interests and values located in this area, such as isolated houses, restaurants and the like risk being washed away during heavy storms. Here on Texel island, such a calamity was only just avoided.



2.3.3 Consequences of coastal recession for user functions and natural values

The dune area covers about 42,000 hectares; 18,000 hectares is represented by the Wadden area (43%), 20,000 hectares along the coast of Holland (48%) and 4000 hectares in the Delta area (9%).

The dune area of the Netherlands is the largest unbroken line of dunes in Europe. It represents a unique, large-scale nature area of international significance.

Large parts of the dune area are subject to the Nature Conservation Act.

Both locally and regionally, the dunes exhibit a varied ecology. Dune swamps, lakes or "sluffers", dunes with dry scrub, woodland and heath alternate with "ordinary" dunes with marram grass or dry grassland or by dunes strongly altered by the hand of man.

Aside from its natural values, the dune area represents great economic interests for drinking water supply and recreation; it is used for residential functions and industry, while military areas and agricultural land are also found on a limited scale. These user functions are mainly located behind the foredune, the most seaward row of dunes. The foredune itself may locally house residential functions and restaurants.

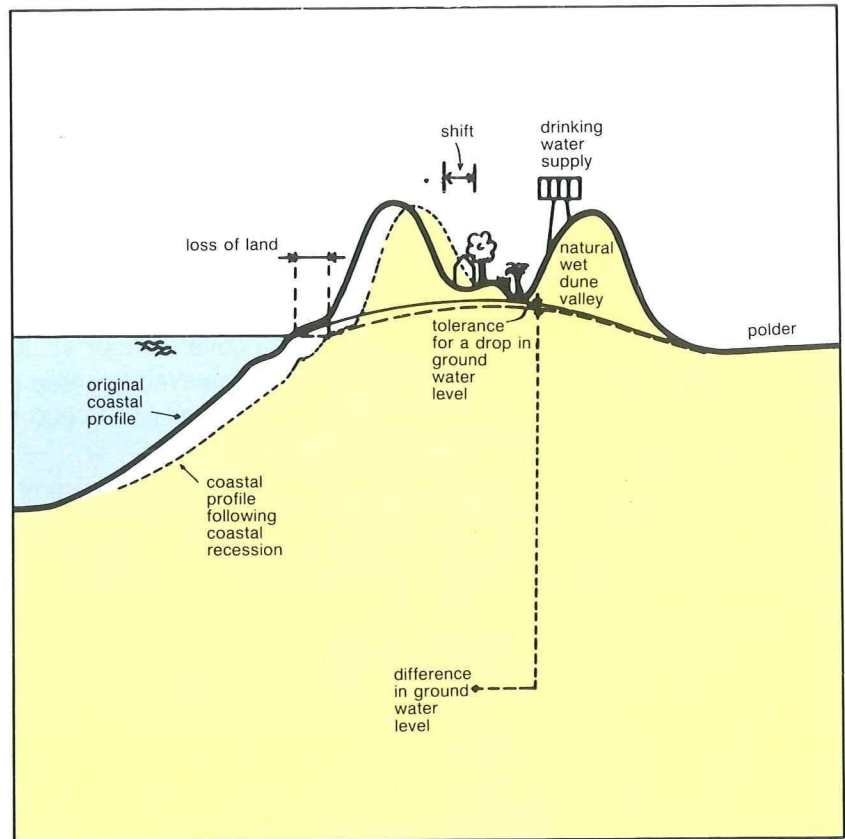
A specific element of the dune area is represented by the foredune. This most seaward line of dunes has a principal function in offsetting dune erosion. Broader foredunes can also act as a buffer against gradual coastal erosion for a certain amount of time: there is room for recession.

User functions and natural values under threat of gradual coastal recession.

Aside from loss of land, this is due to:

- shift of the foredune in a landward direction: areas representing interests and values are buried under the sand of the foredune;
- a drop in the ground water level: where critical levels are exceeded, natural values may be affected.

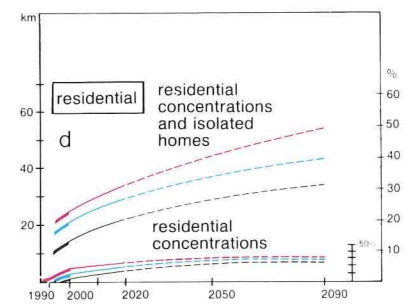
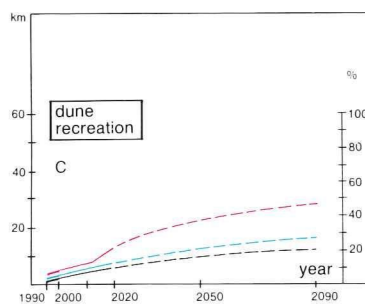
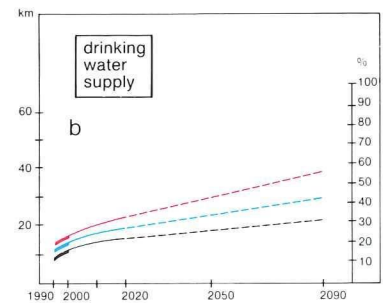
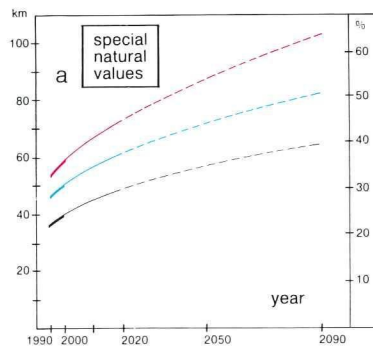
As a result of these processes, the area affected by coastal erosion is considerably larger than the area directly threatened by erosion; coastal recession has a more "far-reaching" effect.



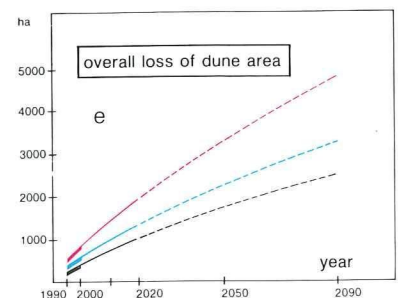
The anticipated loss in interests and values in the dune area if coastal recession is not brought to a halt and only basic maintenance is carried out: controlled retreat.

This approach is used to postpone the loss of interests located behind the foredune.

In a) to d), the number of kilometres of dunes where values or interests are relinquished to the sea or covered by sand are indicated for the three scenarios of a rise in sea level. These numbers are also expressed as a percentage of the total number of kilometres where these functions occur. e) Represents the overall dune area sacrificed as a result of loss of land and landward shift.



— unfavourable scenario
 — anticipated scenario
 — present scenario for a rise in sea level



2

The landward movement of the coast affects user functions and natural values.

As a consequence of dune erosion during storm surges, parts of the foredune are lost within a short period of time. The associated loss of user functions and natural values in the foredune is a risk that must be accepted: the erosion risk. An exploratory analysis has shown that this risk particularly affects isolated homes and recreational facilities.

At several locations along the Dutch coast, the sea may break through the foredunes as a result of dune erosion, thereby flooding the dune area lying beyond. In many cases this is a nature area, so that such a phenomenon does not necessarily have negative consequences. Examples of this can be found on the Wadden islands.

Gradual coastal recession has more drastic consequences: land is definitely lost to the sea. In addition, gradual coastal recession also means that interests and values lying in a more landward direction are lost or affected. Areas with values and interests located directly behind the foredune may become buried under the sand of the foredune; in the accompanying figure this is indicated as shift.

Wet nature areas may dry up, up to hundreds of metres behind the foredune, due to a drop in the ground water level.

Other effects can also take place, such as a rise in the boundary between brackish and fresh groundwater, endangering deep water extraction and increasing salt water seepage into the hinterland.

If no measures are taken against ongoing coastal erosion, losses will be the result. User functions and natural values will be lost to the sea over tens of kilometres of coastline, or else they will be buried under the sand of the foredune. In total, these losses represent tens of hectares per year.

An accelerated rise in sea level will only exacerbate these problems.

Maintenance of the sea dykes, as shown here on the south-west coast of Walcheren, is not subject to discussion here. The efforts required to combat erosion are relatively small.



On the western point of Walcheren, the sea dyke was recently raised as part of the Delta works project. A more rapid rise in sea level will demand new adaptations sooner than planned.



2.4 Sea dykes

Where a sea dyke is present, the coastline is fixed. The user functions and natural values lying beyond are not directly threatened by coastal erosion. However, the adjoining dune coast often does recede. As a result, the dyke will protrude into the sea like a bulwark. This situation demands intensive maintenance. However, a preliminary analysis has shown that relocating a sea dyke is more expensive than maintaining it at its original position, even if the sea level should rise at a higher rate.

Particularly the toe of the dyke is subject to the influence of erosion on the shoreface. Where a channel is present close to the shore, the stability of the dykes may be threatened if the channel moves further landward or becomes deeper. If such a movement is predicted, stone revetments or sand nourishment must be carried out to protect the dyke. Examples of these situations can be found at the northern tip of Texel island, the dykes to the south of Den Helder and several dyke areas in the Delta region. Where it concerns standard maintenance, such measures against erosion demand relatively little extra financial outlay: about 10-15%.

An accelerated rise in sea level means that the crest of the dykes will need to be raised sooner and to a greater height than would be the case at the current rate of 0.2 metres per century. The costs involved can be considerable.

Beach flats are permitted to develop more or less without restriction, as is shown here on the eastern side of Terschelling island.

This area is characterised by great morphological changes. Extensive measures to counteract coastal recession are not considered here, although some maintenance is carried out to keep this very dynamic area in check.



The boulevard of Vlissingen, an example of the "remaining" type of coast category. Upkeep is the only realistic option here.



2.5 Beach flats

Those parts of the coast which do not serve to protect polders are known as beach flats. They are almost exclusively found on the Wadden islands, more particularly at their extremes. These beach flats are permitted to develop more or less without restriction. They are often nature areas, and do not harbour residential functions. If allowed to develop unhindered, their character of "nature area" is preserved.

The beach flats only need minimal defences against erosion and a rise in sea level. More drastic measures will only need to be considered if the stability of the island as a whole is under threat or if their sheltering function for the mainland beyond is affected.

2.6 Other coastal types

At various locations, the dune coast is interrupted by a harbour, for example at IJmuiden and Scheveningen. Here the water defences are located in a more landward direction and are not affected by erosion.

At other locations, residential areas with an esplanade or boulevard are found, for example in Vlissingen, Scheveningen and Katwijk. Here, erosion may be combated by means of beach nourishment. In Vlissingen, the boulevard represents the primary water defence. In Scheveningen and Katwijk, the barriers are situated in a more landward direction. Katwijk even has raised areas located inside the built-up area.

Finally, there is an industrial area located south of Hoek van Holland. The water defences are also inland here. A specific element of coastal defence is represented here by a "block dam".

A more rapid rise in sea level will - as for the sea dykes - result in a need to adapt the water defences at an earlier stage, e.g. the raising of esplanades, quays and streets.

Natural values under threat. Due to coastal recession, many parts of the dune coast are expected to suffer a loss of valuable nature areas in the coming decades.

There is no standard to measure the extent to which natural values - and other interests in the dune area - should be protected against coastal recession. Various choices for a coastal defence policy can be made: these represent policy alternatives.



The prerequisite of any alternative for national coastal defence policy: to uphold the safety of the polders on the basis of the "Delta standards".



3 Options for a national approach to coastal defence: policy alternatives

This chapter presents four alternatives for a national approach to coastal defence. These options indicate which interests and values in the coastal zone are protected against coastal recession. An outline is given of their technical realisation.

3.1 Policy alternatives, technical measures

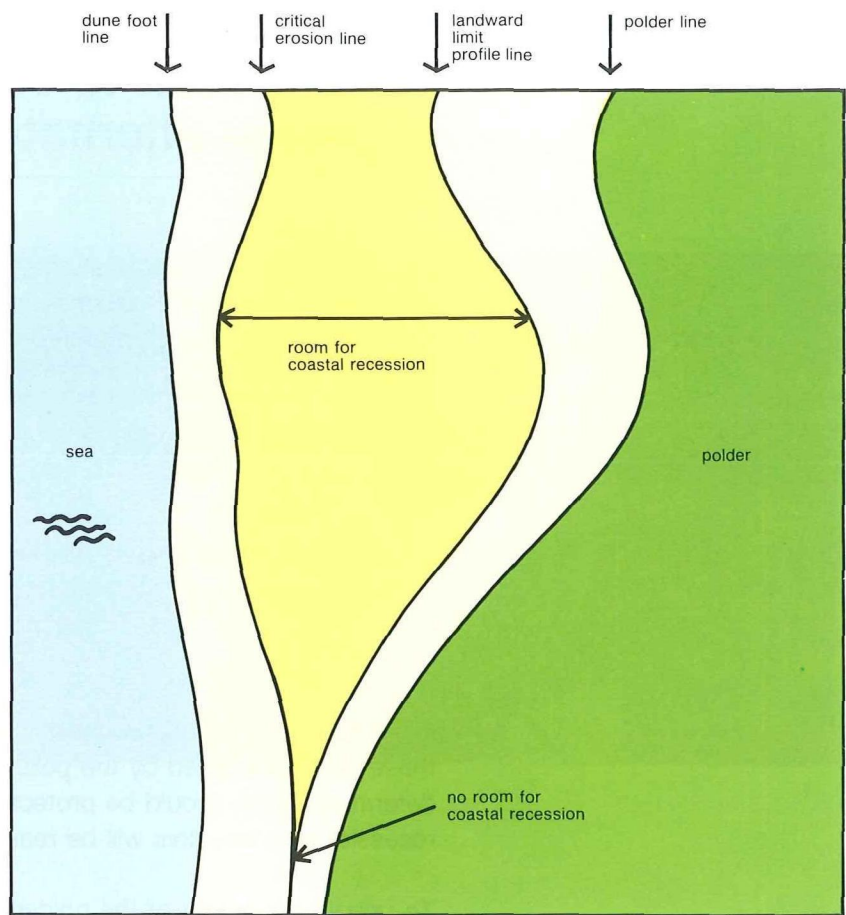
The problem analysis of the previous chapter has shown that coastal recession over tens of kilometres of the Dutch coastline will threaten the safety of the polders and affect the interests and values in the dune area. These problems occur along the entire coast.

A national approach is necessary. Various choices are available: these are represented by the policy alternatives. A policy alternative determines what should be protected against damage by coastal recession and how this will be realised.

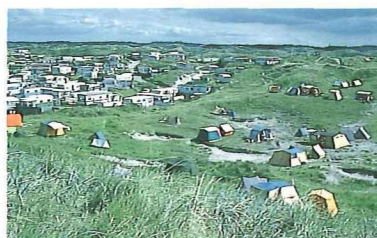
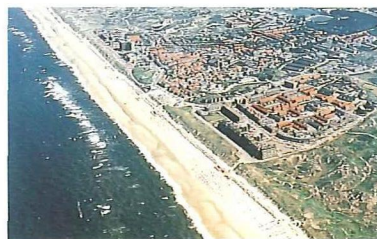
To uphold the safety of the polders against flooding is not a subject of discussion in this Document. All policy alternatives are based on the Delta standards. There are no standards stipulating to which degree interests and values should be protected against coastal recession. In this regard, choices can be made between various coastal defence alternatives.

Aside from the question of what should be protected against coastal recession, it is necessary to ask how this is to be brought about. The costs and benefits of the policy alternatives are strongly related to the technical realisation. That is why a description of the principal measures has been included. On main lines, these measures agree with current coastal defence measures. A distinction is made between maintenance measures and measures combating ongoing coastal erosion. This distinction is important as it affects the distribution of tasks between the Water Boards and the State as defined in the Water Defence Bill.

Options for a national approach with regard to the dune coast. The dune width allowance - the distance between the critical erosion line and the landward limit profile line - determines the area available for coastal recession from a perspective of safety. Within this area, policy alternatives may be selected for the protection of interests and values.



A principle of the Discussion Document: interests and values in the dune area will not be relocated.



3

3.2 The principles

The policy alternatives described in 3.4 are based on a number of principles. A distinction is made between the principles used to distinguish the policy alternatives and those used to establish the technical measures required.

3.2.1 Principles of the policy alternatives

- a The dune coast should retain the character of a flexible coastal defence, even at an accelerated rise in sea level.
The options available for the protection of the dune area are based on the following principles:
 - a1 Maintenance of Delta safety is not subject to discussion. All policy alternatives are based on an unbroken line of limit profiles, located as far inland as possible. Maintenance of the safety of the polders does not permit recession of the coast past this line. This line determines the maximal admissible extent of coastal recession.
 - a2 The policy alternatives are formulated on the basis of interests and values in the dune area. Interests on the beach and the shoreface are not considered by this Document.
 - a3 No prognoses have been made for developing the social potential of the dune area. It is assumed that the situation after 1990 will remain unchanged.
 - a4 The option of compensating for losses of interests and values at other locations is not taken into consideration.
 - a5 No function is allocated to accreting areas of the coast as a potential location for values and interests.
 - a6 The policy alternatives are not based on a valuation of interests and values threatened by coastal recession.
- b Sea dykes and other coastal types must be maintained, also at a higher rate of sea level rise. Studies have shown that there are no better or cheaper alternatives at present.
- c The natural development of beach flats will be supervised. This is in line with the environmental policy for the Wadden area.

The total costs expended for current maintenance of the coast, including salaries.

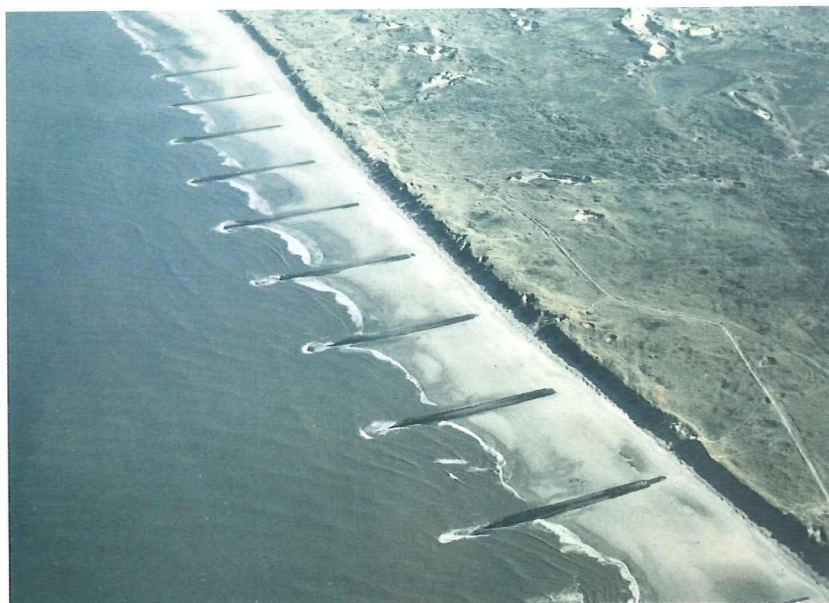
These figures are based on the collective inventory for the period 1975-1984 as conducted jointly by the Water Board Association and the Public Works Department.

coast type	coastline length in km	maintenance costs in millions of guilders per year
dune coast	254	20
sea dykes	34	4
beach flats	38	1
remaining	27	1
total	353	26

1 Dfl is approx. 0.5 US \$ (1989 exchange rate)

It is not fully understood to what extent groyne prevent coastal recession.

They have proven their effectiveness in keeping gullies away from the coast, although they seem to have little effect at other locations. On the other hand, their demolition is thought to be too risky. In principle, therefore, existing works should be maintained.



3.2.2 Description of technical measures

A distinction is made between technical measures for the purpose of maintenance and those used to counter erosion.

Maintenance of the dunes includes measures to keep the foredune, the beach and the defence works they harbour in good condition. This work must be repeated on a regular basis, e.g. the repair of storm damage.

With sea dykes, maintenance is particularly directed at keeping their covering and the local groynes in good condition. For the "remaining" coastal types, upkeep relates to maintenance of boulevards, artificial barriers and the beach, amongst others. Aside from standard maintenance, major upkeep is required for sea dykes and the "remaining" coastal type. This includes: occasionally raising and adapting the crests, to ensure that these structures will continue to hold back the water for several decades.

For beach flats, maintenance is limited to the control of shifting sands.

Combating erosion includes all measures which hold back the gradual recession of the dunes. With sea dykes and the "remaining" coastal type, unfavourable developments on the shoreface are combated.

Maintenance of the sea barriers

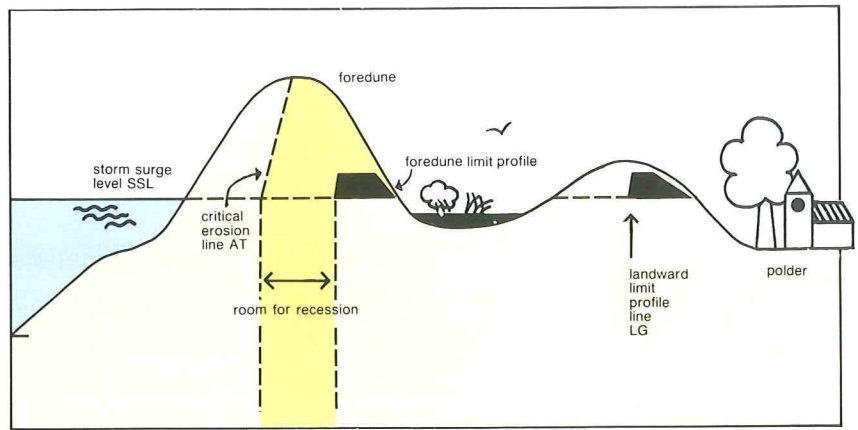
- a The major principle is: to continue current maintenance of the coast - dunes, sea dykes, "remaining" and beach flats - at a similar level. At present, about 26 million guilders is set aside for this purpose every year.

The dunes demand the greatest amount of maintenance: about 75% of the total costs.

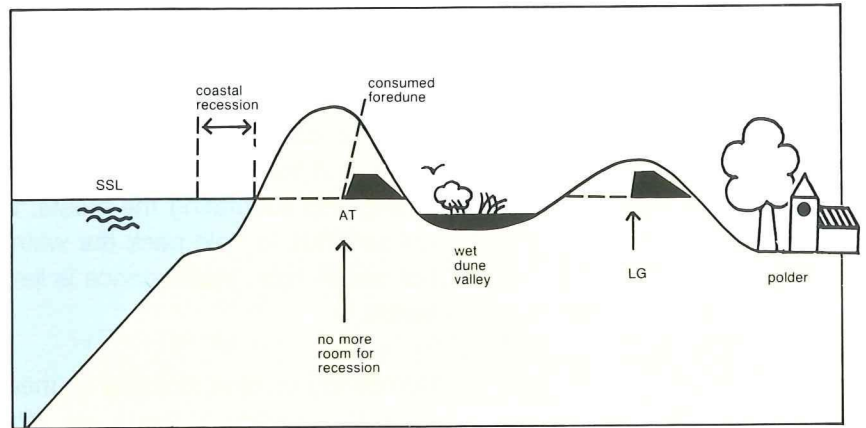
- b With regard to dune maintenance, the following principles apply:
- b1 Existing defence works along the dune coast, i.e. groynes and pile groynes, will be maintained. For 1990, the associated costs are estimated at approx. 7 million guilders. Where sand nourishments are carried out to combat erosion, maintenance costs will be less.

Response to coastal erosion in the foredune with a receding coast.

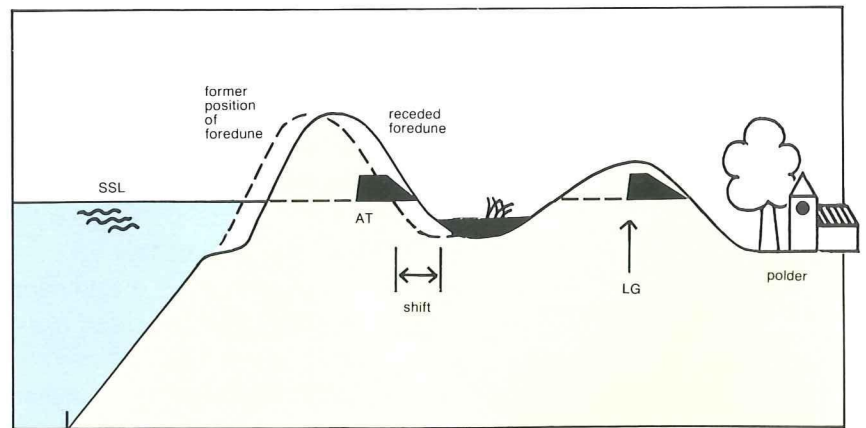
1. The situation in 1990. The foredune can easily resist a super storm. There is room for further recession.



2. The foredune is only just capable of holding back the sea during a "super storm". Further coastal recession cannot be permitted.



3. The foredune is retreated through maintenance measures. At high rates of coastal recession, sand nourishment to the landward side will be required. These nourishments are considered part of erosion defence measures. Interests and values situated just behind the foredune will be buried.



- b2 At locations where coastal recession does not need to be stopped immediately, the foredune is subject to "controlled retreat". If the foredune is wide enough, coastal recession is temporarily offset by the foredune, to postpone the loss of interests and values lying behind. Once the foredune has been reduced to a certain minimal width, it is retreated in its entirety.
- b3 The concept of "controlled retreat" assumes that foredunes that are "Delta safe" in 1990 should continue to be so in the future. At a rate of coastal recession of approx. 1 metre per year, this can be realised through standard maintenance methods. At faster rates, supplementary measures will be necessary. It is assumed that this will be realised through nourishments to the landward side of the foredune. These rear-ward nourishments form part of the measures used to combat erosion.
- c Sea dykes and "remaining" types of water barriers are generally designed to last for 50 years. At the end of this period, measures must be taken to uphold their capacity as water barriers. For example, it may be necessary to raise the crests and adapt the banks.

Combating erosion

- a The costs required for the dune coast depend on the method used to combat erosion. This is based on the following principles:
 - a1 The national approach is based on sand nourishments. These measures compensate for the loss of sand in the coastal defence strip. They allow sufficient flexibility to cope with the extremely varied morphology of the coast and with the uncertainty of a more rapid rise in sea level. They are also benign to the environment. A disadvantage is that they must be repeated on a regular basis. Generally, the costs for nourishments are lower than those associated with the construction and maintenance of hard coastal defence works.
 - a2 If coastal recession must be fought, nourishments to the seaward side of the foredune must be carried out: beach nourishment. If coastal recession does not need to be stopped, while there is no more room for recession of the foredune, sand nourishments are carried out to the landward side of the foredune.

Marram grass: an important aid in catching and holding sand drifts in the dunes.



Proper maintenance of the dunes, beach and defence works is of crucial importance in upholding the safety of the polders.



- a3 The extraction of sand for nourishments is based on the current sand extraction policy. The sand prices differ per region (Wadden, Holland, Delta), depending on the extraction site.
- a4 The nourishments are designed for a lifespan of 5 to 10 years.
- a5 In addition to the national approach with nourishments, hard measures such as groynes and breakwaters can be introduced locally.
- b In order to maintain the sea dykes and the "remaining" coastal types, extra stone revetments and sand nourishments have been allowed for. The total costs of such measures to combat erosion is estimated at 60 to 70 million over the period 1990-2090.

3.3 Current policy

Safety of the polders is the central aim of present policy. As a result of the Delta Act, the sea defences have been reinforced to meet the Delta standards. With the realisation of these reinforcement works, an allowance has been "built in" to offset several years of coastal recession. In addition, the coast is intensively maintained: dunes are subject to "controlled retreat", sea dykes and the "remaining" coastal types are maintained and beach flats are supervised in their natural development.

In recent years, upkeep has not only been performed for the purposes of safety. Several nourishments have been carried out at locations where safety was not under threat, in fact.

At Texel island, nourishments were carried out in order to protect natural and recreational values. At Schouwen, drinking water supply areas and natural values were protected. Sometimes both the safety and the interests in the dune area were served: in North Holland safety and nature, in Zeeuws-Vlaanderen safety and recreation.

The philosophy behind the present policy is: "to stop coastal recession, but not at all locations and not at all costs. Where safety is at issue, coastal recession must at all times be brought to a halt".

Current policy only applies this approach to the most pressing problem areas.

In North Holland, near Callantssoog, countermeasures were taken in 1987.

Almost 2 million cubic metres of sand was nourished to the beach to guarantee the safety of the polders for several years and to protect the valuable nature reserve of Zwanenwater against the North Sea.



With the Retreat alternative, interests and values will sooner or later be buried under the sand of the foredune, as shown here, where some of the valuable nature areas of Texel island were lost.



3.4 Description of the policy alternatives

Within the limitations defined by the principles, a large number of alternatives may be formulated.

In the following paragraphs, four alternatives for the dune coast are described which offer a good impression of the choices for a national coastal defence policy.

3.4.1 Policy alternative Retreat

Policy aim

The aim is: to maintain Delta safety, no more and no less. Coastal recession is permissible up to the point where the dunes only just satisfy the safety standard, regardless of whether interests and values in the dune area are lost. This is the minimal response the Government can offer to its statutory responsibility. This strategy implies that the coastal morphology of the Netherlands will be mainly determined by the natural processes of accretion and erosion.

Technical measures

With the Retreat alternative, two situations take place concurrently, but at different locations: where there is no longer room for recession, the coast-line is "held", while at other locations the coastline is subject to "controlled retreat". Both situations demand specific measures.

Where the coastline must be held, measures are needed to resist further movement of the coastline in a landward direction. This is done by means of sand nourishments on the seaward side of the foredune. In addition, maintenance is still required. This consists of measures to hold the sand at the foot of the dune and maintenance of defence works such as groynes. With retreat, maintenance work is still needed, for example the backward elongation of groynes and supervision of the landward shift of the foredune. In addition, rearward nourishments may be necessary to keep the minimal reserves of the foredune intact.

Valuable nature areas are fully retained with the Selective Preservation alternative.



The "slufter" (wet dune-valley influenced by the tides) on Texel island.



3.4.2 Policy alternative Selective Preservation

Policy aim

The aim is: aside from maintaining Delta safety, to offer protection to the dune area where special interests and values are under threat by coastal erosion.

This aim meets the philosophy of current policy.

The alternative becomes definite when the interests and values that should be protected have been specified. Within Selective Preservation, many choices - variables - are possible.

The variable presented here is related to current policy, however it offers more protection of special natural values.

It concerns:

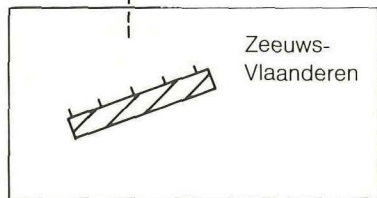
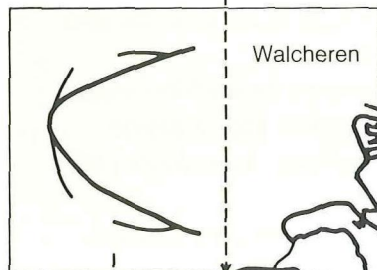
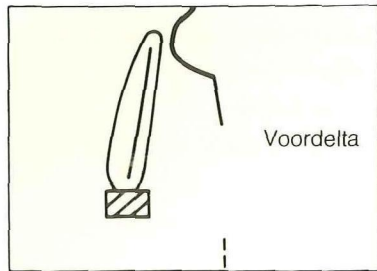
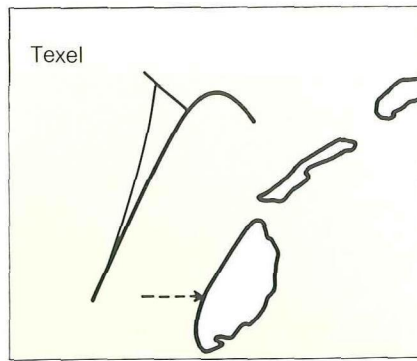
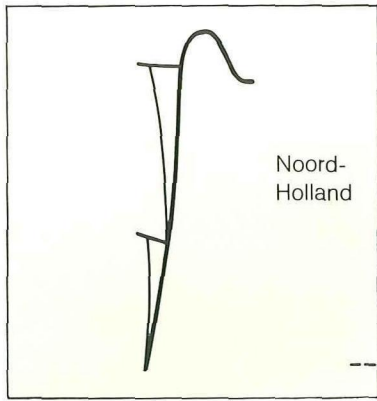
- guaranteeing the safety of the polders;
- protecting the residential concentrations in the dunes;
- protecting special natural values, such as dune swamps and heaths, dry shrub, woods or wet dune areas;
- protection of capital-intensive investments for drinking water supply: extraction wells, infiltration facilities and buildings;
- protection of areas with recreation facilities: bungalows parks and campings;
- protection of capital-intensive industrial areas, such as the Hoogovens company, near IJmuiden.

The analysis shows that the above variable represents the Selective Preservation alternative well.

At comparable price levels, other variables generally offer less protection to interests and values.

Technical measures

For Selective Preservation, the same problems are encountered with holding and retreating the coastline as are found with the Retreat alternative, and the same type of measure is required, i.e. sand nourishments and maintenance.



A preliminary technical study of the Expansion Seaward alternative for five different areas.

location/area	aim	technical realisation
Zeeuws-Vlaanderen	raise and fix the shoreface	build a 'hard' shoreface breakwater between the heads of the groynes; fill with sand
Walcheren	push tidal gullies away from the coast	build two breakwaters on the south side of Walcheren and two breakwaters on the north side
Schouwen Goeree and Voorne	reduce wave attack	artificially raise banks lying before the coast and promote natural accretion
tip of North Holland	push gully away from the coast; restrict transport along the coast. reduce dune erosion by widening beach	build two breakwaters at right angles to the coast-line: a long breakwater several kilometres south of Den Helder and a shorter one at Callantsoog; fill with sand
Texel island	limit sand transport along the tip of the island	build a breakwater at right angles to the coast; fill with sand.

3.4.3 Policy alternative Preservation

Policy aim

The aim is: all interests and values present in the dune area in 1990 should be protected against the consequences of coastal recession. The coastline is not permitted to recede at any location.

Technical measures

To realise this policy, measures are needed to combat erosion and maintain the coastline, in order to hold it in its present position. The type of measures required are already described for the Retreat alternative.

3.4.4 Policy alternative Expansion Seaward

Policy aim

The aim is: to reinforce weak coastal sectors and protect all interests and values in the dune area against the consequences of coastal recession.

At weak points accretion is stimulated. In this way, reserves will increase and new possibilities for nature and other interests are stimulated. At other locations, the coastline is maintained at its current position.

The weak sectors are considered to be:

- sectors that have little or no room to offset coastal recession;
- sectors undergoing marked erosion, where major interests and values are at stake.

This alternative differs essentially from previously proposed land reclamation projects such as between Hoek van Holland and Scheveningen and near IJmuiden. The Expansion Seaward alternative concentrates on eroding coastal areas; any land gained is only a byproduct of this aim. The land reclamation projects are planned in coastal sectors that are chosen specifically because they do not erode and where land reclamation is the objective. The Expansion Seaward alternative and possible land reclamation projects do not in fact influence each other, they can coexist.

policy alternative	aim	measures	
		counteracting erosion	maintenance 1)
RETREAT	only guarantees the safety of the polders	nourishment of seaward and landward sides	<ul style="list-style-type: none"> - recession/retreat of the foredune - extend/lower groynes + maintenance - maintain dune and beach
SELECTIVE PRESERVATION	protect specific interests/values + guarantee safety of the polders	nourishment of seaward and landward sides	<ul style="list-style-type: none"> - recession/retreat of the foredune - extend/lower groynes + maintenance - maintain dune and beach
PRESERVATION	protect all interests/values in the dune area + safety	nourishment of the seaward side	<ul style="list-style-type: none"> - maintenance of dune and beach (prevent sand drift) - maintain groynes
EXPANSION SEAWARD	reinforce weak/eroding coastal areas + protect all interests/values + safety	nourish on the seaward side; local hard construction	<ul style="list-style-type: none"> - maintenance : see preservation - maintain seaward extensions

The four policy alternatives for the dune coast as considered by this study.

1) Only those measures considered most important for managing the dunes as water barriers have been listed.

Technical measures

At weak locations along the coast, a totally different approach is used than with the other alternatives. Rather than compensating for coastal recession, the sea is approached by building works extending out from the existing coastline. These constructions should reduce the attack of the sea on the coast, or block currents causing erosion. The measures include hard constructions, particularly breakwaters. The processes determining coastal morphology differ from one place to another. Therefore, a uniform approach towards this policy alternative is not feasible.

A preliminary design has been drawn up for five locations. In Zeeuws-Vlaanderen, on Walcheren, on the islands behind the Voordelta: Schouwen, Goeree and Vorne, at the tip of North Holland and the northern point of Texel island.

The measures for the remainder of the dune coast agree with the Preservation alternative.

This Document is based on a phased realisation: prior to 2000, projects are carried out at locations where problems of safety may be anticipated in the short term. After that time - but prior to 2020 - the other projects will be carried out.

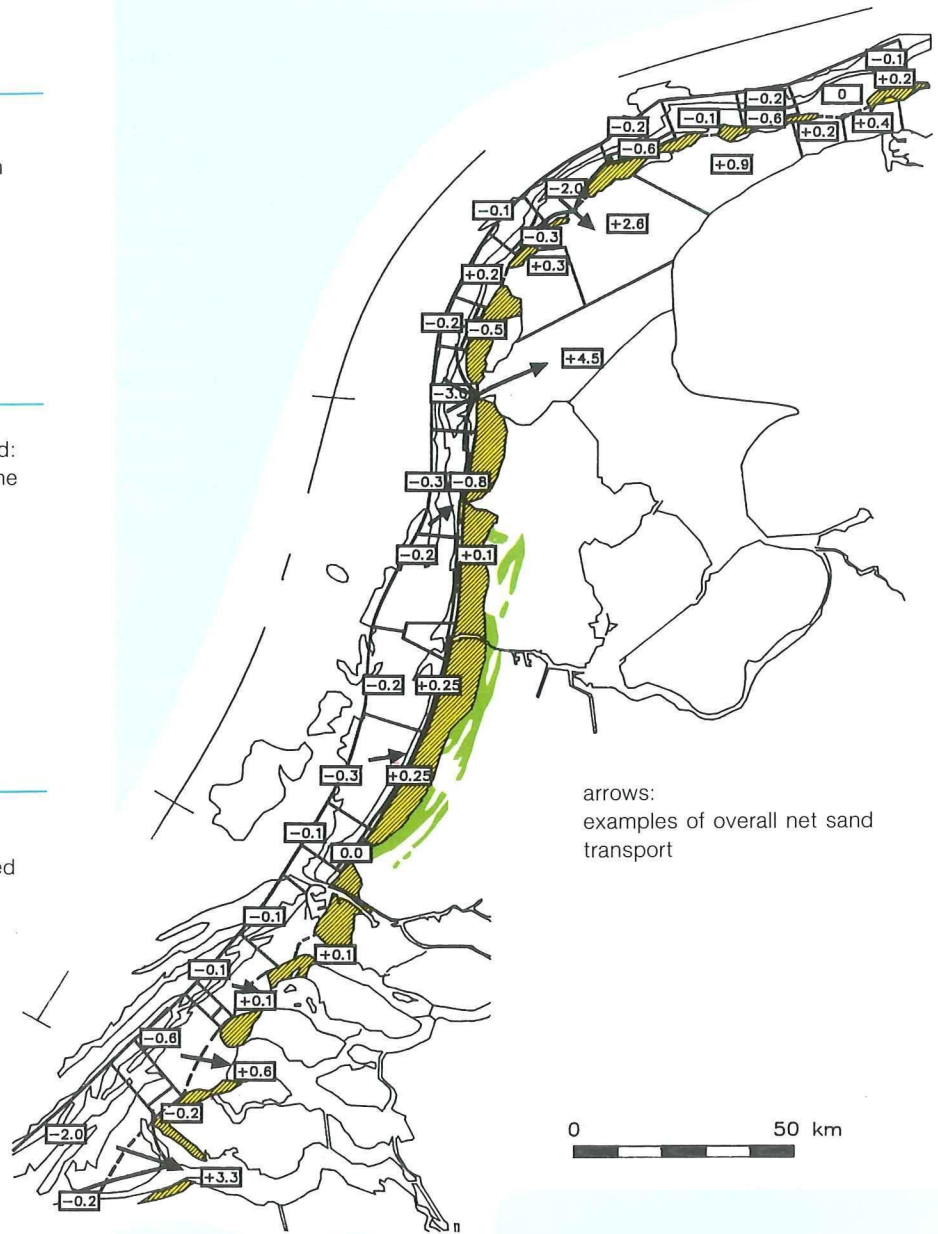
In principle, these measures for reinforcing weak locations could also be used in combination with other policy alternatives. Each of the five solutions described can be carried out separately.

The analysis results depend to a large extent on the prognosis for the position of the coast. This prognosis is based on new insights into the transport of sand alongside and at right angles to the coast, obtained as a result of the Coastal Genesis project.

the "natural" Wadden coast:
sand relinquished to the Wadden Sea

The "segmented" coast of Holland:
trapping of sand brought in by the sea

the "closed-off" Delta coast:
A surplus of sand in the oversized outer deltas



figures:
sand balance in millions of cubic metres per year, based on observations and on process modelling
(N.B. the figures shown on the coastline relate to the so-called active zone which is located between the crest of the first dune row and the 8 m depth contour)

4 Benefits and costs of the policy alternatives

This chapter intends to offer an insight into the benefits and costs of the four policy alternatives: Retreat, Selective Preservation, Preservation and Expansion Seaward. The benefits are: maintenance of the safety reserves and of the interests and values in the dune area. The costs include: the investments required for coastal maintenance and combating erosion.

The benefits and costs are not expressed in the same units, e.g. guilders. There is no single objective standard available to convert all the aspects involved into comparable values. This chapter only describes the analysis results for the present rate of a rise in sea level. The consequences of other scenarios will be dealt with in the next chapter.

4.1 Method of analysis

The analysis is based on predictions for coastal morphology over the period 1990-2090 and for dune erosion with a particular storm. In addition, geographical data have been collected and filed for the entire coastal area, e.g. the position of the limit profile, the width of the foredune and the location and character of interests and values.

The process of analysis divides the prediction period into a number of time zones. For each zone, the natural movement of the coastline is compared to the principles of the various policy alternatives. Where coastal defence is required in the interest of safety or to protect interests and values, measures will be introduced. The area lost as a consequence of coastal recession will be listed and the costs of countermeasures calculated, also taking into account sand quantities required for nourishment. The following is presented for each policy alternative: the number of kilometres of dune coast where coastal recession is combated, the number of kilometres with less than 10 metres of dune width allowance, the area losses in interests and values and the average annual costs of maintenance and combating erosion.




These analysis results offer a quantitative impression of the benefits and costs for each policy alternative. This chapter offers the results for the entire coast and for each of the three regions: Delta, Holland and Wadden.

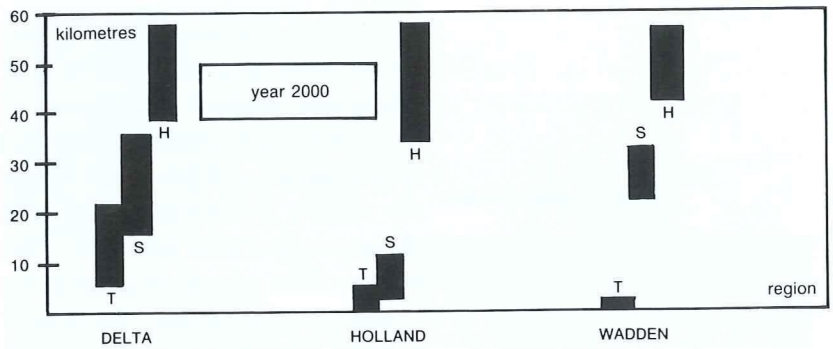
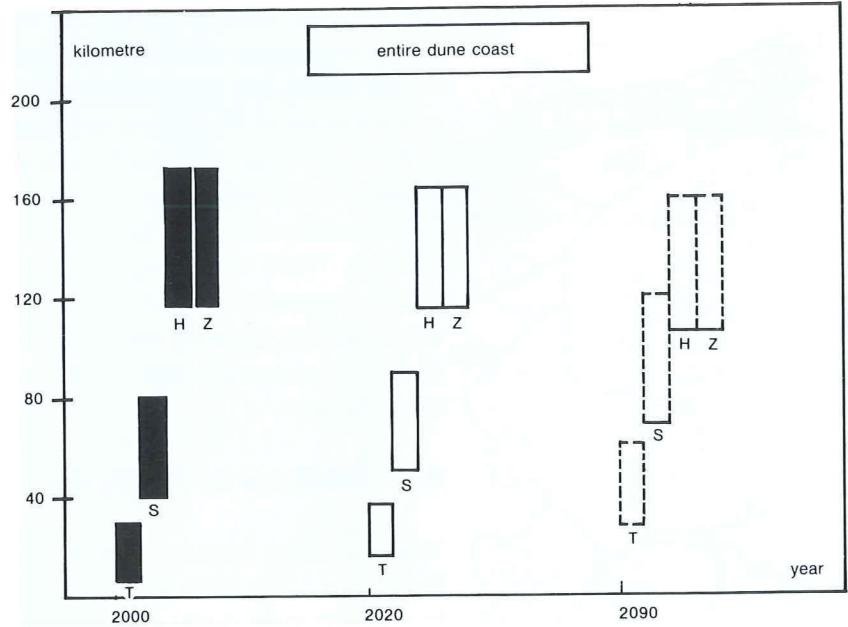
The number of kilometres where measures are taken to counteract coastal recession, in order to guarantee the safety and/or values and interests in the dune area. The distribution over the various regions is indicated for the year 2000.

T = Retreat
 S = Selective Preservation
 H = Preservation
 Z = Expansion Seaward

Although Preservation demands more measures to counter erosion than does Retreat, the differences will become less extreme in the long term.

Bar interpretation:

-  unfavourable prognosis
-  anticipated value
-  favourable prognosis



The factors determining coastal morphology are only known within certain limits. These limits introduce a degree of uncertainty into the prognosis of coastal morphology, affecting the overall analysis. In order to indicate this uncertainty in the analysis results, two values are always calculated for each factor: a favourable and an unfavourable value; the most probable value lies inbetween the two. For prognoses that look further into the future, the favourable and unfavourable values offer a less reliable reflection of the uncertainty limits. This is why the long-term results are shown as a broken line.

4.2 Scope of coastal defence efforts

The length of coastline where measures must be taken against coastal recession differs for each policy alternative. This length offers an insight into the coastal defence effort required for each alternative.

This value ranges from several to tens of kilometres with the Retreat alternative to about 140 kilometres with Preservation. For Retreat, only measures that uphold the safety of the polders are included. For Preservation, any form of recession, however small, must be combated. For Expansion Seaward, hard measures are used over tens of kilometres, in preference to sand nourishment. These measures are intended to stop coastal recession or convert the erosive process to one of accretion.

In the course of time, the number of measures used in Retreat and Selective Preservation show a rising trend. This is because these alternatives initially take advantage of the available dune allowance. The trend for Preservation shows a slight drop, based on the migration of sand bars lying before the coast, e.g. in the Voordelta and near Texel island. In time, these are expected to migrate closer to the coast. The sand stored in these sand bars can benefit the coast, also at locations where the coast is presently receding.

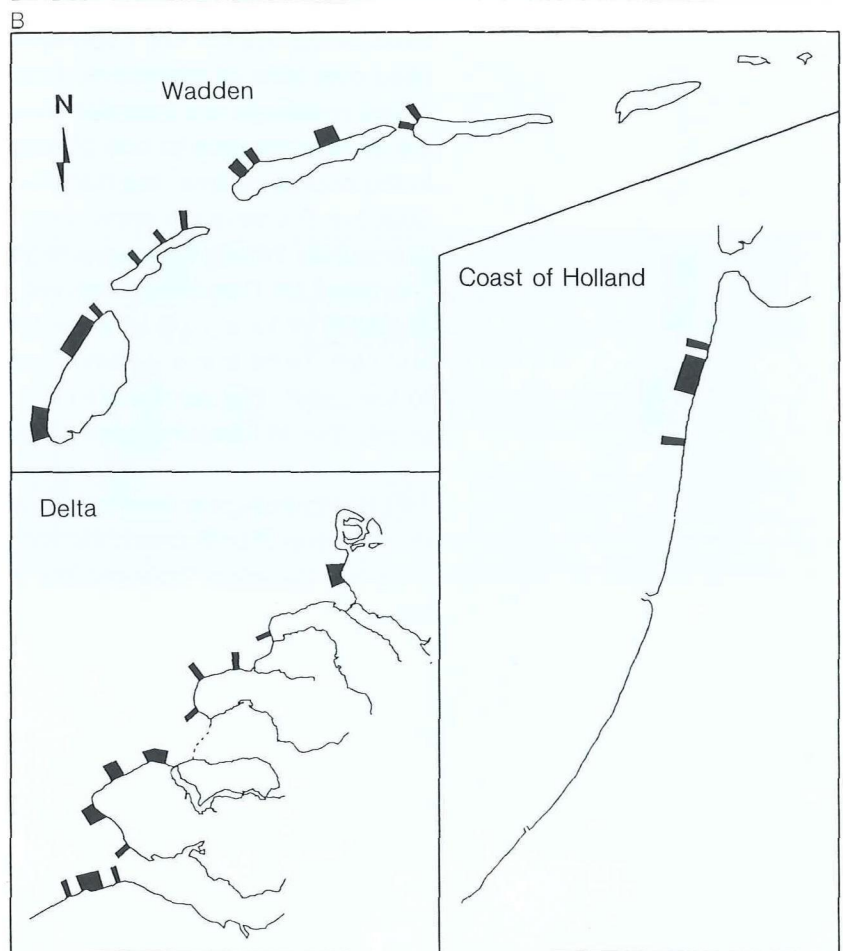
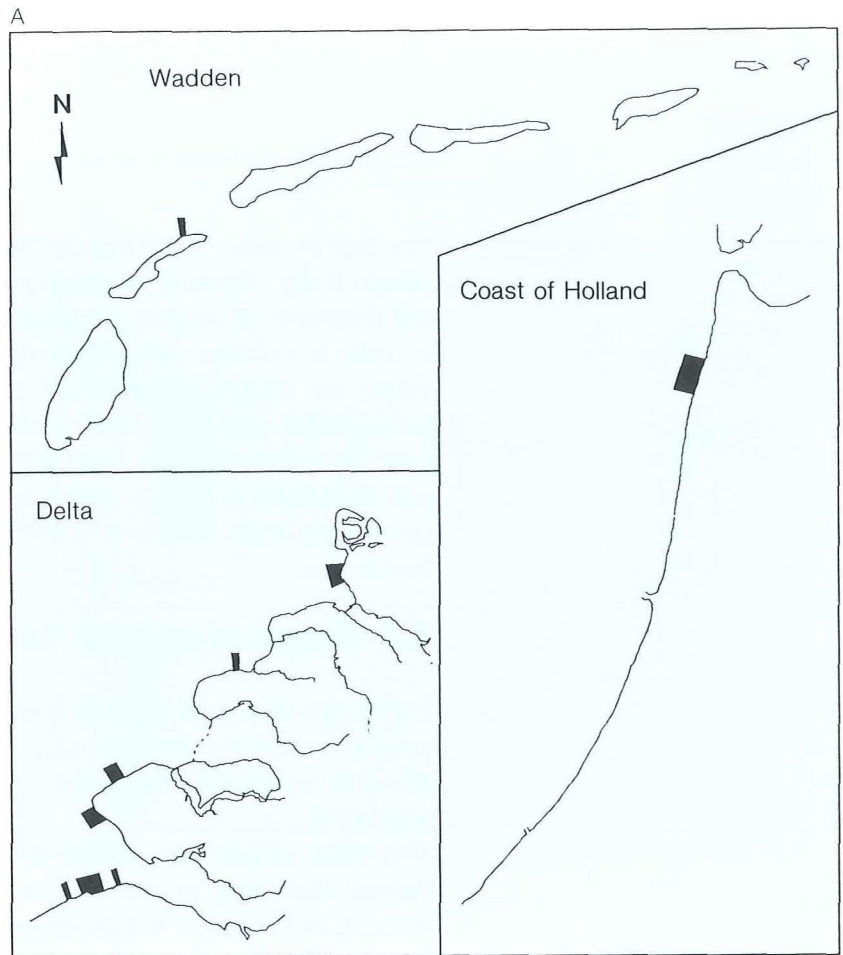
The distribution over the regions shows an even distribution for Preservation. For Retreat, the focus of activities lies in the Delta area. For Selective Preservation, the Wadden islands are added to this.

Locations along the coast where it is expected that measures against coastal recession (sand nourishment) will be necessary from 1990-2000, based on the current rate of the rise in sea level.

A: Retreat alternative

B: Selective Preservation alternative.

For the Preservation alternative, measures against coastal recession are necessary for all eroding coastal sections. These are shown on the satellite photo at the front of this report.



Aside from the dune coast considered here, the coastline is held at its present location over a length of 61 kilometres: 34 kilometres of sea dykes and 27 kilometres of remaining hard water barriers, such as boulevards. In order to maintain these hard constructions, measures must be taken from time to time to counteract erosion.

4.3 Benefits of coastal defence

The policy alternatives vary in the degree to which they offer protection to the dunes. Coastal recession leads to losses in interests and values. The smaller these losses, the greater the benefits of the policy alternative. A particular benefit relates to the length of the dune coastline where the dune width allowance is less than 10 metres. The shorter this length of coastline, the fewer the vulnerable points along the coast: there are more "safety reserves" to offer a buffer against recession.

Safety situation

All policy alternatives guarantee to uphold Delta safety. Any coastal recession that endangers this safety is combated, always and everywhere. For Retreat, all reserves currently available will be used up first. This will cause the dunes to change in appearance. They will take on the appearance of a "sand dyke". Familiar examples are the single row of dunes to the south of Den Helder, to the north of Hoek van Holland and at Walcheren and Zeeuws-Vlaanderen. This type of dune requires extreme vigilance, because any further recession is unacceptable.

The dune width allowance indicates at what point coastal recession threatens Delta safety. In 1990, over 40 kilometres of dunes have a dune width allowance of only 10 metres. With the Retreat option, this figure could increase by another 40 to 50% by the end of the next century. With Selective Preservation, the protection of interests and values is undertaken at an earlier stage. The number of kilometres of dune with minimal reserves will increase by about 24%. With Preservation, the situation as measured in 1990 will remain more or less unchanged. For the Expansion Seaward alternative, about 60% of the weak locations will be permanently reinforced by means of hard defence works.

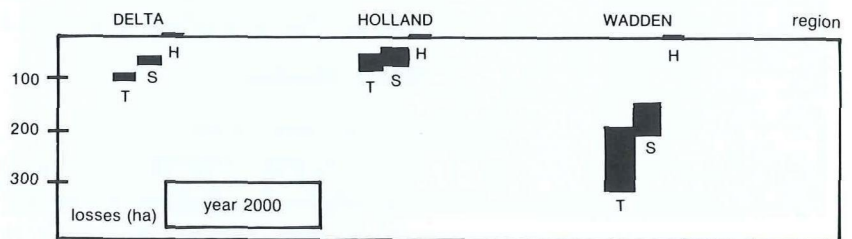
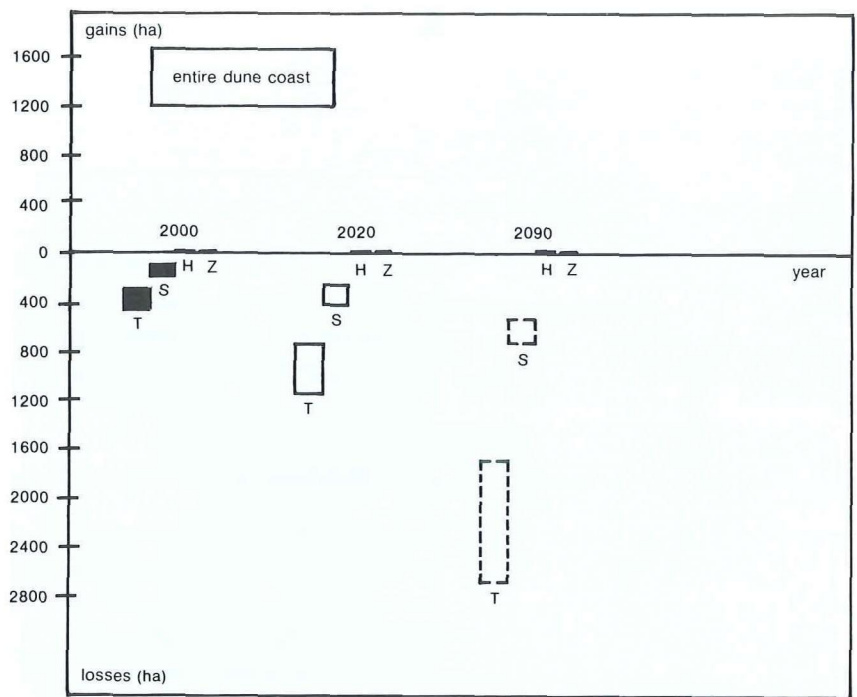
Losses of nature areas and the distribution over the regions for the year 2000.

With the Retreat alternative, losses are expected to rise to over 2000 hectares by the end of the next century.

T = Retreat
 S = Selective Preservation
 H = Preservation
 Z = Expansion Seaward

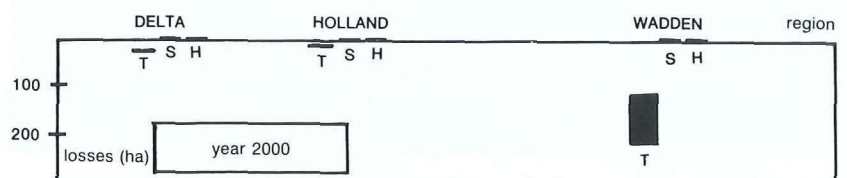
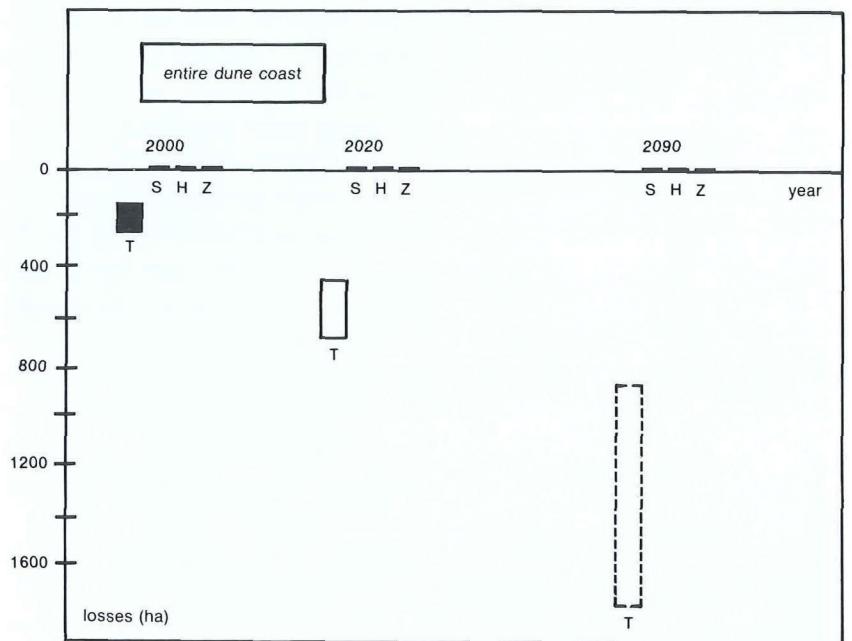
Bar interpretation:

--- favourable prognosis
 --- anticipated value
 --- unfavourable prognosis



Losses of specific nature areas: wet dune valleys and dune forests, and the distribution over the regions for the year 2000.

With Selective Preservation, special nature areas are protected against coastal recession.



Interests and values in the dune area

With Retreat, no measures are taken to protect interests and values against coastal recession: losses are the result. With Preservation and Expansion Seaward, all interests and values are protected. With Selective Preservation, only selected interests and values are maintained.

Total losses

The losses associated with Retreat will increase from several hundred hectares in the year 2000 to over 2000 hectares by the end of the next century. These losses are reduced by 50 to 70% in the case of Selective Preservation.

Natural values

In all cases, nature is at issue: the entire dune area has a natural value. About half of the area losses associated with Retreat affect special nature areas: wet dune valleys, dune woods, dune heath and the like. Selective Preservation will protect these values. The area losses presented only relate to the effects of "land loss" and "shift": natural values are relinquished to the sea or buried under the sand. Coastal recession also leads to side effects that may exacerbate this effect: the nature areas dry up due to a drop in ground water level. This effect is only seen in broad dune areas, particularly on the Wadden islands.

With Preservation, no losses are seen; with Expansion Seaward, opportunities are even created for the development of natural values.


Economic interests

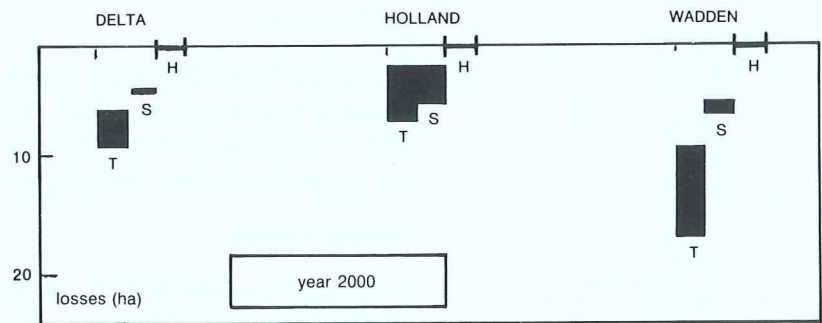
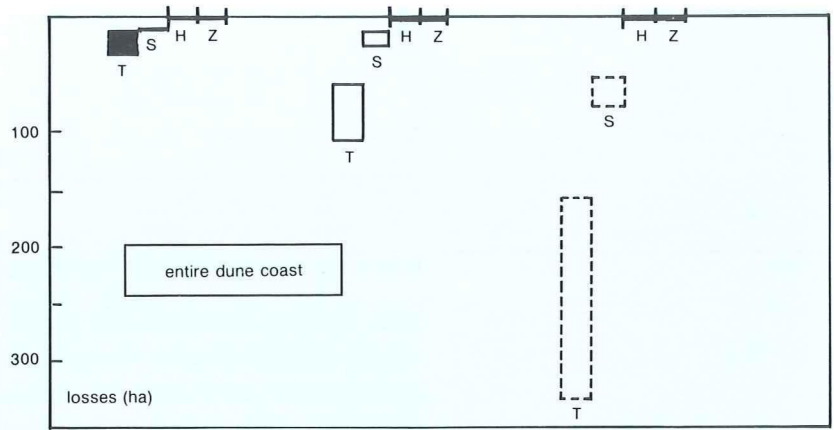
Economic interests are understood to include: drinking water supply, recreation, residential and industry in the dune area. These interests are usually situated behind the foredune. As the foredune still offers some reserves to offset gradual coastal recession at many locations, the problems that would arise once these reserves are depleted can often be postponed for several decades. Analysis shows that with Retreat, short-term losses are restricted to several tens of hectares at most.

Losses of drinking water supply areas and the distribution over the regions for the year 2000. The losses will only increase markedly in the long term.

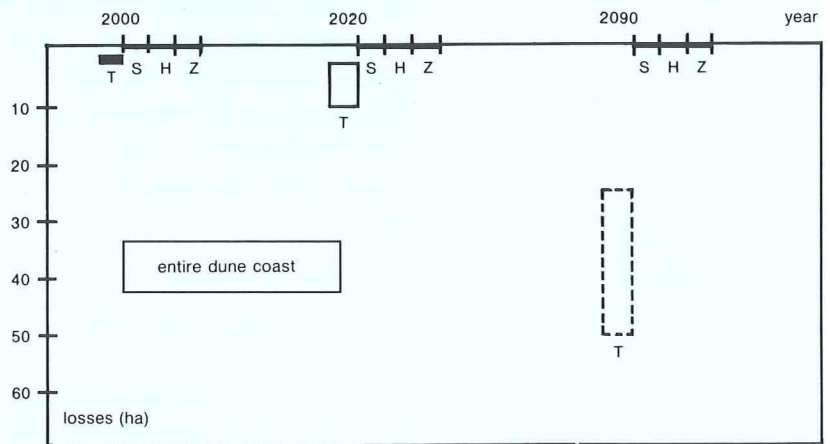
T = Retreat
 S = Selective Preservation
 H = Preservation
 Z = Expansion Seaward

Bar interpretation:

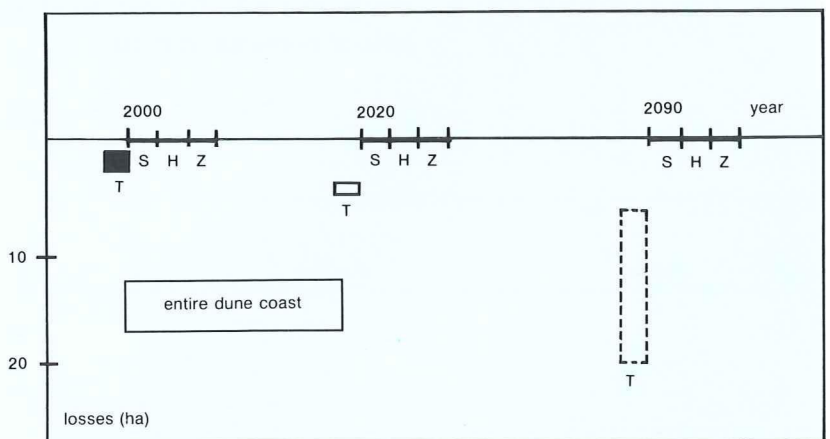

 favourable prognosis anticipated value
 unfavourable prognosis



Losses of dune recreation areas



Area losses of residential concentrations in the dunes.



In the long term, losses with the Retreat alternative will increase markedly: hundreds of hectares of drinking water supply area; several tens of hectares of residential and recreational area. The losses for industry will remain limited to a few hectares. With Selective Preservation, economic losses are largely avoided, although the drinking water supply will suffer somewhat: parts of the exploitation area must give way to the foredune.

For figures related to residential areas, only the losses of grouped buildings are represented: residential concentrations. Isolated houses threatened by coastal recession are found at many places in the dunes. Some are located in the foredune, where they are prone to greater risk of being washed away during storms.

4.4 Costs of coastal defence

A distinction is made between the total costs of coastal defence and the costs of combating erosion (part of the total costs). The latter is closely associated with the quantity of sand needed for nourishments. This aspect will be dealt with in brief, due to its relationship with sand extraction policy.

This paragraph outlines the costs as presented in the Discussion Document (May 1989). The calculations are based on the price level at the end of 1988. All costs are shown in Dutch guilders (1 guilder is approx. 0.5 US\$).

Total costs of coastal defence

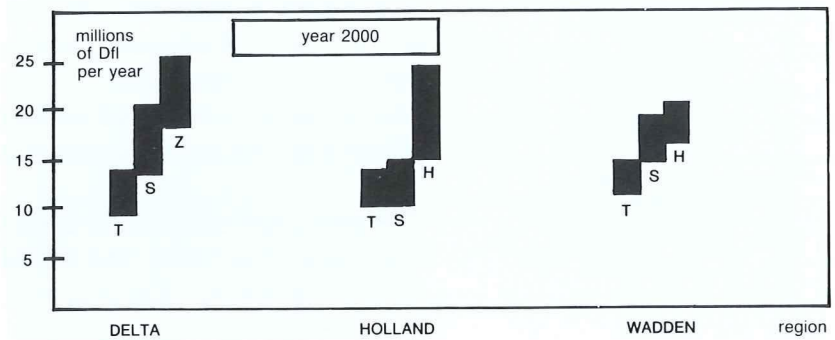
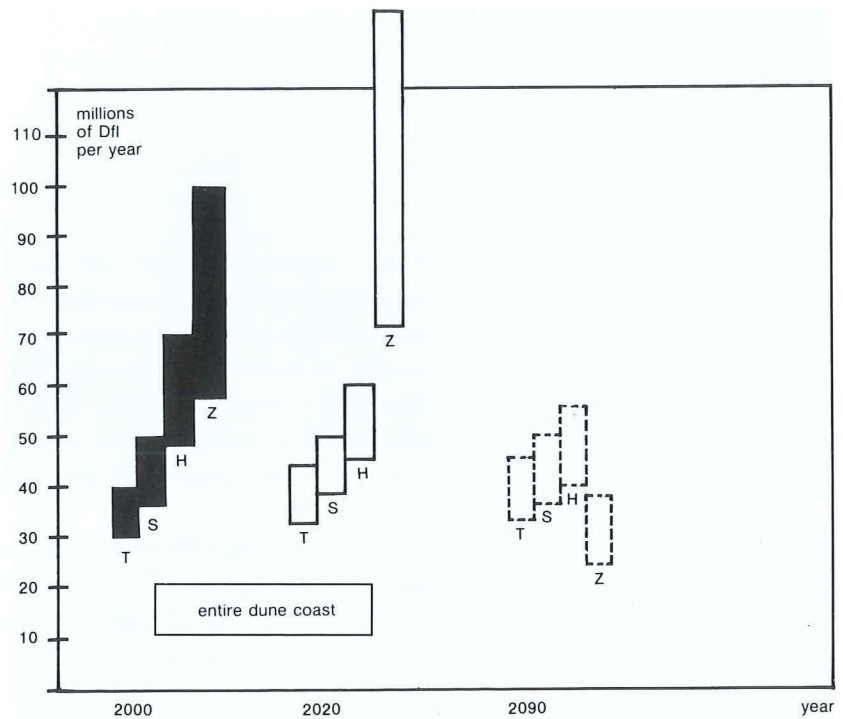
The annual costs of coastal defence vary from several tens of millions of guilders for Retreat to about 100 million guilders for Expansion Seaward.

In the short term, Retreat will cost about 35 million guilders per year: the safety of the polders is upheld and the coast is subject to "controlled retreat". Selective Preservation will cost about 45 million guilders in the short term: 10 million guilders per year more than for Retreat. This is used to protect valuable nature areas and user functions. To counteract any form of coastal recession, i.e. Preservation, will cost about 60 million guilders per year.

Extra reinforcement of weak locations - Expansion Seaward - will demand an annual sum of 80 to 100 million guilders in the next decades. This is due to the high costs demanded for construction: for the five projects combined, this is estimated at 1.3 thousand million guilders. These costs are calculated in the form of an annuity spread over 50 years, based on an interest rate of 5% of the annual costs.

Overall coastal defence costs (upkeep and counteracting erosion) for the entire coast and the distribution over the regions for the year 2000.

As costs associated with Retreat increase, those for Preservation will decrease; eventually the respective costs will level out.



Overview of the costs and savings for various projects within the Expansion Seaward alternative. These estimates are based on rough drafts.

Hard seaward measures are generally more expensive than sand nourishments repeated on a regular basis.

Only after depreciation can one speak of a financial return.

location of works	length of coastline (km)	construction costs (M Dfl/yr)	saving on upkeep and nourishment (M Dfl/yr)
1. Texel island	5	1-2	2
2. North Holland (tip)			
* first breakwater	9	19-40	3-5
* second breakwater	7	3-7	2-4
3. Voordelta (three islands)	10	6-12	5-7
4. Walcheren	23	16-33	4-6
5. Zeeuws-Vlaanderen	2	1	1
total	56	46-95	17-25

In time, the "safety reserves" will become depleted at an increasing number of locations, and erosion will have to be combated. The annual costs demanded for Retreat will therefore increase with time. The costs of Preservation show a downward trend. This is the result of the previously described phenomenon of landward migrating sand bars lying before the coast. In time, Retreat and Preservation will demand the same investment.

The costs for Selective Preservation lie somewhere between the costs for Retreat and Preservation, and will remain roughly stable over time.

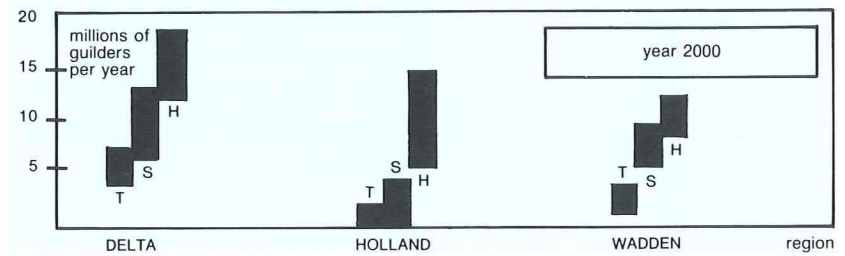
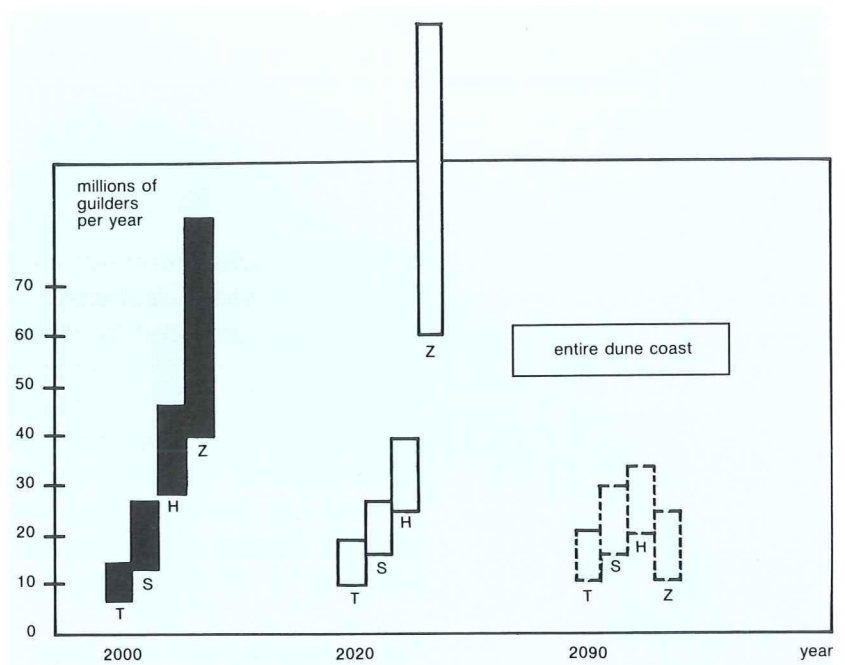
The costs associated with Expansion Seaward depend on the phasing of the works. A choice has been made from the many options available for realisation: those projects planned for locations where erosion poses the greatest threat to safety will be carried out before 2000; the remaining projects will be realised in the following twenty years. It will take until the second half of the next century for all the works to have depreciated; after this time, Expansion Seaward can offer a return in financial sense as well. Preservation of the coastline with nourishments and seaward constructions will then be cheaper than continuation of the Retreat alternative.

The Expansion Seaward alternative consists of five projects which can be carried out separately. In the table on the opposite page, the costs and savings during the depreciation period are compared for each project. The savings relate to a cutback in sand nourishments; the benefits of land reclamation are not taken into account.

The table shows that particularly those projects planned for the tip of North Holland and on Walcheren are fairly expensive. However, only a first draft of the projects has been made. A reliable estimation of costs and effectiveness requires further study.

The costs of combating erosion for the entire coastline and the distribution over the regions for the year 2000.

Over the years, the costs of combating erosion show the same trend as the overall coastal defence costs.



Overview of the principal benefits and costs of the four alternatives for coastal defence for the year 2000, at a 20 cm rise in sea level per century.

	POLICY ALTERNATIVES			
	T	S	H	Z
number of kilometres to maintain	20	60	140	140
loss of area with interests and values	350	150	-	-
total costs of coastal defence (M Dfl/year)	35	45	60	80
costs of combating erosion (M Dfl/year)	10	20	40	60

Costs of combating erosion

The annual costs of combating erosion in the year 2000 as calculated in 1989 are set at 10 million guilders for Retreat, about 20 million guilders for Selective Preservation, about 40 million guilders for Preservation and 60 million guilders for Expansion Seaward. For each policy alternative, the costs of combating erosion represent a different proportion of the overall costs. For the Retreat alternative, this proportion is about 30%, for Selective Preservation about 45% and for Preservation, 60%. The costs of combating erosion for the Expansion Seaward alternative are high when compared with the other three options: about 75%. The difference is due to the construction costs for the works associated with this alternative.

The course in time for the costs of combating erosion almost matches that for the total costs. The reason for this is that maintenance costs - the difference between the total costs and the costs of combating erosion - are at an almost constant level of about 25 million guilders for all the policy alternatives. This relates to the entire coast and all coastal types. Maintenance of the dune coast with Preservation is several millions of guilders cheaper than with Retreat: sand nourishment can offer savings in the maintenance of groynes and pile groynes.

Volumes of sand

The amount of sand required annually for combating erosion of the dune coast in the short term will increase from almost 2 million cubic metres for the Retreat alternative, through about 5 million for Selective Preservation and about 8 million cubic metres for Preservation.

The long-term trends are identical to those for the already mentioned costs for combating erosion and the total costs: more sand is needed for Retreat, less for Preservation.

4.5 Summary for the year 2000

The estimation of the consequences of the four alternatives for the next decade are summarised in the opposite table. Here too, the costs are reproduced as calculated for the Discussion Document (1989).

Scenarios for the rise in sea level

The current scenario:	0.2 metre per century. This is the rate measured at present.
The anticipated scenario:	0.6 metre per century. This is the rate expected on the basis of the latest insights.
The unfavourable scenario:	0.85 metre per century. This scenario also takes into account unfavourable developments in wind and wave climate. The wind-force will increase by 10% and the wave height by 8%. The wind and wave direction will shift 10 degrees.

With an unfavourable climate development, where aside from a more rapid rise in sea level the wave attack on the coast will also intensify, the consequences will be far greater than with an accelerated rise in sea level alone.

The increase in several factors at higher rates of sea level rise (60 and 85 cm/century) measured as a percentage with respect to the scenario for a 20 cm rise in sea level. The values are differentiated according to policy alternative and year.

T = Retreat
S = Selective Preservation
H = Preservation

year (rise)	percentile increase in			
	number of km to maintain	cost of combating erosion	total costs for coastal defence	area losses
2000 (60 cm)				
T	45	25	10	20
S	35	20	10	25
H	40	25	15	-
2000 (85 cm)				
T	80	100	55	70
S	65	80	60	80
H	75	80	65	-
2020 (60 cm)				
T	30	25	10	20
S	35	25	15	30
H	60	30	20	-
2020 (85 cm)				
T	85	100	25	75
S	80	90	35	90
H	95	100	30	-
2090 (60 cm)				
T	60	40	10	25
S	40	45	10	25
H	40	30	10	-
2090 (85 cm)				
T	105	160	30	80
S	80	145	45	75
H	75	120	50	-

5 Rise in sea level

In the previous chapter, the four coastal defence alternatives were presented alongside each other for the scenario of a 20 cm rise in sea level per century.

However, it is anticipated that the rate of a rise in sea level will increase in the next century. This will have consequences for coastal defence, which must be taken into account when comparing the alternatives.

This chapter presents the consequences of an accelerated rise in sea level for the coastal defence alternatives. For the alternatives Retreat, Selective Preservation and Preservation, these consequences have been calculated. For the Expansion Seaward alternative, only a rough estimation is offered. In addition, the consequences of a more rapid rise in sea level for the sea dykes and other hard water barriers are dealt with.

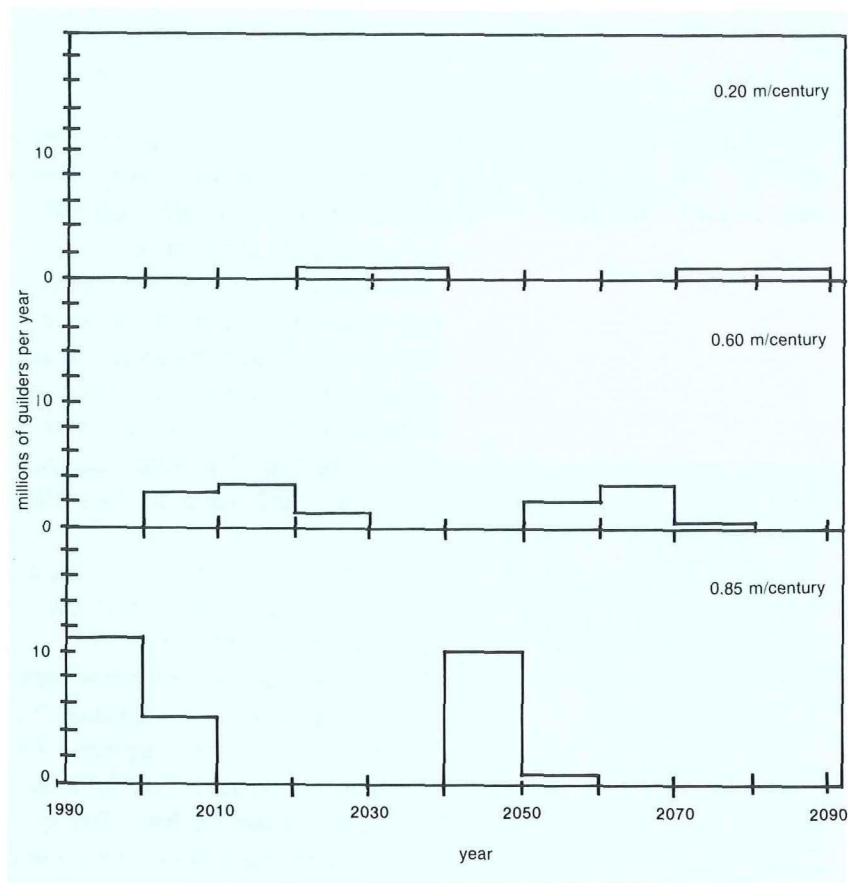
An increase in the rate of a rise in sea level results in further recession of the dune coast, causing more losses and requiring greater defence efforts.

As a consequence of a more rapid rise in sea level, the number of kilometres where the coastline must be held will increase. In comparison with the scenario for a 20 cm rise per century, this increase will be about 40% for all alternatives with the scenario for a 60 cm rise per century. The increase in costs for combating erosion and the added area losses as a consequence of recession of the coastline and the foredune both amount to about 25%. The differences in the percentages between the alternatives are limited and will also change little in time. The increase in costs is less than the increase in the number of kilometres of coast that must be held. The reason for this is that the rate of coastal recession as a consequence of a further rise in sea level will only increase to a limited extent. The most important efforts required to combat erosion therefore remain concentrated on those areas of the coast that would also erode at a low rate of sea level rise.

With an increase in the rise in sea level to 85 cm per century, the differences with respect to the scenario of 20 cm per century will increase even further. The greatest increase is attributable to the different wave climate on the North Sea, a factor which has been included in the unfavourable scenario for a rise in sea level.

If the rise in sea level should accelerate to 60 cm per century, the crest of sea dykes and other barrier constructions will have to be raised after the year 2000 for a period of approx. 30 years. At a rise in sea level of 85 cm per century, the crests will have to be raised even prior to that time.

Cost of raising crests of sea dykes and other barrier constructions in millions of guilders per year, estimated for the three scenarios of a rise in sea level.



The difference in average wave height and the angle at which waves attack the coast seem to influence the rate of erosion and the costs of combating erosion to a far greater extent than the rise in sea level alone. The possibility of a change in wave patterns as a consequence of a change in climate is uncertain. This aspect demands further study.

The Expansion Seaward alternative is less sensitive to an unfavourable development of a rise in sea level and wave climate than the other alternatives. The seaward constructions are mainly based on hard elements, designed to withstand less favourable conditions.

As a consequence of a rise in sea level, the hard water barriers such as sea dykes and the like must be adapted at regular intervals to continue to guarantee Delta safety.

This mainly requires raising the crests. Such adaptations will be required sooner if the rise in sea level accelerates, but will also be more extensive than with the scenario for a 20 cm rise per century. The total costs of raising the crests over the entire period from 1990 to 2090 will be about 140 million guilders at the rate of a 60 cm rise in sea level; a difference of 110 million compared to the scenario for a 20 cm rise per century. For a 85 cm rise per century, the costs will be about 270 million. Expressed as an annual figure, this amounts to between one and ten million guilders per year.

In summary, it would appear that with the anticipated developments in climate and sea level rise, the consequences for coastal recession and defence costs are limited in scope. However, with a less favourable development, considerable consequences may ensue. With the Retreat alternative, the safety reserves in the dunes will be depleted sooner. The point in time when coastal recession must be brought to a standstill everywhere for the sake of safety will also be brought forward. This means that the cost levels for Retreat and Preservation will sooner begin to approach each other.

6 Policy choice of the government

6.1 Principles

Defending the North Sea coast means: control of the water barriers and care for the location of the coastline.

The control of the water barriers is in principle the responsibility of large Water Boards with considerable resources. The Wadden islands form an exception; here, the State is responsible for the primary water barriers.

The processes which determine the location of the coastline exceed the responsibility of the Water Boards. The care for the location of the coastline is therefore the task of the State.

To preserve the location of the present coastline is the central theme of this Document. Protection against flooding of the low polders is regarded as a minimum policy requirement. This safety, achieved with the completion of the Delta works, must be maintained under all circumstances.

Aside from the safety of the polders, protection of the interests in the dunes is also important. The question here is to what degree these interests should be defended. In answering this question, four alternatives have been considered for the dune coast.

- I Retreat. In principle, coastal erosion is accepted. Only where erosive processes pose a threat to the safety of the polders behind the dunes will coastal recession be combated.
- II Selective Preservation. Aside from those locations where the safety of the polders is endangered, a number of locations where major interests in the dunes or on the beach are threatened will be protected against coastal recession.
- III Preservation. The coastline is maintained everywhere at its current position.
- IV Expansion Seaward. At some markedly eroded and relatively weak locations, constructions extending into the sea will be built. This should reverse the receding movement of the coast at that location, allowing it to advance. Elsewhere, the coast is maintained at its current position.

The Government based its policy choice on a 20 cm rise in sea level for the next century.

The extra costs which may be associated with a more rapid rise in sea level were not considered.

However, the possibility of an accelerated rise in sea level was taken into account in the decision-making process.

New user potential and natural areas created as a byproduct of the Expansion Seaward alternative?



6.2 Choice

In making a policy choice, the Government takes the view that coastal defence is of great importance for the sustainable development of Dutch society.

In the first place, the safety of the low polders must be guaranteed, also in the long term. Further recession of the coast would imply that a strip of dunes would be lost at a number of locations along the coast. This strip will be needed at a later stage to provide a barrier against a rising sea.

In the second place, it concerns the preservation of the dunes, as they serve an important function in the development of society.

How this care for the coastline is actually expressed determines the quality of the natural dune coast in the long term.

The choice has been prepared in close collaboration with representatives from the Inter Provincial Consultation body and with representatives from the Water Board Association. In addition, the Government has considered the recommendations and suggestions offered by a number of advisory bodies.

These consultations and recommendations express a unanimous preference for holding the coastline at its present location.

Based on the principles, the recommendations and the discussions on this matter, the Government has decided that coastal recession must be stopped. It has elected for enduring preservation of safety and for sustainable preservation of the functions and values in the dune area.

The choice in favour of the Preservation alternative means that the coastline will be held at least at the location as measured in 1990.

Where the coast consists of dykes or boulevards, it speaks for itself that "Preservation" will always mean maintenance at the current location.

Where the coast consists of dunes, this is not always as self-evident.

The choice for the Preservation alternative demands a balance between the might of the sea and the efforts society is prepared to make for coastal protection. This balance should affect the coast as a whole, but also particular coastal sectors. The efforts needed to ensure this balance should not be greater than necessary.

In time, it may become apparent that at some locations the position of the coastline can be held with less effort if the coastline is allowed some degree of flexibility. At these locations it may be decided - after discussion in the Provincial Consultative Bodies - to "shift" the coastline to some extent.

Sand-drifts and the formation of "sluflters" enhance the natural dynamics of the dune area.



Sand nourishments form the basis of the fight against erosion.



In some cases, this may imply a slight landward shift. Of course, the social value of the strip of dune sacrificed to such a shift may impose restrictions on the degree of movement allowed. Sometimes, a seaward shift of the coastline will be desirable. The approach of the Expansion Seaward alternative is likely to offer a solution here. In order to gain greater insight into these possibilities, plans will be worked out for the two smallest projects referred to in Chapter 3: Texel and Zeeuws-Vlaanderen. Based on the results of these projects, a decision can be made at a later stage to realise larger seaward coastal defence projects.

The coastline of a dune coast is inherently flexible to some degree, in response to the varying forces exerted by the sea. Some room should be allowed for movement of the coastline. Where such an allowance is available, the coast can be defended efficiently. This means that the coastline must be maintained within certain boundaries. Of course, the use of the dunes and of the beach may limit these boundaries at some locations. These boundaries will be set after consultation within the Provincial Consultative Bodies. Considerable freedom of movement can be permitted at the extremes of most Wadden islands. Strictly speaking, only the coastal sectors where residential areas or polders are located behind the dunes should be maintained. At most outer ends of the islands, natural movement can be permitted, with the proviso that the islands should continue to exist as a whole.

Where natural movement of the coastline is permitted, the dune front will also show some movement. This fits in well with the dynamic management demanded by nature conservation organisations. At a number of locations, such movement may be allowed to go even further, by allowing a certain amount of sand drift in the dunes or even the formation of a "slufter". The Provincial Consultative Bodies must consider whether the safety and protection of interests in the dunes offer enough leeway for further dynamic movement.

The Government believes that the choice for the Preservation alternative contributes to the sustainable development of Dutch society. By lending the Preservation alternative a certain degree of dynamics, the charm and quality of the natural dune coast is permitted to continue far into the future.

The choice for sand nourishments as the major means to defend the coast is entirely in line with this philosophy. The Government believes that Preservation should therefore be more specifically defined as "Dynamic Preservation".

The imminent danger to buildings may be extremely great. This is illustrated by these photos taken at Egmond aan Zee, in North Holland.



6.3 Considerations

In realising a new policy for the defence of the North Sea coast in the coming decades, the Government has been guided by a general assessment of the coast and the care for the location of the coastline. The following have been given special consideration:

- enduring preservation of safety
- sustainable preservation of the dune area
- administrative aspects
- costs of coastal defence

6.3.1 Enduring preservation of safety

From early days, coastal protection has been intended to defend the country against flooding. By maintaining a strong and reliable water defence, the conditions for sustainable development of the Netherlands and Dutch society were created. Over the centuries, these conditions have been further defined by society. The most recent emphasis was based on the recommendation of the Delta Commission. Since then, terms such as "Delta safety" and "Delta standard" have come into common usage.

Virtually the entire coastline, with its dykes and dune areas, satisfies the Delta standards set by Government and Parliament. These standards have been laid down in the Water Defence Bill. Delta safety represents the principle on which coastal defence policy is based.

The Government is aware that the long term morphological prognosis cannot be specified exactly, and concludes that the different prognoses offer a varied picture of the location of the coastline in the next century.

The Government expects that, as a result of the greenhouse effect, the rise in sea level will accelerate. The pressure on coastal defence will therefore increase. This effect may even be enhanced by changes in storm direction and storm frequency.

Dykes have no reserves to respond to a more rapid rise in sea level. Narrow dunes have a very limited reserve. Here, any form of erosion must be combated to uphold the safety level. Good upkeep of the water defences, in order to maintain safety, is essential. However, in broader dune areas where some reserves are available, the safety of the polderland is not directly threatened by ongoing erosion.



Aside from coastal defence, the dunes harbour the following functions: nature a), recreation b), industry c), drinking water supply d), residential e). Beach access ways and footpaths f) are also found in the dune area.

Where the dunes provide a defence against the sea, the continued safety of the polders is determined to a large extent by the size of the dune width allowance. The Government believes that the reserves calculated for some dune areas should not be reduced any further at this point. Based on this view-point, the only choice remaining is for the alternatives that would maintain these reserves: Preservation or Expansion Seaward.

6.3.2 Sustainable preservation of the dune area

In the discussion on a new coastal defence policy, an important issue was to decide to what extent further recession of the dune areas was justified.

The Government believes that the dune areas, like the rest of the Netherlands, should be offered sufficient protection against erosion by the sea. Alternatives which result in irreversible losses in dune area, such as Retreat and Selective Preservation, are in conflict with the principle of sustainable development.

Where the dune allowance is sufficient, natural processes in the dune area, such as sand drift, can contribute to the development of natural values.

It is important for the coastal defence works to respond to the dynamic character of the coast, in order to allow sustainable development of the dunes. Maintenance of the coastline by sand nourishment is the best method to effect this aim.

Locally, a seaward shift of the coastline can supplement this dynamic approach.

Aside from their function as a natural water barrier, a large proportion of the dunes also serves a function as nature area and, to a lesser extent, as an area for drinking water supply, residential, industrial and recreational functions.

A considerable part of this nature area is extremely valuable, due to its wet dune vallies and dune woods. That is another reason why the Nature Conservation Plan attributes so much importance to the dune area, and further development of their natural values has been announced. The dunes represent an important part of the principal ecology in the Netherlands. Here, natural values must be stimulated through a flexible management policy. This is also laid down by the Nature Conservation policy of the Government.

The dune area is of great importance for the drinking water supply. At various locations, the supply in the dunes can hardly meet the demand. Cutting back on the area available for drinking water supply as a consequence of coastal recession will lead to problems.

Where the coast is receding, buildings formerly situated behind the foredune come to lie close to the foot of the dunes. Deliberately allowing buildings to be lost to the erosive processes will continue to elicit strong social resistance.



	Retreat	Selective Preservation	Preservation	Expansion Seaward
Costs of maintaining the coastline	20	35	60	75
Upkeep of water barriers and existing coastal defence works	25	25	20	20
Total costs of coastal works	45	60	80	95

Costs in millions of guilders per year (price level 1989).
(1 Dfl is approx. 0.5 US \$ [1989 exchange rate])

The dune area harbours residential concentrations and a number of industrial areas, representing a great social and economical value.

In the choice of a coastal defence policy, the beach-related interests have also been considered. In particular, tourist areas which benefit from a spacious beach. At locations where the coast is eroding, the part of the beach that will not be inundated during flood tide will become narrower.

With the alternatives Preservation and Expansion Seaward, the beach will generally be wider than with those alternatives where the coastline is allowed to recede.

The Government believes that with a sufficient beach width at certain locations, it is possible to stop recreational pressure spreading to vulnerable parts of the dune area or to beaches and dunes which should maintain their extensive recreational character. From this viewpoint also, a choice for at least the Preservation alternative is desirable.

6.3.3 Administrative aspects

A choice for Retreat or Selective Preservation demands permanent administrative attention and will lead to a greater burden on administration.

With these alternatives, the primary water barriers will be located at the most landward position in the dune area. In broad dune areas, a strip that may be lost as a result of erosion, would be reserved in front of the primary water barrier.

To define such a strip, seaward of the water defence line, will elicit great social resistance. It will be difficult, particularly at a local level, to define a "sacrificial" strip within the municipal physical planning schemes. In addition, every time a valuable area or object is under threat, discussions on this matter will flare up again.

Therefore, the Government doubts the administrative feasibility of the Retreat and Selective Preservation alternatives. From the point of view of administration, it prefers to at least preserve the present coastline.

6.3.4 Costs of coastal defence

The annual costs of coastal defence in 1990 (at the time of publication of the Policy Choice Document) are estimated as shown in the table opposite.

The difference with the costing as presented in Chapter 4 is mainly the consequence of an adapted (more cautious and expensive) sand extraction policy, an increase in prices on the dredging market and an intensification of the coastal research and monitoring programme.

Collaboration within the provincial consultative bodies

The Water Defence Bill specifies that the State shall work together with the Provincial Authorities and Water Boards in an effort to effect joint coastal defence. This collaboration is expressed by the so-called Provincial Consultative Bodies. Each authority assumes a different role:

- the Water Board is responsible for statutory administration and upkeep of sea defences;

- the State is responsible for the position of the coastline;

- the Provincial Authorities coordinate overall regional policy in relation to aspects of physical planning.

Water Boards are public bodies, specifically created to maintain the dykes and other sea defences and take care of water control and water quality at a local level. They may also assume responsibility for roads and waterways. The interested parties (local real estate owners) select the administrators of the Water Board through a democratic process. The Water Board imposes taxes to raise the funds necessary to perform its tasks.

The Netherlands has about 130 Water Boards (situation in 1990).

Together, they employ some 6000 people.

On the Wadden islands, the State bears responsibility for upkeep of the defences facing the North Sea. In this case, it also assumes the task of the Water Board.

At a national level, the Rijkswaterstaat (Public Works Department) of the Ministry of Transport and Public Works is responsible for the preservation of the coastline. The Public Works Department has about 20 Divisions. It has its own regional office in all provincial capitals to take care of local civil and hydraulic engineering works, insofar these form part of the task of the State. In addition, the Public Works Department has a number of specialised divisions to conduct research and provide advice on specific areas. The Public Works Department employs about 10,000 people in total.

Of the twelve Dutch provinces, five are directly concerned with coastal policy: Groningen, Friesland, North Holland, South Holland and Zeeland. The provincial authorities are charged with the chairmanship of the Provincial Consultative Bodies and coordinate policy between the State, Provinces and Water Boards. These bodies deal with all matters relevant to preservation of the coast, including the fight against erosion.

In consideration of the interests at stake, the Government considers the differences in costs to be relatively minor. Delta safety is upheld with all alternatives, although with Retreat and Selective Preservation doubts still exist about safety in the long term. When assessing the differences in costs, it is important to consider to what degree the dunes and the interests they harbour are protected.

A difficult aspect in the assessment is that the value of the dune area itself cannot be expressed in monetary terms. Even the costs of a fictional restoration of the lost dune in another location would be greater than the difference in costs between Retreat and Preservation. The financial value of those interests that would be lost, both with respect to economic activity and the buildings and areas themselves, is not even taken into account in this regard. In the long term, the maintenance of safety would seem cheapest with the choice for the Preservation alternative.

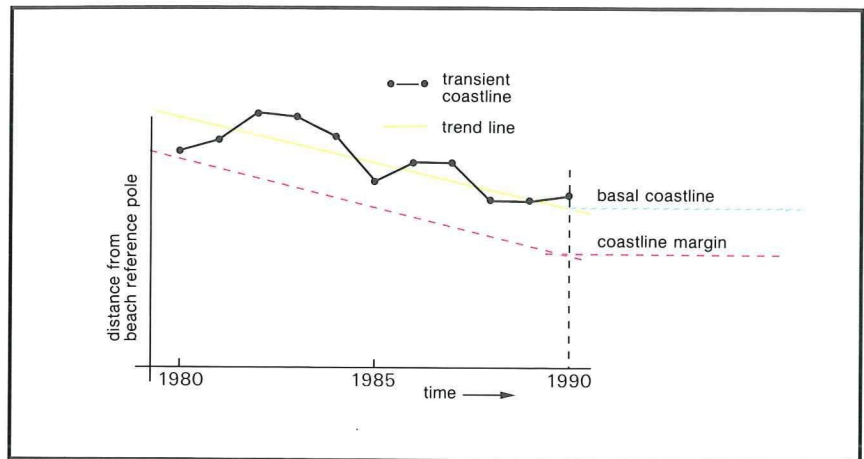
Of particular importance in the assessment is the development of the costs in the long term. A choice for the Retreat alternative, and to a lesser extent for Selective Preservation, would in the short term lead to financial savings. However, in time the costs would rise as an increasingly larger area of the coast must be protected against further recession. Eventually, the entire North Sea coast will need to be preserved. As reserves will no longer be present to offset the continuing rise in sea level, continuous reinforcement of the dune water defences will be necessary.

The short-term costs increase from Retreat, through Selective Preservation to Expansion Seaward. In the long term, simply maintaining safety is cheaper if the Preservation alternative is chosen now. To opt for this alternative now will eliminate the concern for safety that is still present with the choice for Retreat or Selective Preservation. By choosing the option of Preservation today, thousands of hectares of valuable dune area will be saved. Finally, the interests related to beach recreation would benefit from such a choice.

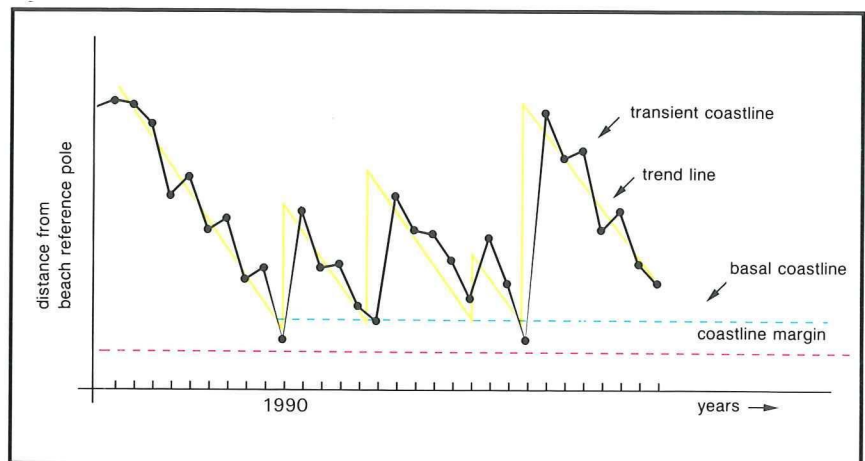
The Government has come to the conclusion that Preservation should be chosen today, as the interests that are associated with a sustainable development of Dutch society are so great that they should not be sacrificed for the benefit of a cost saving of some tens of millions of guilders in the coming years.

The Government knows that its viewpoint is shared by the statements of a number of advisory bodies. One of these recommendations states: "what is worth saving, should not be lost in the interim".

The transient coastline is found at a different location every year. The basal coastline is determined from the trend line, which is derived from the the transient coastlines measured in previous years. The basal coastline is fixed at the position of the trend line for 1990. If the position of the transient coastline for 1990 was taken, chance would play too great a role in establishing the basal coastline.



Structural erosion is combated by sand nourishment. This is generally performed when the trend line exceeds the basal coastline, but may take place even sooner. The landward boundary of the margin represents the outer limit: if this is exceeded, nourishment must definitely be carried out.



6.4 Realisation of the choice

6.4.1 The coastline

At locations where the water barrier is represented by a dyke, the location of the coastline is clear: the low water level measured at the dyke.

If erosion at the foot of the dyke endangers the stability of the sea defences so markedly that the polders are under threat, such erosion will always be combated. "Preservation" implies preservation at the location where the dyke is presently located.

For the dune coast, Preservation demands a more subtle approach, in response to its natural character.

The location of the coastline at the dune coast varies, both in time and in space. This is due to the recent history of storms and to the sand waves that may or may not enhance each other at a particular location.

The choice to preserve the coastline at its location in 1990 is therefore not based on one single measurement of the coast, but is based on preserving the "average coastline" at the level in 1990. This line forms the basis for realisation of coastal policy and is known as the "Basal coastline".

At several locations it may prove desirable to shift the Basal coastline somewhat with respect to the coastline as measured for 1990. This could be in both a landward and a seaward direction. Such a shift is only acceptable if the coastline can then be preserved with less effort. A shift can only be accepted if there are no important interests of a technical, financial or social nature opposing such a shift. These interests should be determined in proper consultation with the parties involved.

From the position of the transient coastline in past years, the "Trend line" is derived. Around the Basal coastline, a margin is defined within which the transient location of the coastline may vary without actually demanding that structural erosion be combated. When the Trend line crosses the Basal coastline however, structural erosion of the water barriers will be actively combated, generally by means of sand nourishments. This will lead to a sawtoothed development of the transient coastline around the Basal coastline.

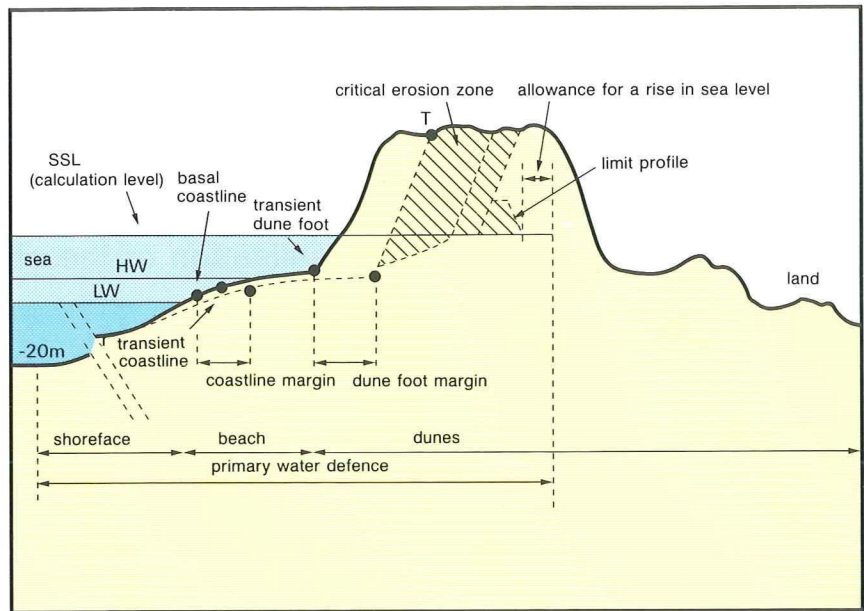
The margin is determined on the basis of the changes in position of the coastline as measured in past years, allowing the natural fluctuation of the coastline to be estimated for each coastal sector. The size of the margin can be limited by the requirements set for the interests in the dunes and on the beach at that location.

The primary water defence along the dune coast consists of that part of the shoreface, beach and dunes necessary to ensure "Delta safety" with a rising sea level.

The area of dune required is calculated according to the "Guide to the assessment of the safety of dunes as a sea defence", published by the Technical Advisory Committee on Water Defences.

It consists of the critical erosion zone and the limit profile. The limit profile represents the minimum remaining dune area required to hold back the water at the end of a "super storm".

When the sea rises, the attack on the primary water defence will be even greater. Therefore, the area allowance for a rise in sea level is considered to be part of the primary water defence.



6.4.2 The water defences

Part of the water defences along the coast is provided by dykes. To the landward side, the strip of land which determines the stability of the dyke is considered part of this defence. A similar strip is calculated for the seaward side; it may extend quite far and quite deep into the sea.

Along the dune coast, the primary water defence is made up of the whole of the shoreface, beach and dune area required to guarantee the safety of the hinterland, also in the future (see figure on opposite page).

The section of dune required to withstand a "super storm" is calculated from the landward boundary of the dune foot margin and is defined in agreement with the "Guide to the assessment of the safety of dunes as a sea defence", published by the Technical Advisory Committee on Water Defences (TAW). It includes an erosion zone and a limit profile.

Behind this area, as part of the primary water defence, a reserve is defined which is needed to uphold the strength of the water defence for a period of at least 200 years, even with the anticipated rise in sea level. This reinforcement of the water defence is necessary to ward off the heavier attack on the water defences resulting from the anticipated higher sea level, higher waves and a more severe storm surge level, calculated over a period of at least 200 years. Such a reinforcement of the primary water defences must be realised such that other interests will not be endangered.

The size of the water defences in the dune area are defined on the basis of maintenance of the sand volume, where sand drifts are taken into account to a limited degree. To ensure good management, it is necessary to be conservative with regard to permitting building within the confines of this water defence area.

The movement of the transient coastline will be "translated" into the shifting location of the dune foot, albeit more slowly and more subdued. This implies that the location of the dune foot must also be defined by a margin within which movement is permitted, without demanding measures to combat erosion. The landward boundary of the dune foot margin serves as a basis for the definition of the water defence. The mass required according to the "Guide to the assessment of the safety of dunes as a sea defence" of the TAW is defined behind this boundary.

If the dune foot does not exceed the landward limit of the margin, active restoration of damage is not necessary, as the strength of the water defence is maintained. If the dune foot margin does exceed the landward limit, however, damage to the dune must be actively combated.

COLOFON

Coordination/lay out : Public Works Department, Tidal Waters Division
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