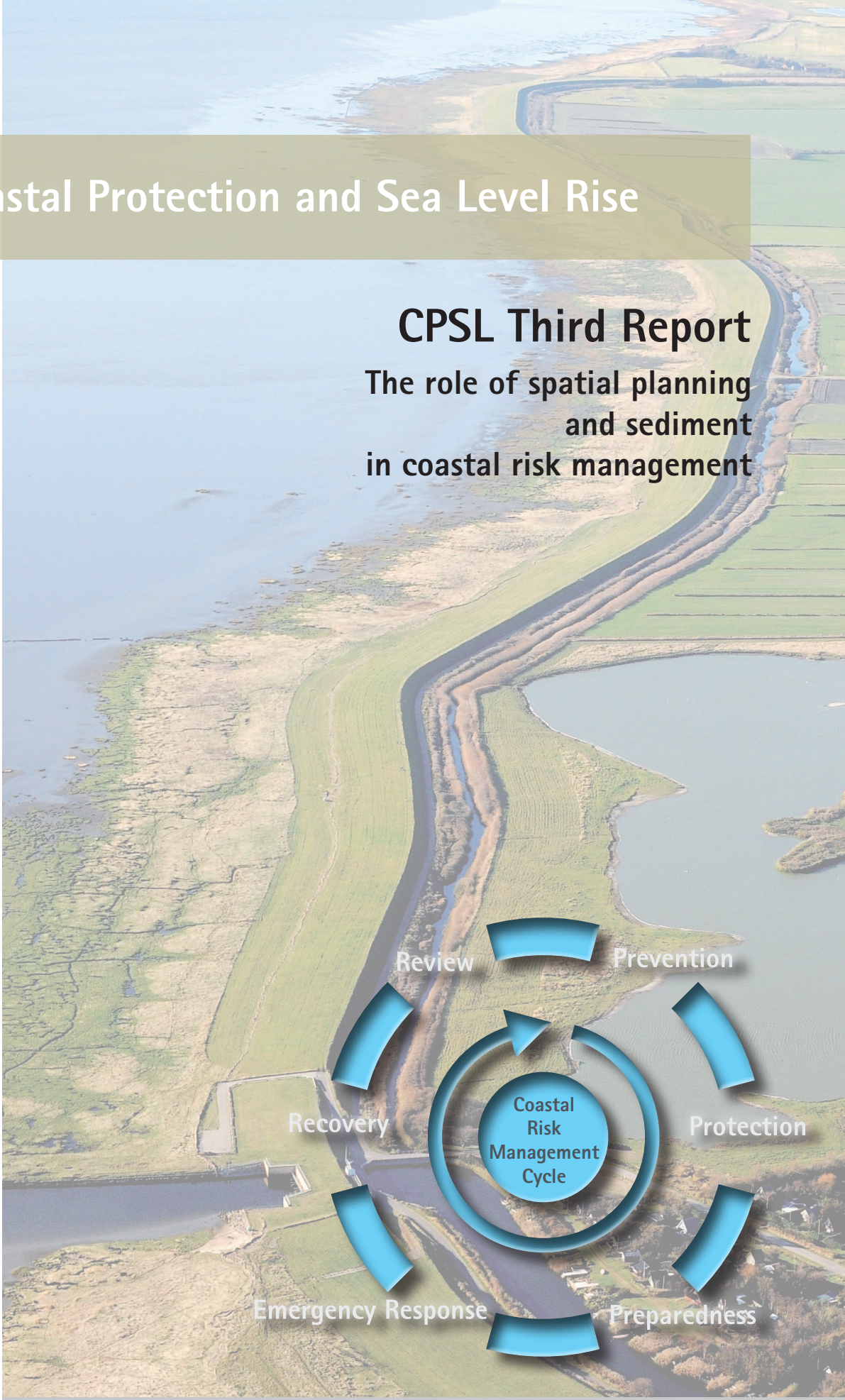
Coastal Protection and Sea Level Rise

CPSL Third Report

The role of spatial planning and sediment in coastal risk management



WADDEN SEA ECOSYSTEM No. 28 - 2010

CPSL THIRD REPORT

The role of spatial planning and sediment in coastal risk management

Colophon

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The role of spatial planning and sediment in coastal risk management

Trilateral Working Group on
Coastal Protection and Sea Level Rise (CPSL)

2010
Common Wadden Sea Secretariat
Working Group on Coastal Protection and Sea Level Rise

Contents

Executive Summary

At the 10th Governmental Wadden Sea Conference (Schiermonnikoog, NL, 2005) it was decided that the existing CPSL group would continue its work with the following main tasks:

- to initiate a study on the feasibility of coastal spatial plans that consider climate change;
- to investigate the possibilities of a study on the feasibility and effects of sand nourishment to balance the sediment deficit of the Wadden Sea tidal basins under increased sea level rise.

For the first task, CPSL was augmented with experts from spatial planning.

This report presents the results of the work of CPSL III, carried out between December 2006 and December 2009.

Spatial planning

CPSL concluded that spatial planning may present a flexible and sustainable tool to deal with the effects of sea level rise. Spatial planning measures may diminish the risk to the coastal population by reducing the damage likely from flooding and land loss. In this context, risk is defined as the likelihood of a harmful event (flooding, land loss) and the resultant damage. Consequently, coastal risk management is more than protection against the hazards of flooding and land loss. It may be seen as a holistic control loop that consists of a number of interacting elements or tasks, involving a comprehensive set of measures designed to either reduce or avoid vulnerability to coastal hazards.

In general, some basic characteristics of good spatial planning regarding coastal management were defined. Good spatial planning

- includes and integrates all elements of the coastal risk management cycle;
- offers solutions that are area-specific and which are tailored to fit the specific context of the area;
- contains general guidelines and aims to define and integrate the ingredients of wide-zone and location-specific plans;
- applies an integrated and holistic approach;
- considers natural values and resources;
- makes use of the natural physics and guiding principles of nature.

Looking at the flood defence system as a zone implies that integrated developments may take place within these areas. These need to be supported by spatial planning. If this approach is extended to the flood defence system, a sustainable oriented approach (a so-called Three Steps Strategy) can be defined: Spacing, Broadening, Raising

- Spacing means employing extra flood defence barriers of various sorts, spread over an extended zone in front of or behind the primary flood defence line.
- Broadening implies the creation of broad super- or Delta-dikes, which are made so broad that they never breech, although water may overtop them.
- Raising is the regular way of strengthening the dike. Raising provides coastal defence, but without integrated development or a combination of functions.

These three steps should be considered in sequence. If a spacing solution is not feasible, broadening needs to be looked at, and if that is not possible, raising comes into consideration.

In dealing with flood risk in an abstract way, three kinds of matter can be moved: water, sand and people. These may be defined as Guiding Principles for spatial planning in coastal flood-prone areas.

Moving water: If a region has to deal with surpluses of water, generally the water is moved out of the region. During times of heavy rain, water is pumped from the land into the sea. Keeping the water from the sea out of areas where it does not belong is also a form of moving water. In case of sea level rise this task becomes more difficult. If water is let into the region, it will influence people or sand movements.

Moving sand: Another option is to move sand. The problem with too much water is the hazard of flooding, both from inland rivers and from the sea. This hazard can be met by moving sand. If lower parts of the landscape are raised with sand, the probability of flooding is reduced. The same goes for the coast: if the flood defence zone (e.g. dikes, dunes, wetlands) is raised with sand or other sediments, the probability of flooding is minimised.

Moving people: The third possibility to lower the effects of floods is to move people. If an area is under (high) risk of flooding, the removal of people diminishes the vulnerability. The same goes for the values (economic, property, infrastructure) in the flood prone area. Excluding people, (which is also a form of moving people) from a flood prone area is also a possibility to lower the vulnerability.

Generally, the context of the situation demands a balanced combination of moving water, sand and, eventually, people.

CPSL analysed and assessed the current spatial planning systems and instruments in the Wadden Sea states and concluded that these required further development in order to fully cope with an-

ticipated impacts of climate change. Designation of buffer and flood-hazard zones in coastal regions was seen as an efficient spatial planning option, allowing the prescription and implementation of tailor-made and proportionate regulations for the utilization of coastal lowlands. CPSL identified a catalogue of regulations and prescriptions relevant to coastal risk management. Examples include: designation of areas of preference for coastal flood defence; restrictions on building/development in hazard zones; the compartmentalisation of flood-prone areas through the use of second dike lines; the raising of roads or the construction of flood-proof houses and the designation of areas of preference for sand extraction for coastal defence purposes. These regulations must be incorporated via regional plans in local building plans, and made possible by extending the powers and influence of spatial planning.

It was also acknowledged that spatial planning, based on physical instead of administrative boundaries, enables an efficient handling of coastal challenges resulting from climate change, in that it considers the physical characteristics, as well as the governing principles of sand, water and people in coastal regions.

CPSL furthermore emphasised the importance of applying extended planning horizons in dealing with long-term impacts of climate change.

CPSL acknowledged that, in a longer-term perspective, additional objectives may become relevant for spatial planning, among them nature restoration, increased coastal resilience and sustainable economic development.

Sand nourishment

CPSL concluded that the future stability and integrity of the Wadden Sea region will be determined by sediment; its availability and its redistribution potential (by water). Consequently, sediment (sand) and water represent guiding principles in the Wadden sea region (see also above). Several natural processes lead to a net transport of sediments towards the back-barrier part of the Wadden Sea and may thus help in balancing sea level rise. The first and potentially most sustainable option to combat sediment deficits due to climate change is the enhancement of natural processes (for example sediment trapping, overwash creation).

Artificial deposition of sand in strategic locations is another option to avoid sediment deficits. In the Wadden Sea area, nourishments are presently being applied in three locations:

- In the dunes in order to maintain the flood defence function of the dunes;
- On the beaches to balance structural coastal erosion;
- On the foreshore, nourishments have the same goal as on the beach. However, the volumes may be higher since the costs per cubic meter are lower and the effects seem to last longer.

CPSL agreed that, in the long term, beach and foreshore nourishment help to stabilize the back-barrier basins as well. The nourishments are eroded and the material is transported into the basins and alongshore. However, little is known about the morphological behaviour of the nourishment, or about transport routes, volumes and terminal sinks of the nourished material.

Based upon the fact that the Wadden Sea is a sand-sharing system with permanent sediment redistribution from one element to another, CPSL identified several research questions related to optimal locations, volumes, timing and grain size of the nourishments.

With regard to the sediment sources, CPSL agreed that, in order to balance additional sediment demands resulting from sea level rise, the sediment should be taken from outside the Wadden Sea sand-sharing system. The seaward border of this system is between 10 and 15 meters depth. Several research questions for sand extraction were formulated regarding, amongst others, required future amounts, morphological and ecological impacts, available grain sizes and optimal water depth.

1. Introduction

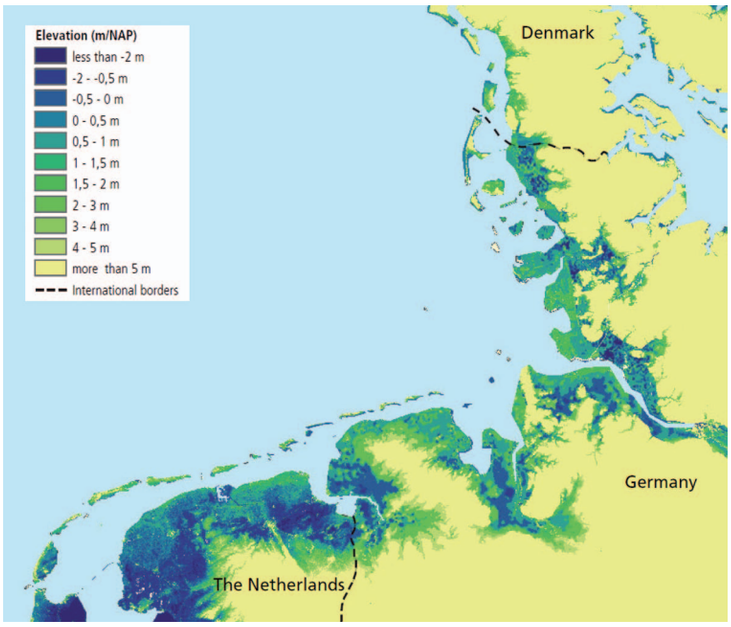


Figure 1: Wadden Sea region low-lying areas. Source: Safecoast, 2008.

The fourth progress report of the Intergovernmental Panel on Climate Change (IPCC, 2007) markedly intensified the discussion about our common future in the face of a changing climate. Front page stories such as: "Coastal towns could drown in this century, UN experts predict horror climate" underline that climate change and its possible consequences have reached the media's attention and hence the general public. Although the press coverage is far from objective, it becomes evident that, apart from mitigation, adaptation strategies are required. In this context, it is promising that the European Union adopted a Directive on the Assessment and Management of Flood Risks in November 2007. As a result, by the end of 2015, flood management plans for all areas with significant flood risk (including coastal zones) are to be drawn up. In these plans, Member States should define appropriate objectives for the management of flood risks, and list measures designed to achieve these objectives. The plans should address all aspects of flood risk management, focusing on prevention, protection and preparedness and taking into account regional/local characteristics (tailor-made solutions).

Climate change, with its possible consequences and sustainable adaptation strategies, is particularly significant for the Wadden Sea region (Figure 1, Table 1). About 3.5 million people in the region depend on flood defences, and 16 populated sandy barrier islands will be directly affected by changes in sea level rise and storminess. There is a fundamental need to protect the local population and the lowlands against storm floods in order to allow people to live in safety and earn a living. It is a precondition of the trilateral Wadden Sea Cooperation that sustainable human activities and sustainable economic developments in the area should remain possible in the future (Stade declaration, 1997). The climate change issue entered the political agenda of the trilateral Wadden Sea Cooperation in 1997, at the 8th Trilateral Wadden Sea Governmental Conference in Stade (Germany), when it was decided to investigate the possible impacts of raised sea levels on the Wadden Sea and, based on this study, to develop recommendations for coordinated coastal defence and nature protection policies.

In 1998, a trilateral expert group, the Coastal Protection and Sea Level Rise group (CPSL I) was charged with this task. The members of the group represented coastal protection and nature conservation authorities in the three Wadden Sea countries. In the first phase, for three sea level rise scenarios, the impact upon physical, biological, and socio-economic characteristics was investigated. In addition, a preliminary screening of sustainable coastal defence measures which minimize impacts on the natural system was carried out, with the goal of maintaining present safety standards into the future. The results were presented and accepted at the 9th Trilateral Governmental Conference in 2001 in Esbjerg (Denmark). Noting the urgent importance of sustainable strategies,

Table 1: Surface area (< +5m above mean sea level) and number of inhabitants in the coastal flood-prone lowlands in the Wadden Sea region.

	Area (km²)	Inhabitants
Denmark	600	100,000
Schleswig-Holstein	3,404	250,000
Hamburg	270	180,000
Bremen	360	550,000
Niedersachsen	6,600	1,200,000
The Netherlands	6,294	1,250,000
Sum	**17,528**	**3,530,000**

Ministers decided to continue the work. The expert group (CPSL II) investigated, for two geomorphological scenarios, a number of tools and measures which might contribute to sustainable coastal defence strategies for the Wadden Sea: spatial planning, sand nourishment; dune management; salt marsh management techniques; mussel and sea grass beds; outbanking of summer polders; and sea dikes. Based on the results of the studies, the expert group agreed the following recommendations:

1. Coastal spatial plans that include buffer and coastal flood hazard zones should be established, based on the principles of integrated coastal zone management. Coastal protection and climate change should be duly considered. The feasibility of such plans should be investigated by a follow-up group, comprising trilateral experts from coastal protection, nature protection and spatial planning.
2. Sand nourishment should be applied, wherever feasible, to combat erosion along sandy coastlines. A study should be carried out on the feasibility and effects of sand nourishment to balance the sediment deficit of the Wadden Sea tidal basins under increased sea level rise (e.g., volumes needed and costs, search for optimal locations, ecological impacts).
3. Regional salt marsh management plans should be established to harmonize the demands of coastal protection and nature conservation.
4. An evaluation of maintaining present day safety standards with respect to feasibility and ecological consequences, especially above breakpoint, should be carried out.

The results were presented at the 10th Trilateral Governmental Conference in 2005 in Schiermonnikoog (The Netherlands). The delegations, as well as invited NGOs, welcomed the report, and agreed to give serious consideration to the recommendations within the revision of the Wadden Sea Plan in the future. The results of CPSL I and II are available in reports at www.waddensea-secretariat.org.

At the Schiermonnikoog Conference it was decided that the existing group, augmented by spatial planning experts, should continue its work with the following main tasks:

- to initiate a study on the feasibility of coastal spatial plans that consider climate change, and
- to investigate the possibilities of a study on the feasibility and effects of sand nourishment to balance the sediment deficit of the Wadden Sea tidal basins under increased sea level rise.

In this report, the results of the work of CPSL III, carried out between December 2006 and December 2009, are presented. The Terms of Reference are in Annex 1; the members of the expert group are in Annex 2. The report opens with an executive summary and in chapter 2, an update of the scenarios, in relation to coastal protection, i.e., sea level rise and storm surge activities, is presented. Chapter 3 starts with an overview of relevant EU regulations. In addition, a description of the administrative structures for coastal protection, nature conservation and spatial planning in the three countries is given. Chapter 4 deals with the initial task of the expert group, the feasibility of coastal spatial plans with regard to coastal risk management. Existing plans and measures as well as possible options are described. The second task of the expert group is considered in chapter 5: a number of research questions with respect to sand nourishment and its capability to balance sea level rise in the Wadden Sea are formulated. The report ends traditionally with conclusions and recommendations.

Throughout the report, examples of successful projects combining nature conservation and coastal defence are presented in boxes.

The expert group recognizes that the expected acceleration in sea level rise will affect not only coastal protection in the Wadden Sea but will also have other important impacts such as saltwater intrusion, reduced drainage of the lowlands and rising groundwater levels. It was, however, not within the remit of the group to consider these impacts.

2. Scenarios for the Wadden Sea Region

Future changes in storm surges and the rate of sea level rise will significantly influence the development of the Wadden Sea ecosystem, as well as the safety of the 3.5 million inhabitants of the Wadden Sea region. Since the last CPSL report (CPSL, 2005), new scenarios[1)] have been published (Table 2, IPCC 2007) and are described below. The IPCC report reflects the shared knowledge of the vast majority of climate scientists.

2.1 Sea level rise

Modelled projections of global average sea level rise at the end of the 21st century range between 0.18 and 0.59 m (IPCC, 2007; Table 2).

The new IPCC ranges are narrower than in the earlier IPCC report from 2001, mainly because of improved information about some uncertainties in the projected contributions. Significant remaining uncertainties are the:

- contribution of the Greenland and Antarctic ice sheets;
- regional variations of the global mean values; and
- (non-linear) trend of sea level rise.

With respect to uncertainties about the contribution of the Greenland ice sheet to future sea level rise, IPCC (2007) states: "The projections include a contribution due to increased ice flow from Greenland and Antarctica at the rates observed for 1993-2003, but these flow rates could increase or decrease in the future. For example, if this contribution were to grow linearly with global average temperature change, the upper ranges of sea level rise for SRES scenarios would increase by 0.1 m to 0.2 m. Larger values cannot be excluded, but understanding of these effects is too limited to assess their likelihood or provide a best estimate or an upper bound for sea level rise." With regard to the Antarctic ice sheet IPCC (2007) stated that it will remain too cold for widespread surface melting and is expected to gain in mass due to increased snowfall. However, net loss of ice mass could occur if dynamic ice discharge dominates the ice sheet mass balance.

	Temperature Change (°C at 2090-2099 relative to 1980-1999)[a]		Sea Level Rise (m at 2090-2099 relative to 1980-1999)
Case[c]	Best Estimate	Likely Range	Model-based range excluding future rapid dynamical changes in ice flow
Constant Year 2000 Concentrations[b]	0.6	0.3 – 0.9	NA
B1 scenario	1.8	1.1 – 2.9	0.18 – 0.38
A1T scenario	2.4	1.4 – 3.8	0.20 – 0.45
B2 scenario	2.4	1.4 – 3.8	0.20 – 0.43
A1B scenario	2.8	1.7 – 4.4	0.21 – 0.48
A2 scenario	3.4	2.0 – 5.4	0.23 – 0.51
A1FI scenario	.0	2.4 – 6.4	0.26 – 0.59

Table 2: Projected global average surface warming and sea level rise at the end of the 21st century. Source: Solomon et al., 2007. Table notes: [a] These estimates are assessed from a hierarchy of models that encompass a simple climate model, several Earth System Models of Intermediate Complexity and a large number of Atmosphere-Ocean General Circulation Models (AOGCMs). [b] Year 2000 constant composition is derived from AOGCMs only. [c] See Box SRES scenarios

With respect to the Wadden Sea, regional and local factors will give rise to deviations from the global IPCC values:

1. geodetic surveys show a long term land subsidence in the Wadden Sea, varying between 0.0 and 0.1 m per century;
2. gas and oil extraction cause further land subsidence, locally amounting to about 0.4 m;
3. changes in tidal dynamics, as suggested by Stengel and Zielke (1994), may result in increased tidal ranges (greater mean high water rise, smaller mean low water rise). These factors should be added to the global IPCC values.

The regional increase in mean sea level, as in the southern North Sea, which is an epicontinental sea, can differ significantly from the global mean sea level increase shown in the IPCC 2007 report (Fig. 2).

Time series, e.g. from the tidal gauge at Norderney beginning at the end of the 19th century (Fig. 3), show phases of greater and lesser rises of MSL over the whole period under consideration. However, in investigating the development of MSL or other tidal values, such as mean high

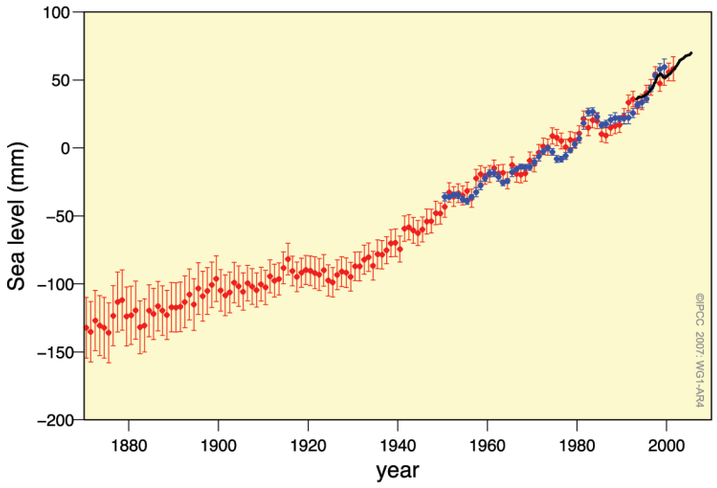


Figure 2: Annual averages of the global mean sea level based on reconstructed sea level fields since 1870 (red), tide gauge measurements since 1950 (blue) and satellite altimetry since 1992 (black). Units are in mm relative to the average for 1961 to 1990. Error bars are 90% confidence intervals. (Source: Solomon et al., 2007)

[1)] A scenario is a hypothetical sequence of events, constructed to analyse causal relations. Hence, it is not a prediction of a future situation that is going to happen (with a certain probability), but a plausible and mostly simplified description of a possible future.

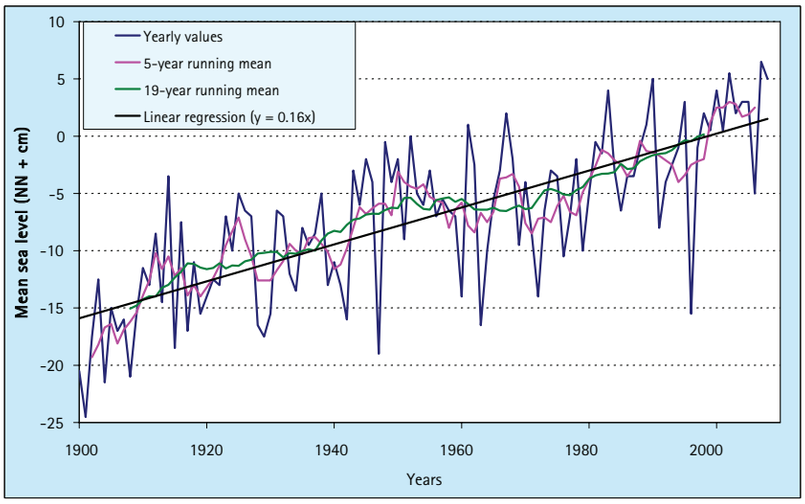


Figure 3: Development of mean tidal half water level (= approximately Mean Sea Level) at Norderney (Data NLWKN).

tide, it is important that human impacts are duly considered. For example, embankments or corrections to navigation channels can significantly influence tidal dynamics and MSL.

Finally, with respect to future sea level rise, IPCC (2007) states that it will continue long after 2100, especially with regard to the Greenland ice sheet. It is stated that: "If a negative surface mass balance were sustained for millennia, that would lead to virtually complete elimination of the Greenland ice sheet and a resulting contribution to sea level rise of about 7 m."

However, different views, especially in relation to future sea level rise, do exist. For the North Sea region, the range of scenario values is from "no anthropogenic sea level rise" to up to 2.0 m by 2100. For example, in the year 2008, the Dutch Delta Commission published a strategic paper on the protection of the Dutch lowlands against the consequences of climate change. They recommended that a regional relative sea level rise of 0.65 to 1.3 m should be considered for 2100, and from 2 to 4 m in 2200. In the calculations, an average soil subsidence of 5 cm by 2050 is taken into account. Local variations in soil subsidence due to mining activities may occur. These figures represent plausible upper limits based on the latest scientific insights. The Commission decided to take these "worst case scenarios" into account so that the decisions and the measures will be sustainable in the long term.

2.2 Storm surges and wind

The latest IPCC report (2007) provides only a general statement concerning future storminess: "Extra-tropical storm tracks are projected to move poleward, with consequent changes in wind, precipitation, and temperature patterns, continuing the broad pattern of observed trends over the last half-century." The report further states that several modelled studies have suggested increased average and/or extreme wind speeds in northern and/or central Europe, but some studies suggest the opposite. It is assumed that the changes in both average and extreme wind speeds may be seasonally variable, but again, these variations seem to be model-dependent (IPCC, 2007). The effects of increased wind speeds on maximum storm surge levels, together with possible changes in the wind direction of cyclones in the North Sea have to be taken into account. For example: if higher maximum wind speeds correspond with a more south-westerly wind direction, no higher surge levels will occur. However, higher wind speeds in combination with a westerly or north-westerly wind direction may cause high surge levels.

Model-based projections of storm surges in the North Sea region at the end of the 21st century were also published by the GKSS research centre in Geesthacht (e.g. Woth et al., 2006). Based upon the IPCC A2 and B2 SRES scenarios (see Box 1) and the IPCC 2001 report, future storm surges along the North Sea coastlines were calculated on two climate models with a constant morphology. The calculations still suffer from major uncertainties, but the outcomes of all four calculations show a similar pattern (Fig. 4).

For the Wadden Sea region, storm surges are calculated to be 0.1 to 0.4 m higher in 2085 compared to the control period of 1961-1990. The IPCC scenarios for mean sea level rise should be added to these figures. The highest increases occur in the inner German Bight, the Danish sector of the Wadden Sea and in the estuaries. This increase, however, lies within the natural variations of recent centuries. For example, the annual

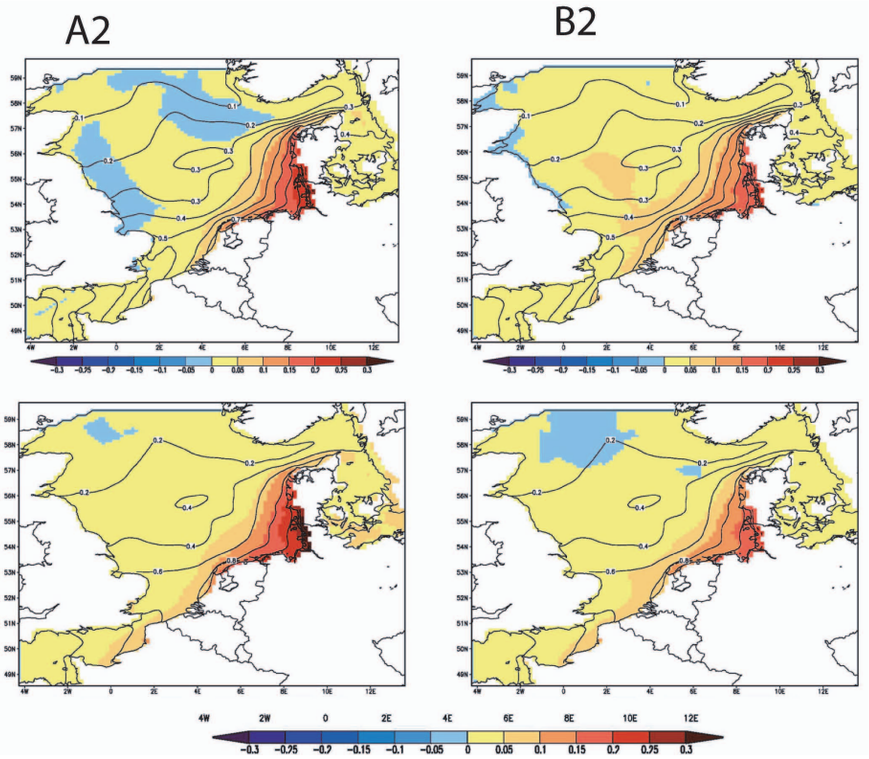


Figure 4:
Changes in storm-induced water levels, calculated for IPCC A2 and B2 scenarios (columns) with two different models (rows). Isolines: current levels. Colours: calculated deviations from current levels (in m.). Source: Woth et al., 2006.

highest water levels at Husum (Germany) show a linear trend of 0.58 m per century since 1900 (Fig. 5). By comparison, a linear regression of annual highest water levels since 1900 amounts to 0.32 m per century at Cuxhaven, to 0.25 m per century at Norderney, to 0.23 m per century at Delfzijl and to 0.60 m per century in Den Helder. demonstrating a very high variation. This shows the high temporal and local variability of storm surges and, in part, reflects artificial influences (e.g. the construction of the "Afsluitdijk"). If we exclude the development of annual mean tidal high water level at the gauge stations, the resulting values are 0.22 m in Husum, 0.08 m in Cuxhaven, -0.02 m in Norderney, -0.08 m in Delfzijl, and 0.33 m in Den Helder.

As well as sea level rise and increased wind speed, changes in tidal dynamics and wind directions will also have a significant impact on the geomorphological processes in the coastal zone. A change in the prevailing tidal dynamics and wind direction will affect prevailing erosion/accumulation patterns and shoreline sediment transport processes. On some coasts, a change in prevailing wind direction may increase coastal erosion

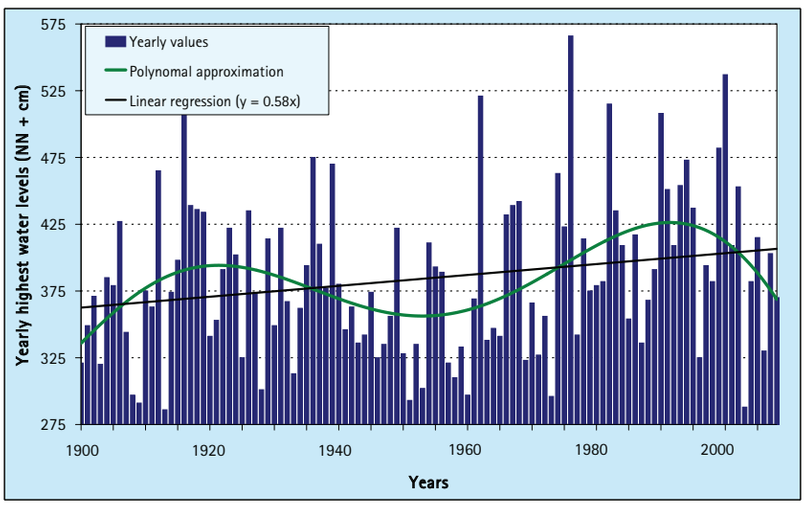


Figure 5:
Development of annual highest water levels (including mean high tide water level development) at Husum since 1868. The polynomial approximation shows that there are variations in trends through time.

or even initiate it, whilst in other cases; a similar change may reduce coastal erosion or even cause accumulation. In general the interdependence of meteorology, hydrology and morphology has to be considered and further investigated.

2.3 Synthesis

The future height of the storm surge water levels, being the sum of mean sea level rise and storm surge increase, needs to be taken into account when considering coastal flood defences. The research group around von Storch (Grosmann et al., 2006) gives figures of about 0.4 to 0.6 m in 2085 for Cuxhaven at the mouth of the Elbe estuary and between 0.12 and 0.18 m in 2030. From Esbjerg in the north and Den Helder in the west, the values decline relative to the regional variance in storm surge values (Fig. 4). In addition, tectonic land subsidence, varying between 0 and 0.1 cm per year in the Wadden Sea region, should be added.

As well as absolute changes in storm surge water level heights, the rate of sea level rise is an important factor in coastal protection, It is not expected that sea level rise will occur linearly (i.e. 0.18 to 0.59 cm per year), but with increasing rates in the future. At present, no acceleration in sea level rise can be observed in the Wadden Sea (Hofstede, 2007). Therefore, to arrive at the absolute values at the end of this century, the annual rates in the second half of this century should rise disproportionately. This would significantly affect long-term coastal erosion rates.

The annual rate of sea level rise is also the determining factor for the stability of the Wadden Sea in its present state. Higher sedimentation rates will be needed to balance the stronger annual rise in sea level. As described in CPSL I and II, this will be possible only up to a certain threshold, which is expected to lie between 0.5 and 1.0 cm of sea level rise per year for tidal flats (the threshold values for salt marshes are higher).

Model-based projections of changes in average and extreme wind speeds for northern and/or central Europe do not show a consistent picture. The model-based calculations still suffer from major uncertainties which also account for the fact that no references to a possible change of wind direction could be found in the latest IPCC report (2007).

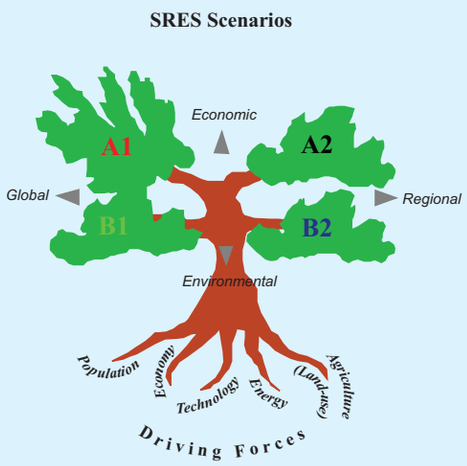
Another major uncertainty is changes in storm tracks that directly influence the regional distribution of storm surges and their height and duration. Changes in storm tracks (wind direction and duration) as a result of climate change also need to be considered since they may have a significant influence on coastal erosion and accumulation.

Box 1: SRES scenarios

In 2001, the IPCC published a new set of scenarios for use in their Third Assessment Report (Special Report on Emissions Scenarios - SRES). The SRES scenarios were designed to explore future developments in the global environment with particular reference to the production of greenhouse gases and aerosol precursor emissions. They use the following terminology:

- Storyline: a narrative description of a scenario (or a family of scenarios), highlighting the main scenario characteristics and dynamics, and the relationships between key driving forces;
- Scenario: projections of a potential future, based on a clear, logical and quantified storyline;
- Scenario family: one or more scenarios which have the same demographic, politico-societal, economic and technological storyline.

The SRES team defined four narrative storylines (see Figure), labelled A1, A2, B1 and B2. These describe the relationships, for large regions and globally, between the forces driving greenhouse gas and aerosol emissions and their evolution during the 21st century. Each storyline represents different demographic, social, economic, technological, and environmental developments that diverge in increasingly irreversible ways.



3. Administrative structure

3.1 The European Union

3.1.1 Coastal Defence

In 2007, the EU adopted a Directive on the assessment and management of flood risks, the so-called Flood Directive. Based upon a preliminary assessment of flood risks (including climate change aspects), by the end of 2011 the Member States should, for each river basin district, identify areas with a potential significant flood risk. For these areas, flood hazard and flood risk maps should be drawn up by the end of 2013. Finally, by the end of 2015, flood risk management plans should be in place.

The hazard maps delineate the areas of potential flooding, indicating low, medium and high probability. Member States may decide that, for coastal areas where an adequate level of protection exists, the preparation of flood hazard maps can be limited to "floods with a low probability", or extreme event scenarios. The risk maps include vulnerability indicators such as the number of inhabitants and land use types. In the management plans, the EU Member States are required to establish appropriate objectives and measures for the management of flood risks. The plans must take account of relevant aspects such as costs and benefits as well as the environmental objectives of the Water Framework Directive. Finally, the management plans must address all aspects of flood risk management focusing on prevention, protection and preparedness (see also Ch. 4.1; Fig. 7), taking into account the characteristics of the particular coastal stretch (i.e., tailor-made solutions).

3.1.2 Nature Conservation

EC Directives provide the legal framework for EU Member States' national legislation including nature conservation and environmental quality. Most significant in this area are the Birds and Habitats Directives, the Water Framework Directive and the recently adopted Marine Strategy Framework Directive.

The Bird and Habitats Directives require EU Member States to designate Special Protection Areas (SPAs) and Special Areas of Conservation (SACs) respectively. Together, these areas form a European network, the so-called Natura 2000. Within Natura 2000, species and habitats have been designated for which conservation objectives have been formulated and officially adopted. Member States are obliged to maintain and improve the quality of the designated sites and species with the aim of achieving favourable conservation status.

Most of the trilateral Wadden Sea is Natura 2000 area.

3.1.3 Spatial Planning

The EU Treaty does not vest any fundamental competences in the EU Commission in respect of spatial development policy; accordingly, it is a matter for the Member States. However, Community policies (agricultural policy, regional policy, policies on trans-European transport and telecommunications networks, environmental policy) do exert an influence on spatial development, not only within EU Member States, but also – and increasingly – beyond the external boundaries of the Community.

In 1999 the informal Council of Ministers responsible for spatial planning adopted the European Spatial Development Perspective (ESDP). Although not a legally binding document, the ESDP sets out the fundamental goals and options for action for future spatial development. It does not establish any new competences at EU level. However, the ESDP does constitute an important framework, both for direction and for action for sectoral policies of the EU Community, which is committed through its goals and policy options to contributing to balanced and sustainable development throughout the European Union.

The goals of the ESDP are to be pursued jointly both by European institutions and national, regional and local governments and authorities. Implementation of the ESDP is underpinned by practical measures within the framework of a 12-point programme of action, adopted by Ministers, including the EU Community initiative INTERREG. At national level, the regions are urged to take account of the ESDP in framing or up-dating spatial development programmes, and in co-ordinating sectoral plans.

A number of institutions are co-operating in the creation of a European spatial development policy, including the European Conference of Ministers responsible for spatial planning (CEMAT – Conférence Européenne des Ministres responsables de L'Aménagement du Territoire), the informal Council of Ministers (EU Member States) responsible for spatial planning, the Directorate-General for Regional Policy, the Committee on Spatial Development (CSD) and the Committee for the Development and Reconversion of Regions (CDRR).

3.2 The Netherlands

3.2.1 Coastal defence

The entire mainland coast of the Dutch Wadden Sea, about 200 km, is defended by dikes, as are the polders on the Wadden Sea side of the islands. The extent of dikes on the different islands varies from a few to 30 km. Dunes form the coastal protection of the 155 km of North Sea coasts of the inhabited islands. Since 1990, sand losses from the North Sea coast have been compensated by sand nourishment and this will continue in the future. On Texel and Vlieland, the sandy coast receives additional protection from breakwaters made of basalt and concrete. On the tips of some of the inhabited islands, natural coastal development is allowed within certain limits. No, or very limited, maintenance is carried out on several uninhabited eastern and western parts of the islands.

At the national level, the Ministry of Transport, Public Works and Water Management (Min V&W) and the Ministry of Agriculture, Nature and Food Quality (Min LNV) are responsible respectively for coastal defence and nature conservation in the Wadden Sea. The Ministry of Housing, Spatial Planning and the Environment (Min VROM) drew up the guidelines for local and regional plans in a national directive, the PKB-Waddenzee (Key Planning Decision Decision Wadden Sea; see below).

The protection of the North Sea coast of the islands is the responsibility of the Directorate-General for Public Works and Water Management (RWS) of the Min V&W. The Provinces along the coast each have a Provincial Consultative Body for the Coast (POK). Through this body, national, provincial and municipal authorities and regional water boards discuss all issues concerning coastal defence and give recommendations to the Minister of VROM.

In 2008 a new Water Law was adopted, through which most of the laws concerning water management were modernized, co-ordinated and integrated. The Water Law covers surface waters and ground waters and co-ordinates water management and spatial planning.

Tasks and responsibilities of the authorities involved will be streamlined in this new law:

- The State Government will be responsible for the national policy and the strategic goals for water management. In addition, measures of a national nature will be the responsibility of the State. The State is the competent authority for the Provinces;
- The Provinces must incorporate the provisions of the Water Law into regional policies and strategic goals. The Province is the competent authority for the water board and municipality where regional water management is important;
- The water manager (water boards and the Min V&W are responsible for the regional water systems and the main water system) is responsible for operating the water management;
- The Municipality is responsible for the local spatial adaptation of the measures and has to take care of the municipal waters.

For coastal defence the following points are most important:

1) The law stipulates that safety standards must be defined for all primary water defences.

Based on the advice of the Delta Committee (2008), the National Water Plan states that prevention of flooding forms the core of the Dutch water safety management strategy. Spatial planning and innovative techniques may be used to achieve this. The safety standards must be maintained by the State (Min V&W), or (preferably) devolved to the water boards (public organizations which raise their own taxes) or other responsible organisations. The water boards are controlled by the Provinces, who report to the Minister of V&W.

2) The law states that landward retreat of the coastline will be prevented by the State, as far as this is needed for maintaining safety. In practice, this will be done mainly by sand nourishment and, where they exist, maintaining the dikes.

3.2.2 Nature Conservation

The conservation of the Dutch part of the Wadden Sea is based upon the Key Planning Decision Wadden Sea (PKB) and the Nature Conservation Act, 1998, supported by additional designations.

The PKB is a national physical planning decree, defining the overall objectives of conservation, management and use of the Wadden Sea. It is an instrument of the Spatial Planning Act, and its objectives and conditions, applying to the whole Dutch Wadden Sea, are binding for all state, regional and local authorities. The first PKB was adopted in 1980 and currently the third version (adopted by Parliament in 2007) is in force.

Through the Nature Conservation Act (1998), biodiversity sites have been designated as Special Areas of Conservation (SACs) according to the Habitats Directive, and as Special Protection Areas (SPAs) under the Birds Directive. The conservation objectives and boundaries for these Natura 2000

Box 2: Combining clay mining and nature conservation in Denmark

Clay mining in Denmark takes place in the marshlands behind the sea dikes and not in the more fragile natural or semi-natural salt marshes. For decades, the material for dike restoration projects had been taken from the low-lying marshes, and in several places along the coast clay pits are found just behind the sea dike. For many years these clay pits were not exploited, but simply regarded as lost agricultural land or good wildfowling possibilities.

However, new clay extraction requirements for dike restoration projects have appeared in the last fifteen years. In addition to best practice in relation to improving coastal protection and protecting the salt marshes in front of the dikes, a new set of principles for clay extraction in the marshes has developed. This demonstrates that reinforcement activities, such as making the dikes higher or re-profiling old dikes, are now part of a common project for both the restoration works and the extraction of raw materials. One of the requirements is that nature conservation or habitat restoration measures have to be included.

This requirement stems from the Danish nature protection law (and also the EC-Habitats Directive), by virtue of which the salt marshes in front of the Wadden Sea dikes are protected. In addition, any losses of this habitat must, in most cases, be compensated. In order to meet these requirements, the notion of creating a combined extraction and nature conservation area in the agricultural marshlands behind the dikes developed when the restoration project for the Darum-Tjæreborg Dike (dating from 1929) in the northern part of the Danish Wadden Sea was initiated in 1992. The project was a joint effort by the state, the former county council, the local municipality, the dike-owners' association and the farmers who owned the marshland.

Although expropriation of land is possible for dike reinforcement projects, the land required for the Darum-Tjæreborg project was provided on a voluntary basis. In order to secure both the present (approximately. 230.000 m3) and future local needs for clay, as well as meeting the wildlife management requirements, 56 ha of marshland were bought. A 24 ha lake was created, and, based upon the new principles, the biological diversity in both the freshwater lake and the surrounding marshlands was made as high as possible. To achieve this, the clay pit – or in this case the lake – was built in such a way that it contained the best possible habitats for plants and animals, with small islands, a winding shoreline with bays and spits and large areas of shallow water. These elements were specifically included in the project to meet the needs for a rich and diverse birdlife. Since then, the whole area has developed into a very rich and important site for birds in the northern part of the Danish Wadden Sea.

The Darum-Tjæreborg project has not only resulted in an area with high biodiversity content, but with its location near the river Sneum Å and Sneum Sluse (the sluice) and with its proximity to the adjacent Wadden Sea, it has also turned out to be a hot spot for recreation, education and interpretation. With Esbjerg only a short distance away, complete with its excellent visitor facilities which were also included as part of the project, it has turned out to be one of the main attractions in the region where thousands of people are able to enjoy the Wadden Sea landscape, its wildlife and the cultural aspects of the marshlands.

sites are set out in a Ministerial order. Management plans outlining the required measures have been drawn up for each site and arrangements will be made with provincial authorities to implement them. Under the law, it is prohibited to undertake, without permission, activities which destroy or damage the protected area, including its flora and fauna or its scenic value. The guiding principle is that human activities are allowed, as long as they are consistent with the major goal of the policy set out in the PKB document. Therefore, the legislation includes an assessment framework to be applied when the acceptability of proposed new activities has to be decided.

The Water Framework Directive (WFD; responsible Ministry: Min V&W) deals with the quality of water bodies and their surroundings. The Directive aims to achieve sufficient quality of the surface

and ground waters in Europe by 2015. Important instruments in the Netherlands are the "Water Directive River Basin management plans". These describe the agreements on the qualitative and quantitative goals and on how to implement them, with some species or habitats specifically named. Natura 2000 and the Water Framework Directive are closely linked, with all Natura 2000 sites part of a Water Directive River Basin which often rely heavily on water quality. Coordination between them is therefore essential.

There are three National Parks within the Dutch Wadden Sea region, the Dunes of Texel, the island of Schiermonnikoog and the Lauwersmeer. The system of National Parks protects a wide range of landscapes characteristic of the Netherlands, ranging from dunes, tidal flats and stream valleys to woodland, heath and fens. A National Park must extend to at least 1000 ha.

3.2.3 Spatial Planning

In 2008 the new spatial law entered into force. The main provision is that binding planning in land-use plans takes place at the municipal level. Land-use plans specify which functions are allowed and sought in certain areas. These plans are valid for 10 years.

Besides the land-use plan, the new law introduces one other planning instrument - the Structure Vision. This planning instrument is not exclusively used at the governmental level, but may be drawn up jointly by the central government, the province or the municipality for the whole area or parts of it. Different governmental bodies, at varying levels, may cooperate in a Structure Vision for a specific area, as defined by the cooperating parties and may define policies for longer than the 10-year period. Mandatory elements in the Vision are: vision; policy; and regulation. In the regulatory part, those elements which are of special interest for the spatial quality in the defined area are detailed.

In addition, another change in planning practice is taking place in the Netherlands. The planning process used to focus on the definition of the functions that were permitted in a certain area, but development planning emerged in order to define what is desired in a certain area. The question is no longer what the government allows, but instead what a combination of interested parties finds desirable and wants to achieve. In this new way of planning, cooperation takes place between different governments, industry, environmental groups and groups of inhabitants. The expectation is that through a joint planning process, as well as a realisation process, delivery of the plans will be easier, because all stakeholders are involved from the beginning and fewer people raise legal objections afterwards.

Water is a strong influence in the Netherlands: at present much of the spatial planning system is implicitly driven by the problems the Dutch encounter with their salt and fresh water systems. For instance, spatial planning in relation to water management is a guiding principle in the program "Ruimte voor de Rivier" (Space for the Rivers), which states that sufficient space should be allowed within the river basin to cope with extreme run-off. In addition, the "Derde Kunstnota" "Third Coastal Policy Document", forbids building outside designated areas and allows natural sand movement along the coasts. The problems with, and the impacts on, spatial planning are likely to increase as a result of climate change (i.e. run-off from rivers and the need for fresh water and safety related problems). The Water Law (see above) will therefore become an important instrument in spatial planning, focusing on integrated water management.

3.3 Germany, federal level

3.3.1 Spatial Planning

Spatial planning is the methodical organisation and development of areas (regions, states, etc.) to use their land in the best possible way. The economic and social aspects need to be co-ordinated with ecological factors to reach a long-lasting, spatially balanced state.

In Germany there are several levels involved in spatial planning. Since September 2006, spatial planning at the federal or national level has been part of the concurrent legislation, which means that the states can implement their own laws if and where the federal level does not do so - in which case the states can diverge from the federal legislation. Accordingly, the Federal Spatial Planning Act was revised and came into force in June 2009. This Act defines the goals for spatial planning in Germany and includes regulations for spatial planning at the federal and the state level, including general specifications for the content of the state and regional spatial plans. As well as this Act there are also guidelines, but no plan, for mainland areas at the federal level. However, there are spatial plans for the EEZ (see below).

In relation to housing and urban planning, the main federal act is the Federal Building Act. This Act makes general regulations for town planning, stipulating what should be included in a land-use plan or what must be considered when a land-use plan is drawn up, including regulations for expro-

priation etc. There are also specific regulations for town planning in rehabilitation areas, developing areas or social aspects of town planning.

In 2006 the federal and state Ministers responsible for spatial planning adopted a strategy for spatial development in Germany which includes the main tasks for the coming years. It consists of three guiding principles: "growth and innovation"; "securing public welfare"; and "conserving the resources, developing cultural landscapes". It draws attention to important economic, social and ecological issues and is directed at decision makers and investors.

Spatial planning in Germany is currently undergoing a shift away from regulation-oriented to more support-oriented planning, influenced by globalisation, demographic changes and decreasing funds.

Box 3: Renaturation of the Langeoog Summer-Polder

The sandy barrier island of Langeoog covers a total area of 20 km². It consists mainly of dunes on its northern side and salt marsh and wetlands on its Wadden Sea side (see photo). In 2002/2003 compensation measures were implemented in parts of the salt marshes.

At the beginning of the 20th century farms were established in the uninhabited middle and eastern parts of the island. By building brushwood groins and drainage systems, new farmland was reclaimed. In 1934/1935 a 5.5 km long summer dike was constructed, which protects 210 ha of summer polder against small summer surges in order to enhance the agricultural potential.

The low-lying summer polder was grazed by cattle as a management technique in the Lower Saxony Wadden Sea National Park. Nowadays the former agricultural use of these farms has changed to hostels and gastronomy. The summer dike, including two sluices, had an important role in flood protection and water management for the northern areas, and included the only small road to the facilities mentioned above, as a link to the eastern part of the island for tourism, maintenance and disaster management.

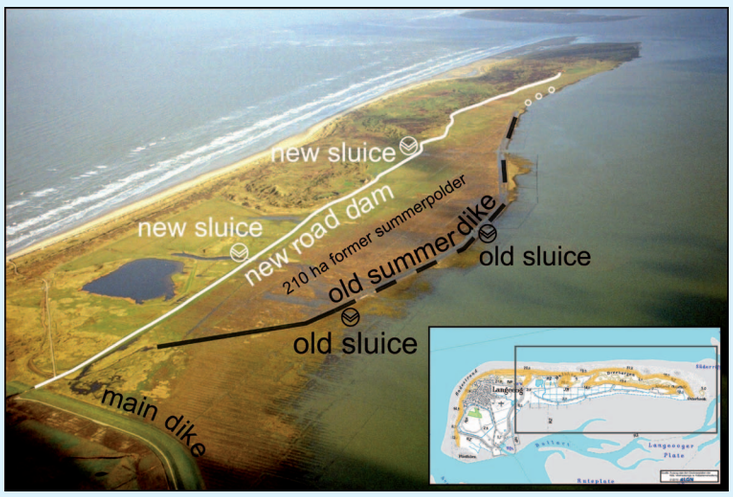
In order to find a suitable compensation measure for the gas pipeline STATOIL, the Lower Saxony Water Management and Coastal Defence Agency (NLWKN) was authorised to plan a suitable project. The Langeoog summer polder was chosen because the summer dike interfered with the natural sequence of salt marsh plant communities from the dunes to the tidal flats and, as a result, lower salt marsh vegetation was almost entirely missing. In addition, there was an artificial drainage system in the summer polder.

The main objectives of the renaturation project were to enhance the naturalness of the summer polder and enhance the conditions for salt marsh species without any negative effects on water management, erosion protection and traffic.

The following measures were planned:

- Outbanking of 210 ha of summer polder by total or part removal of the summer dike;
- Demolition of two summer dike sluices;
- Restoration of former natural ditches;
- Partial damming artificial drainage systems;
- Extensive grazing in higher areas to protect grassland birds and to establish diverse plant communities;
- Construction of a paved, overtopping-resistant road dam for pedestrians, cyclists and vehicles in the middle of the island to create access to the youth hostel, gastronomy and the eastern end of the island and provide water management and erosion protection functions;
- Construction of two controllable sluices within the road dam to control the water in the adjacent lowlands to the north of the dam.

The project was carried out between 2002 and 2003. Since then, significant changes in the former summer polder have taken place: In the low lying ungrazed areas, plant communities of the lower and middle salt marsh developed within a few years and the drainage system became natural. The usability of the road dam was enhanced and elsewhere disturbance to the areas was reduced by guiding. After initial scepticism from some local people, the measures were accepted by tourists and the local population as a win-win-situation.



In addition, greater attention is being paid to maritime and coastal areas. In 2004, it was decided that the spatial plan for the EEZ (Exclusive Economic Zone) would be developed at the federal level, while the states would be responsible for the spatial planning within the 12 nautical mile zones.

The states and their subdivisions on the other hand devise the plans (state and regional spatial plans) and use other instruments for spatial planning. The organisation and legislation differs between states.

Instruments

At the federal level is the Federal Spatial Planning Act and guidelines but no plans exist for on-shore areas. Spatial plans for the EEZ in the North Sea and Baltic Sea came into force in 2009.

For housing and urban affairs, the main federal act is the Federal Building Act. The municipalities draw up land-use plans which are developed in two-stages:

1: land utilization plan (F-plan);

2: building plan (B-plan).

The land utilization plan is more generalized and large-scale (as a rule, at a scale of 1:10,000 to 1:5,000). It complies with the principles and objectives of the regional plans and forms the basis of the municipal building plans. These building plans are more detailed and at a smaller scale (as a rule, between 1:2,000 and 1:1,000). The result is firstly to define the layout of the settlement and its structural development, and secondly, the indirect regulation of land value. The different plans have different goals and commitments. The land utilization planning binds the municipality (how to develop the land in the future), the building plan binds the land owner and the people (where and how to build a house).

3.3.2 Nature conservation

The nature conservation legislation in Germany is divided into two levels, the federal level and the state level. The Federal Nature Protection Law (BNatschG of 25.3.2002, last amended 22.12.2008) is the framework law for nature conservation in the states. These state nature conservation laws may vary, except for the common principles, species protection and protection of marine areas in the EEZ. For example: in national parks the federal nature protection law defines the principles that must be upheld. Niedersachsen, Hamburg and Schleswig-Holstein have included detailed regulations in the state specific National Park Law. This is the basis for the creation of the three Wadden Sea national parks in Germany.

3.4 Lower Saxony

3.4.1 Coastal Defence

In Lower Saxony, an area of 6,600 km² with 1.2 million inhabitants is protected against coastal flooding. The legal basis for coastal defence is the Lower Saxony Dike Act which contains regulations for design, maintenance, management and use of coastal defence structures, such as dikes, dunes and forelands, as well as defining the responsibilities of the authorities and the water boards. The main objective of the Dike Act is to protect settlements, economic and agricultural areas, and infrastructure against flooding and erosion.

The main principle is that all those who benefit from protection against flooding are responsible for maintaining the dikes. They are organized in water boards, which must carry out maintenance works on the mainland dikes except for some, which are under state responsibility. The state, moreover, is responsible for all coastal protection structures on the islands and the storm surge barriers.

The Ministry of Environment and Climate Protection is in charge of general guidelines and major issues on coastal defence, as well as being responsible for master plans for coastal defence.

The rural district authorities are responsible for the management of the water boards and their dikes and routine licences, under the Dike Act.

The Lower Saxony Water Management, Coastal Defence and Nature Conservation Agency (NLWKN), as the state authority accountable to the Ministry, is in charge of conceptual and technical planning of coastal protection structures, maintenance works and applied science in coastal engineering. NLWKN is also the authority for legally defining the dimensions of the dikes and for granting permission for large scale coastal protection measures.

Construction works for coastal defences, such as strengthening, are financed at the federal level and by the state of Lower Saxony.

3.4.2 Nature Conservation

The legal foundations for nature conservation are the Federal and the Niedersachsen Nature Conservation Act and the State Act for the Wadden Sea National Park of Niedersachsen. Apart from the estuaries of Ems, Jade, and Weser, the whole Niedersachsen part of the Wadden Sea has been designated as a National Park which includes the uninhabited parts of the East-Friesian islands.

The general objective for the protection of the tidal flats and the adjacent sublittoral, the dunes, and the salt marshes as valuable habitats, is to

preserve the species composition and natural processes, including the natural morphology and dynamics.

Under the responsibility of the Ministry of the Environment and Climate Protection, the National Park Administration develops general guidelines and implements the regulations of the National Park Act. In addition, the local authorities at the rural district level are responsible for nature conservation in areas above MHTL, except for those with the highest protection. The other legal regulations remain in force.

3.4.3 Spatial Planning

In Lower Saxony, based in law on the Regional Planning Act of Lower Saxony, two levels of spatial planning exist:

- the State Planning Programme (SPP) and
- the Regional Planning Programmes (RPP).

The SPP is an initial blueprint for the sustainable development of space and is currently being updated. It covers the whole area of Lower Saxony with its 38 Landkreise and eight municipalities not associated with a Landkreis, and applies up to the 12 nautical mile limit. Based on the SPP, every Landkreis specifies its own aims and development measures in a RPP. The eight municipalities establish Land-use Plans (F-Plan) and building plans (B-Plan), instead of RPPs. All authorities and municipalities, as well as NGOs, are able to participate in the development of the plans. The plans are legally binding on the authorities and municipalities and are valid for about 10 years.

The SPP is set up by the Minister of Food, Agriculture, Consumer Protection and Regional Development and is adopted by the state government. RPPs, devised by the Landkreise or municipalities, are also approved by the state government.

The SPP was revised in 2008 and has been supplemented by a special chapter on ICZM, which takes into account the special interests of the coast, the islands and the sea and which allows for integrated planning.

More information at http://www.ml.niedersachsen.de

3.5 Schleswig-Holstein

3.5.1 Coastal Defence

In total, the North Sea coast of Schleswig-Holstein extends to 553 km (including islands and Halligen). About 425 km of the coastline are protected by primary sea dikes. These dikes protect more than 250,000 inhabitants in an area of about 3,500 km^2 against flooding during severe storm surges. A second line of dikes extending to 570 km behind the primary dikes gives additional safety for the population behind it. Coastal defence is regulated by the State Water Act. Under that Act, coastal defence (flood defence and protection) is the responsibility of those who benefit from it. However, measures in the common public interest are a public obligation and the law defines which measures fall into this category. In 2005, state responsibilities for coastal defence transferred to the Schleswig-Holstein State Ministry for Agriculture, Environment and Rural Areas (MLUR). The Flood Defence, Coastal Protection and Harbours Unit within the Division for Water Management deals with legislation, financing and strategic planning. In 2008, two state regional offices responsible for coastal defence merged with the state office for the National Park Wadden Sea of Schleswig-Holstein to one state agency for coastal defence, national park and marine protection (mirroring the Division for Water Management in the Ministry). It is responsible for the preparation and implementation of plans, monitoring, permits and management of the National Park.

3.5.2 Nature Protection

A National Park extending to 4,410 km^2 lies on the North Sea coast of Schleswig-Holstein. It consists of the Wadden Sea proper and a whale protection area in the North Sea (west of Sylt) -the islands and the main Halligen are not included. On these islands are a number of nature reserves. The National Park and most of the nature reserves are designated as Natura 2000 sites under EU legislation. Two state laws, the State Nature Conservation Act and the National Park Act regulate nature conservation in the Wadden Sea region of Schleswig-Holstein. Under the National Park Act, conservation objectives and other purposes are defined. Furthermore, the designated area is divided into zones with varying protection measures, e.g. land-use controls. Two boards of trustees advise the National Park administration on basic issues and long-term planning. The highest authority for nature conservation is the Schleswig-Holstein State Ministry for Agriculture, Environment and Rural Areas (MLUR). In the Water Management, Marine Protection and Coastal Defence Division, the unit Marine Protection and National Parks, deals with legislation, financing and strategic planning.

3.5.3 Spatial Planning

In Schleswig-Holstein there are two levels of spatial planning, the state level and the regional level. In addition, in land use plans, there is the municipal planning of areas for housing, business,

industry, public utilities etc. This planning could be seen as a fourth level (with the federal level as the first). The state spatial plan (the one currently under preparation is called the State Development Plan) outlines the principles and objectives for the spatial development across the whole of Schleswig-Holstein, including the marine area up to the 12 nautical mile limit.

The five regional spatial plans constitute the state spatial plan for the five regions in Schleswig-Holstein. The legal basis for this at the state level is the State Planning Act of Schleswig-Holstein. All relevant authorities and municipalities, as well as NGOs, are able to participate in the development of these plans, which are legally binding on the authorities and the municipalities, and which run for about 15 years. Until now the State Ministry of the Interior has been responsible for both the state and the regional spatial plans. However, wide-ranging discussions are now taking place to transfer the responsibility for the regional spatial plans to the districts.

The main instruments for spatial planning in Schleswig-Holstein and which are defined more specifically in the state development plan, its corresponding regulations and the regional plans amongst others, are:

- the system of the central places;
- a development outline for housing, based on population and housing forecasts;
- settlement routes, running along motorways from the bigger cities;
- the definition of conurbations, designated areas, rural areas, cities and suburbs;
- areas of preference and areas of reservation for specific uses, such as nature conservation, groundwater protection or tourism and recreation (in the areas of preference no other

Box 4: Tetrapods on Sylt

In order to stop coastal retreat in front of a built-up area (Kersig-Siedlung) on the Isle of Sylt, a large structure of tetrapods was erected (Fig. a). It consists of a 1270 m section on the beach in front of the dunes, and a 270 m groin. The groin functions by intercepting the southward longshore drift. While the accumulated material reduces the coastal erosion in front of Kersig-Siedlung during storms, regular sand nourishment remains necessary to stabilize the beach entirely. South of the groin, severe lee-erosion occurs due to an absence of sediment transport from the north. As this area is undeveloped, greater erosion and retreat of the Hörnum Odde spit can, to a certain extent, be accepted.

After construction it became clear that the tetrapods parallel to the shore were causing complex storm wave-interactions on the beach. It was noted that, after some storm surges, more sediment was eroded from the beach stretch with tetrapods compared to the beach immediately north of the construction (without tetrapods). In addition, the tetrapods hindered the development of primary dunes on the beach. In 2005, it was decided to remove the northern 450 m of the block of tetrapods and monitor the impacts. Unfortunately, heavy storm surges in 2006 required extra sand nourishment in the test site. This hindered the evaluation of the hydro-morphological consequences of the removal. Nevertheless, it seems that the removal of the tetrapods had an overall positive effect in that the wave turbulence on the beach during storms was reduced. A project group, consisting of representatives from the State administration, the local municipality and the water board, is now considering the removal of more tetrapods.

Fig a.: Tetrapods in spring 2008

Fig b.: Aerial view of the southern part of the tetrapod construction on Sylt in 2005 (Note that the section north of the groin is hidden under primary dunes)

uses which interfere with the stated use are permitted and in the areas of reservation the stated use has an extra weight over other uses) and
- the so-called "Eignungsgebiete" (areas of suitability), outside which the defined use is not permitted.

Other instruments are
- spatial planning procedures, which are regulated moderation procedures relating to (mostly larger-scale) projects;
- observations on the urban development plans of the cities and the municipalities,
- spatial planning reports,
- the initiation and moderation of co-operation between municipalities and
- spatial planning coordination procedures. This means a procedure for planned large-scale projects, such as large hotels, campsites or holiday homes, for example at the coast, in which the compatibility of the project with the environment, the ability to experience the landscape, as well as the tourism concept of Schleswig-Holstein, will be assessed.

In this context, it is very important to note that some of the instruments relate to spatial planning per se, meaning that the Department for Spatial Planning decides if and how they will appear in the draft of the plan, while other instruments are based on regulations or plans from other special fields, such as the Ministry for Environment or the Ministry for Transport.

For example, the State Development Plan identifies 'areas of preference for river high water protection', flooding areas of rivers which are defined according to the State Water Act. In these 'areas of preference for river high water protection' other uses are not generally prohibited but only those which conflict with the stated purpose of the area. Another example is the 'areas of preference for nature conservation' where settlements (housing and business) are excluded.

As the plans are legally binding on the municipalities, all regulations, defined areas and so on need a democratic endorsement, which is achieved by a wide-ranging public consultation process.

The municipalities draw up land-use plans which on the one hand must satisfy the principles and objectives of the regional plans and, on the other hand, are the basis for the municipal building plans. In the land-use plans and the municipal building plans, the municipalities determine, for example, where houses may or may not be built and give specifications for the construction of the houses.

3.6 Denmark

The coastline of Denmark amounts to 7,300 km. At a European level, this length of coastline compared to the country size (43,094 km^2) is exceptional. The national interests relating to the use of the coastal zone are governed by regulations for spatial planning, adopted in the Danish Planning Act of 1994. One of the overall objectives of the Act is to ensure that the undeveloped coasts remain an important natural and landscape resource and that new urban developments are located inland and not on the coast.

The Ministries responsible for coastal defence and nature protection are the Ministry of Transport and the Ministry of the Environment. Through the Ministry of Transport, the Danish Coastal Authority is responsible for the administration of the Coastal Protection Act. Legislation relating to nature conservation, incorporating regulations that directly influence the management of the coastal zone, is the responsibility the National Forest and Nature Agency accountable to the Ministry of the Environment.

In 2003 the Danish government decided to implement a major reform of regional and local government. This administrative reform, effective from January 1, 2007, replaced the 13 counties with five regions. The 270 municipalities were consolidated into 98 larger united municipalities, most of which have at least 20,000 inhabitants. Many of the responsibilities of the former counties were taken over by the enlarged municipalities. The most important area of responsibility for the new five regions is the national health service.

In conjunction with the administrative reform, a revision of the national Coastal Protection Act of 1988 was carried out, since the counties' responsibilities under the Coastal Protection Act were transferred to the new enlarged municipalities. The revised Coastal Protection Act also became effective from January 1, 2007.

3.6.1 Coastal Protection

The most significant element of coastal flood defence in the Danish Wadden Sea consists of clay-covered grass dikes with a sand core. Along the mainland coast, dikes extend to approximately 71 km, including 6 km of summer dike. The inhabited areas on the three barrier islands of Fanø, Mandø and Rømø are protected by 28 km of sea dike. In total, nearly 100 km of sea dike protect approximately 600 km^2 of flood-prone area. Most dikes are maintained by local water boards under the supervision of the municipalities of Esbjerg and Tønder, as well as the Danish Coastal Authority.

There are very few hard defences and no land reclamation measures are carried out. Salt marsh areas in front of the dikes are maintained for coastal protection purposes; designed to maintain a 250-300 m wide salt marsh area in front of the dikes.

The Coastal Protection Act dates back to 1988. It is the main piece of legislation regulating all coastal defence measures along the Danish coast. In its original form, it was mainly a procedural code that the relevant authorities were obliged to follow when an application for building or altering coastal defences was made. With its revision in 2007, the Coastal Protection Act has been complemented by an Article of Intent, which defines the purpose of coastal defence measures: 'The protection of human life and property against flooding due to extreme high water levels, and against coastal erosion due to attack by waves and currents'.

Furthermore, the Article of Intent defines an assessment of the different considerations to be carried out before permitting defence measures to be carried out, such as the need for the defence measure, the technical and environmental aspects, the economic case, the impact on wildlife and landscape and access to the beach. The procedural code has also been simplified in relation to the granting and the implementation of coastal defence measures.

The overall principle is that the responsibility for establishing and maintaining defence measures lies with those who benefit from them. On the other hand, landowners do not have an immediate right to protect property. Each new defence measure has to be considered to be appropriate by several authorities. The submission of a request for permitting a coastal defence measure may proceed in two ways: (i) by application to the Danish Coastal Authority, and (ii) by inquiry to the relevant municipal body.

In general there is no public obligation to undertake coastal defence. In extreme situations the relevant bodies have considered it a public duty to build or repair dikes on the Wadden Sea coast, either partly or fully financed by public funds by way of special construction laws.

3.6.2 Nature Protection

The Danish part of the Wadden Sea Area is covered by both national and international protection measures.

At the national level, the Danish part of the Trilateral Conservation Area is designated as the Wadden Sea Nature and Wildlife Reserve, which was created by statutory orders in 1979 as a wildlife reserve and in 1982 as a nature reserve. The orders were merged into one order in 1992, amended in 1998, in order to incorporate some additional elements of the Trilateral Wadden Sea Plan.

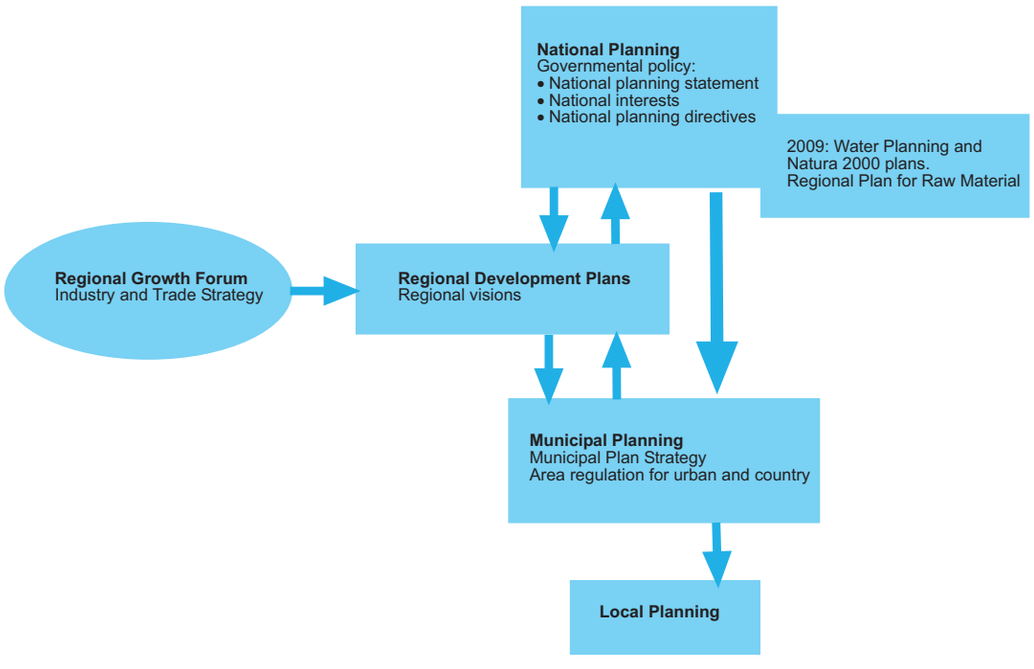


Figure 6:
The Danish spatial planning structure.

The area covered comprises both maritime and land areas. It consists of the Wadden Sea beyond the seawalls on the mainland and islands, and where dikes are absent, the mean high water level is the boundary. On the North Sea coast, the reserve boundary is 3 nautical miles west of the imaginary line between the Wadden Sea islands and the peninsula of Skallingen. Also included are most of Skallingen, state-owned beaches and salt marshes on the islands and the Margrethe Kog area near the Danish-German border. The Reserve covers almost 1,000 km^2.

The provisions of the Nature and Wildlife Reserve Executive Order mainly concern public access, hunting, sailing/shipping and other human activities which may cause disturbance to wildlife or may be harmful to the natural environment. There are three zones with different levels of protection, including a core zone making up 10% of the protected area.

In addition to the Executive Order, the coastline zones of the mainland and of the islands are protected by the federal Nature Conservation Act, and some specific areas are also designated as nature conservation areas. Furthermore, the dunes and salt marshes, as well as other suitable habitats, are subject to a general biotope protection regime under section 3 of the Nature Conservation Act. The areas covered by the Nature Conservation Act make up substantial parts of the Danish Wadden Sea Area. Major parts of the Danish Wadden Sea area have been designated as a National Park, which will be established formally in the second half of 2010.

At the international level the entire Danish Wadden Sea area is designated as a Ramsar Site and as a Natura 2000 site under EU legislation (the EU Birds Directive and the EU Habitats Directive). In addition to the Conservation Area and the Nature and Wildlife Reserve, this area includes the islands, the beaches, the salt marshes around Ho Bugt, in the Varde Å estuary and near Måde, as well as the extensive freshwater marshlands behind the seawalls. The Executive Order on the Demarcation and Administration of International Nature Protection Areas defines the areas and lays down obligatory rules for the authorities. Furthermore, Natura 2000 plans for each International Protection Area are prepared, and the first action phase to implement these plans will run from 2010 to 2016.

The main players responsible for the administration and protection of the Wadden Sea Area are the four local municipalities (Varde, Fanø, Esbjerg and Tønder) and the State Ministries of the Environment, Agriculture and Transport (The Danish Coastal Authority).

3.6.3 Spatial Planning

The municipality and regional structure changed on 1 January 2007 (see above), resulting in the spatial planning structure depicted in figure 6 and described in detail below.

National Planning

The Minister of Environment (and Planning) is responsible for developing a National Planning Statement after each national election and inviting a public debate on its contents. The National Planning Statement defines the overall guidelines for planning, while it is the task of the municipalities to translate the overall guidelines and visions into spatial planning on the ground. In specific cases, obligatory directives on national planning issues, so called National Planning Directives, are also developed – this is the case for deciding areas for holiday cottages near the coast, gas pipelines etc.

The National Planning Statement encourages the municipalities and regions to aim for quality in planning – in the city, in rural areas and in the wider countryside, providing sustainable cities – where we can work and live, with open landscapes and a suite of wildlife areas to visit and enjoy. The Statement deals with current development trends and problems in relation to town planning policy, housing and industrial development, the tourism sector etc.

Five primary objectives for spatial planning

In order to ensure the connection between decentralized and centralized planning, the National Planning Statement specifies five primary objectives which must be applied to spatial planning across the whole country:

- Maintain the distinction between countryside and city;
- Development should benefit the entire country;
- Planning should be based on respect for the city identity, nature, environment and the landscape;
- Spatial planning and investment in the infrastructure must be closely connected;
- Spatial planning must provide overall guidance, including securing the dynamics between city and country and the functionality of the city.

Regional development plans

The five new regions must develop regional development plans, which reflect what the regional board considers important for the future develop-

ment in the cities, rural areas and outskirts. The regional development plan must therefore focus on the overall and more strategic visions for the future development of the region, especially creating regional co-ordination across municipal boundaries. Regional development plans have no official status as spatial plans and are not binding on the municipalities.

Before local government refom in 2007, when the regions were smaller and known as counties, each county was responsible for developing binding regional spatial plans. After the reform, most of the County Regional Plans were merged into National Planning Directives. Ribe County Council and South Jutland County Council adopted a supplement to their regional plans for the two counties to cover the Wadden Sea and its surroundings. The regional plan supplement was merged into the National Planning Directive and provides the framework for municipal planning and administration of the area. It contains common visions and goals and common principles and approaches to future planning and management of the area.

The main views expressed and the goals are:

- Highest priority for public safety against floods;
- The urban development in the Wadden Sea area and the hinterland can be carried out on an equal basis to other parts of the region;
- The ports of Esbjerg and Havneby need continued development;
- Farming should continue and be developed on a sustainable basis;
- Nature conservation is a priority, particularly in the international nature protection areas;
- Areas of high natural value may continue to be exploited for tourism and recreation, while having due regard to the natural heritage;
- Construction of technical installations, etc. must take into account the natural, landscape, environmental and cultural values;
- The undeveloped coastal landscape, of great natural and landscape value, must remain free from buildings, etc., except when needed for agricultural development.

The plan contains guidelines primarily to conserve nature and to ensure that there is room for development of various urban and industrial areas, and agriculture in general.

Municipal Planning

From January 1st 2007 the municipalities were given authority to plan their own development – in both the urban and rural areas. The municipality plan is the link between national planning and detailed local planning, which is directly binding on the owner and user of the property in the local plan.

The municipal plan will be the foundation and definitive plan in which objectives and rules for land-use in the municipality and local area are presented to citizens and businesses.

The municipal plan must –as well as the usual municipal planning subjects – also include sectors, which formerly have been considered to fall within the regional planning process and furthermore provide guidelines on how spatial planning supports strategic sectoral development plans, e.g. tourism, industry and agriculture.

Local Planning

The local plan is the tangible and detailed spatial plan for a specific area in a municipality. The local plan determines how a smaller area should be used and it determines size, appearance and location of buildings, roads, recreational areas etc. The local plan may also determine individual elements in a larger area e.g. signs and architectural features.

An example can be found at http://www.fanoe.dk/dokumenter/lokalplan_88.pdf (in Danish)

4. Spatial planning in coastal risk management

4.1 Introduction

CPSL concluded that spatial planning may present a flexible and sustainable tool to deal with the effects of sea level rise. Spatial planning measures may diminish the risk to the coastal population by reducing the damage likely from flooding and land loss. In this context, risk is defined as the likelihood of a harmful event (flooding, land loss) and the resultant damage. Consequently, coastal risk management is more than protection against the hazards of flooding and land loss. It may be seen as a holistic control loop that consists of a number of interacting elements or tasks, involving a comprehensive set of measures designed to either reduce or avoid vulnerability to coastal hazards (Fig. 7; Hofstede, 2007).

Prevention aims at avoiding or minimizing risk, e.g., by specific regulations for new building areas in hazard zones. Hence, the main tool is spatial planning. Protection aims at minimizing the probability of a harmful event by technical measures (e.g., dikes, sand recharging, groins, etc.). Preparedness has much to do with hazard awareness. Informed people are (more) willing to take precautionary actions (incl. evacuation), and they accept the high costs and other possible constraints of coastal risk management. The main tool to achieve hazard awareness is risk communication. Like protection, emergency response manages the "worst case" scenario (i.e., flooding). Flood warning and evacuation are two well-known measures. Recovery defines all aftercare measures, such as repairing the dike breaches and psychological assistance for those affected. Finally, review is learning from new data and research outcomes as well as from disasters. It aims at optimizing the next control loop and monitoring programmes are an important aspect of this element. New or, perhaps more correctly, re-invented in this cycle are the elements of prevention and preparedness

This description of CRM demonstrates the importance of an integrated approach, as at least three disciplines -spatial planning, coastal protection and disaster management (incl. research on each)- are involved.

The main purpose of this chapter is to place spatial planning in an integrated coastal zone risk management perspective. First, in section 4.2 an overview is given of existing national spatial planning instruments relating to coastal risk management. In Section 4.3 spatial planning is considered in a more systematic and holistic way, taking account of the changing context regarding coastal defence management, caused mainly by the potential impacts of climate change.

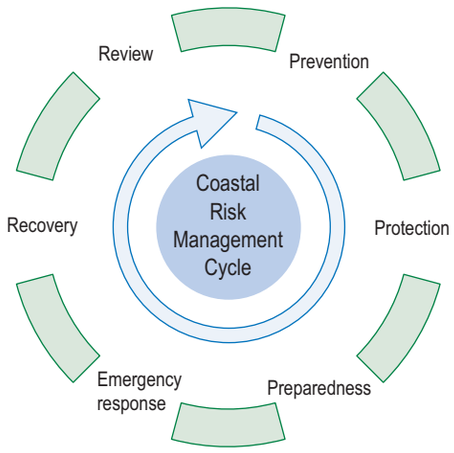


Figure 7:
Coastal risk management cycle.

4.2 Existing spatial plans for the Wadden Sea coastal area

4.2.1 The Netherlands

The main spatial planning instrument for the Wadden Sea is the Key Planning Decision Wadden Sea (PKB Waddenzee) (see also Section 3.2). The current PKB Wadden Sea, the third, runs from 2006 to 2016. The area covered by the PKB (Figure 8) includes the Wadden Sea proper and uninhabited parts of the islands and is bounded by the dikes on the mainland side. The main aim for this area is sustainable protection and development of the Wadden Sea as a wildlife area and conservation of its unique open landscape. The PKB is an integrated policy document, covering areas of competence of several ministries. It contains guidance which must be taken into account by responsible authorities, as well as obligatory decisions. Examples of the latter are the prohibition of harbour extension within the area, the prohibition of construction works and the prohibition of wind turbine construction.

The PKB itself does not specifically address coastal protection or the possible impacts of sea level rise. These themes are covered in the management and development plan, setting out the main points of the implementation of the PKB (see further below).

The three Wadden Sea provinces, Noord-Holland, Fryslân and Groningen, have also drawn up a joint policy plan for the Wadden Sea (1994). This Plan, which remains in force, contains a section on coastal defence, referring to the national policy plan for coastal protection. This national plan aims at dynamically maintaining the sandy coastline as it was in 1990.The main instrument

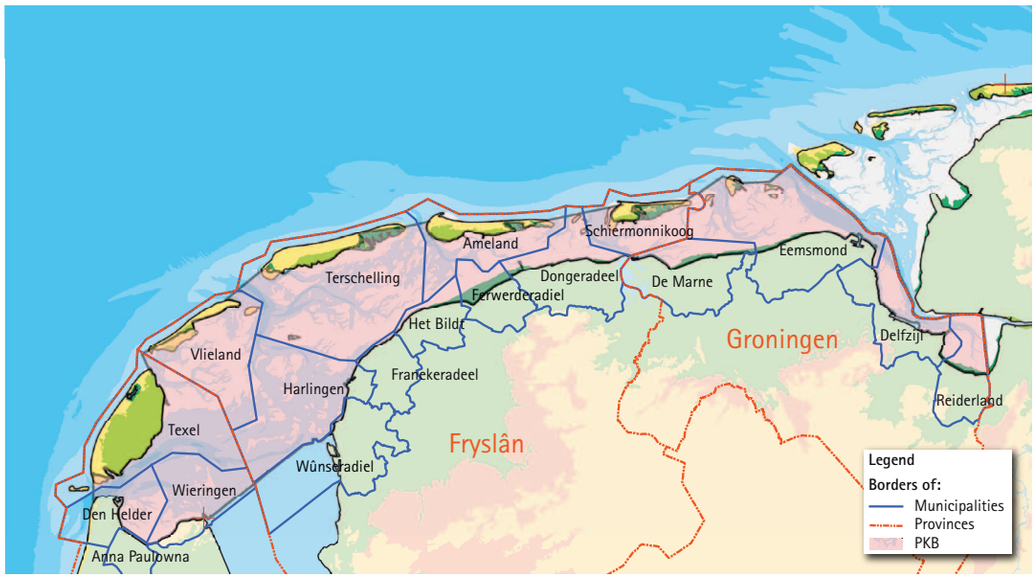


Figure 8: Boundaries of the PKB area and municipalities. Source: Derde Nota Waddenzee.

for achieving this goal is sand suppletion. Under the terms of the Delta Plan, dikes are maintained to specific safety standards. The Plan contains no specific spatial planning relevant decisions in the face of increasing sea level rise.

There are 18 municipalities bordering the Wadden Sea (of which 5 are island municipalities). These municipalities cover part of the Wadden Sea, the islands and/or the mainland (see figure 8). The non-marine parts of these territories are included in the land-use plans of these municipalities. So far, the land-use plans contain no specific spatial planning elements, relating to coastal protection and sea level rise.

Management and Development Plan

As described above, the PKB Wadden Sea is the main spatial document for the Wadden Sea. The framework for the implementation of the PKB is set out in the Management and Development Plan (B&O Plan). The first part of this plan, (part A), sets out the objectives of the PKB for all responsible authorities, i.e. 5 ministries, 3 provinces, 4 water boards and 18 municipalities. It has the status of a structural vision document (see section 3.2) and will be implemented through, inter alia, municipal land-use plans.

An interesting feature of the B&O Plan is that it covers an area larger than the PKB itself; it also includes the inhabited parts of the islands and mainland areas behind the dikes. This area is called the Wadden Sea area and includes the territories of all 18 Wadden Sea municipalities (Figure 8).

The first draft of part A of the B&O Plan was published in June 2008. One of the four main implementation objectives of the B&O Plan is to increase the resilience of the Wadden Sea area against possible impacts of climate change. This will be achieved by improving and restoring natural processes and interactions within the Wadden Sea, its salt marshes, islands and the mainland.

Strengthening of dunes and repairs to dikes have been or will be encouraged through spatial plans. As a result of pilot studies and projects, knowledge about new methods of coastal protection and dike strengthening will be gained. Such new methods include broader dike zones and the re-installation and use of secondary dike lines. Dunes will be re-inforced through sand suppletion. The dynamics of dunes and salt marshes will be augmented. The role of bio-engineers (mussel beds, sea grass beds) for coastal protection will be further investigated.

Anticipated problems with fresh water storage on the mainland will be tackled by increasing the storage volume and providing sufficient sluice and pump capacity. Furthermore, measures will be taken to prevent salinization of agricultural areas behind the dikes or to anticipate this process by growing salt-tolerant crops.

Further refinement of the above broad objectives is planned for the period 2009 to 2014.

National Water Policy Plan

The National Water Policy Plan contributes to integrated spatial development by seeking to reach a balanced development of nature, economy and infrastructure within the coastal zones. As suggested by the Delta Committee (2008), space for this purpose might be found in the North Sea zone by additional supplementary feeding of sand to compensate for the losses. Although this

is mainly proposed for the Holland coasts, the barrier islands are not specifically excluded from this option - the Government has decided to study this proposal in the future. For the moment, the water managers will continue to carry out the high-water protection program, which aims at increasing the safety levels (including the Frisian and Groningen mainland coasts) so that they will meet present day demands by 2015. The 'yes if – no unless' policy principle for spatial developments is maintained.

4.2.2 Schleswig-Holstein

In Schleswig-Holstein the State Development Plan (see also 3.3.3) is currently being updated and extends to the 12 nautical mile limit. In this revision there will be, for the first time, principles and objectives for the coastal and maritime area and encouragement for a harmonization of land-use in the coastal area. Furthermore, it will place greater importance than ever before on coastal protection and sea level rise for Schleswig-Holstein.

Principles and objectives for maritime spatial planning in Schleswig-Holstein will be addressed in the state spatial plan only, because the municipalities have no jurisdiction beyond their shorelines.

The area of the "Schleswig-Holsteinisches Wattenmeer" National Park is included in the State Development Plan as an area of preference for nature protection. In these areas the protection of nature more widely or parts of it outweigh all other uses. That does not exclude all other uses, but those that may adversely affect wildlife and conservation.

Regional plans in Schleswig-Holstein therefore do not cover coastal seas but finish at the shoreline. For the mainland and the islands, however, they include coastal defence as well as other aspects. For example, it is stipulated that plans and measures in the potentially flood-prone coastal lowlands (see fig. 9) must take coastal defence into account.

When considering different interests, coastal defence always has clear preference over other sectors. Furthermore, coastal defence has to be implemented as described in the master plan Integrated Coastal Defence in Schleswig-Holstein. This plan describes the strategy for protecting the inhabitants of Schleswig-Holstein against the forces of the sea and includes a number of measures for the Wadden Sea area, such as sand nourishment, salt marsh management, dike strengthening, etc.

Figure 9:
Coastal flood-prone lowlands in regional plan V (Schleswig-Holstein North). The shaded areas indicate the area that could be flooded if no flood defence measures were taken (i.e. up to five meter above mean sea level along the North Sea coast; up to three meter above mean sea level along the Baltic Sea coast). In this 1,650 km² large area about 97,500 people live.

Prior to the updating of the state development plan, the spatial planning report Coast and Sea was prepared. This report formulates for the first time a holistic view of the uses in the coastal and maritime areas relevant to Schleswig-Holstein. It also contains several measures which should be considered in the state development plan. As a result, the state development plan deals with nature conservation, resources, off-shore wind energy, transport, tourism, harbours and, of course, coastal protection.

A number of user restrictions along the coast are prescribed in the SH Water Act. For example, building on coastal flood defence structures, dunes, beach walls and cliffs (up to 50 m landward from the upper edge) is not allowed. Excavations in any form are not allowed up to 200 m seaward from the shore (or in water less than 6 m deep).

4.2.3 Lower Saxony

After its amendment in 2008, the State Planning Programme of Lower Saxony (SPP, see also 3.4.3) contains for the first time aims and principles for integrated coastal zone management (Figure 10). The reason is that within the coastal zone land and marine-based interests and protection requirements interact and thus have a substantial potential for conflict. Therefore an integrated view is a precondition for planning and measures in the coastal zone.

The following principles of integrated coastal-zone management are to be taken into account when dealing with proposals likely to have spatial impacts in the coastal zone:

- Sustainable development is to be encouraged within the coastal zone;
- Within the coastal zone, a themed and geographically comprehensive perspective is to be adopted which integrates all the interests affected;
- Planning and development processes are to involve all affected stakeholders and all relevant local, regional and national authorities;
- Plans and measures should be reversible and adaptable to allow them to take account of the dynamics of the situation, the possibility of change, and any subsequent increase in knowledge;
- Planning and decision-making processes are to be supported by performance appraisals.

The state spatial plan for Lower Saxony has the objective of protecting the Lower Saxon coast and the East Friesian barrier islands against damage from storm surges, as well as land loss. The necessary space requirements are to be reserved, with a further objective that in regional spatial plans (RPP) preference areas for dike building and coastal protection measures are also to be secured (see further below).

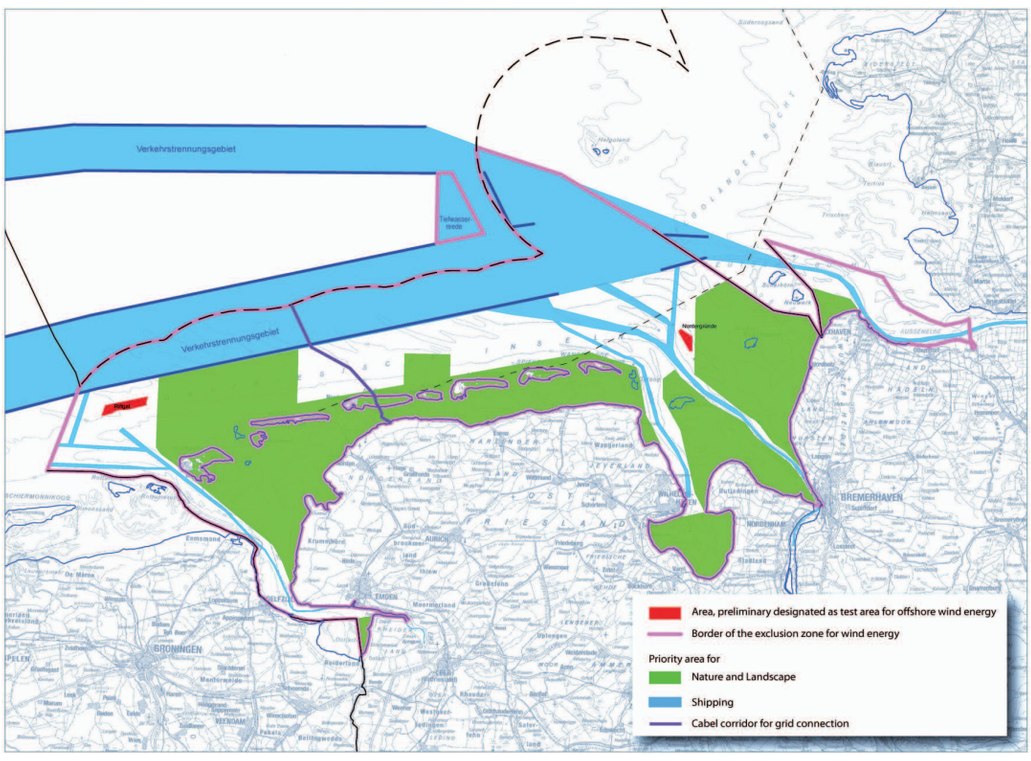


Figure 10: Spatial planning in the coastal zone of Lower-Saxony. Source: LROP Niedersachsen, 2006.

The Lower Saxony Spatial Programme is currently being updated because, during its initial amendments, completed at the beginning of 2008, the policies for raw material production were omitted. These will now be re-assessed and updated.

In chapter 1.4 - The Integrated Development of Coasts, Islands and the Sea - as well as in chapter 3.2.1 - Management and Supply of Water, Coastal Protection and Flood Control - further policies will be added, including for coastal protection e.g. by reserving necessary construction materials (extraction of clay and sand).

These new policies are intended to be implemented at the beginning of 2011.

Clay mining

Precautionary areas for clay mining have partially been designated by the Landkreise. However, no RPP has been carried out and, as a result, sufficient knowledge about all sites with suitable clay reserves is lacking. It is considered necessary that, at the level of the Landkreise and the state, sites with clay suitable for diking should be secured, as part of forward-looking spatial planning. Sufficient suitable clay is not available everywhere which explains why, in some Lower Saxon regions, the dike boards have developed clay management plans involving all relevant interests, especially agriculture, nature conservation and tourism. Processes exist by which an exchange of areas is possible, so that farmers do not lose agricultural land. In this way, the schemes become increasingly acceptable.

When clay mining ceases, the pits are generally made over to tourism and leisure activities. Through this kind of co-operation, acceptable and sustainable solutions can be found for all stakeholders.

In Lower Saxony clay is generally mined on the landward side of the dike but clay mining is also possible in front of the dike. The mandatory balancing of ecological, technical and economic interests has resulted in the conclusion that clay mining in front of the dike is sometimes necessary. In such cases mining must be carried out in such a way that restoration for biological diversity is achieved..

Spatial Aspects of the Lower Saxony Dike Law (NDG)

The Lower Saxony Dike Law comprises spatial aspects, intended to reserve space for future raising and strengthening of coastal defences, in preference to other uses. Exceptions, with tight restrictions, can be permitted. The main terms are:

- Large dune areas on the Wadden Sea islands are designated as "coastal defence dunes", where no use other than for coastal defence (flood and erosion protection) is permitted. This regulation is especially designed to reserve space for dune strengthening measures and protection of the dune vegetation against destabilisation by development;
- Landward of the main dikes, in a 50 m wide zone, any kind of construction is not allowed in order to allow space for future extensions of the dike;
- The use of coastal defences (e.g. dikes, revetments, dunes) is limited to coastal defence purposes;
- The dike authority can regulate the use of the dike foreland by decree, in order to protect the main dike;
- In case of a foreland with a width of less than 200 m, sediment for coastal defence purposes may be taken from within a 500 m wide tidal flat area next to the shoreline.

4.2.4 Denmark

As well as the Coastal Protection Act (see 3.6.1), the national interests governing the use of the coastal zone are contained in regulations relating to spatial planning, adopted under the Danish Planning Act in 1994. One of the overall objectives of the Act is to ensure that undeveloped coasts remain an important natural and landscape resource, confining new urban developments to existing built-up areas and not along the coast.

According to the Regional Development Plan (see 3.6.1), protection of the public against flooding has the highest priority. The plan contained no reference to new dikes but stated that there is a need to re-inforce some existing dikes. The Plan indicates that the dikes occupy large areas of marshland, which are the most endangered habitats, and, therefore, suggests that consideration is given to developing more benign coastal protection methods.

Expropriation for Dikes

Danish Authorities can expropriate the land necessary to build dikes. They can obtain the necessary land not only for dikes, but also areas where the material needed for construction can be mined.

The owner receives compensation for the value of the land he surrenders.

Building restrictions in Ribe Marsh

The Law of 1976 on Reinforcement of the Ribe Dike states that in the area protected by the Ribe Dike (Ribe Marsh, see figure 11), new buildings may not be erected without a permit from the Minister

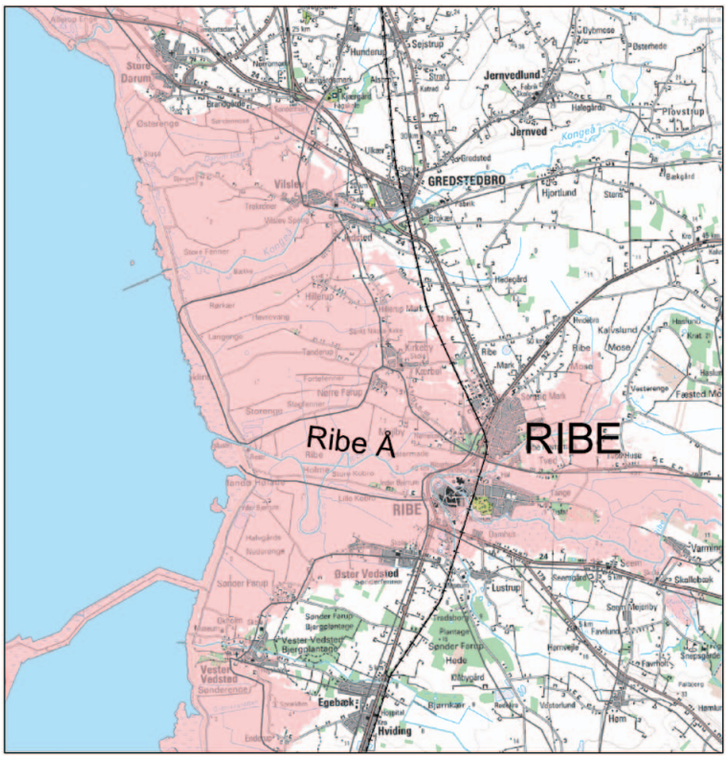


Figure 11: Ribe marsh. The area tinged pink has an altitude of 0 – 4.75 m.

for Public Works unless the building is required for the continued commercial use of the property as an agricultural holding. The same applies to any addition to, or rebuilding of, existing buildings.

The Minister for Public Works determines the boundaries of this area, after consultation with the local municipalities and makes the boundaries publicly known. The law was incorporated in the Regional Plan 2005 - 2016 for Ribe County, which specifies that new town development in those parts of the Municipality of Ribe (Now Esbjerg) protected by the Ribe Dike must be built with a floor level at least 4.75 m above sea level west of the Bramming – Tønder railway and at least 3.9 m above sea level to the east of it.

According to the regional plan the purpose of the regulation is to reduce the risk of damage caused by flooding.

4.3 Spatial planning instruments with CRM potential

4.3.1 Introduction

This section gives an overview of new ideas and initiatives, taking account of the changing context in relation to coastal defence management, mainly as the result of potential impacts of climate change, in particular rising sea levels, increasing storms and increased peaks in inland discharge of freshwater. In a number of cases it also incorporates additional objectives with spatial planning relevance, including habitat restoration, increasing coastal resilience and sustainable economic development. These additional elements are highly relevant for developments in a longer-term perspective, already taking into account several of the objectives of the 2010 Joint Declaration of the trilateral Wadden Sea Cooperation and the Lower Saxony Spatial Development Programme (see 4.2), as well as sustainable development strategies, developed by the Wadden Sea Forum.

In general, some basic characteristics of good spatial planning for coastal management can be defined. Good spatial planning:

1. includes and integrates all elements of the risk management cycle (see 4.1);
2. offers local solutions and which fit in the specific context of the area;
3. contains general guidelines and aims at defining the components of these integrated and location specific plans;
4. applies an integrated and holistic approach;
5. considers natural values and resources;
6. makes use of the physics characteristics and guiding principles (see 4.3.2 and 4.3.3).

It should be noted that the first element concentrates on coastal defence, whereas the subsequent ones increasingly offer the option of integrating

additional objectives into the coastal spatial plan.

In the following section, 4.3.2, examples will be given of spatial planning elements, mainly concentrating on coastal defence. In 4.3.3, spatial planning on the basis of physical characteristics will be examined. In 4.3.4, proposals of spatial planning elements with a wider perspective will be considered.

4.3.2 Spatial planning strategy and Guiding Principles

Treating the flood defence system as a single zone implies that integrated development may take place within these areas, which need to be supported by spatial planning. If this approach is extended to the flood defence system, a sustainable oriented approach (a so-called Three Steps Strategy) can be defined: spacing, broadening, raising.

1. Spacing

Spacing means that the flood defence solution is sought by creating an extended zone in front of or behind the primary flood defences. This can be a second dike, a reef or extended salt marshes. The advantage of spacing is that, as well as the integrated and cooperative way of planning, the different mechanisms work better than if they were separated.

2. Broadening

Broadening implies the creation of broad super- or delta-dikes, which are made so broad that they never breach, although water may overtop. The advantage is that on top of the broadened dike new activities can take place, such as use for biodiversity, homes or agriculture.

Box 5: The Governing Principle of Moving Sand

Several examples exist of how the concept of moving sand is or may be implemented to counteract greater sea level rise.

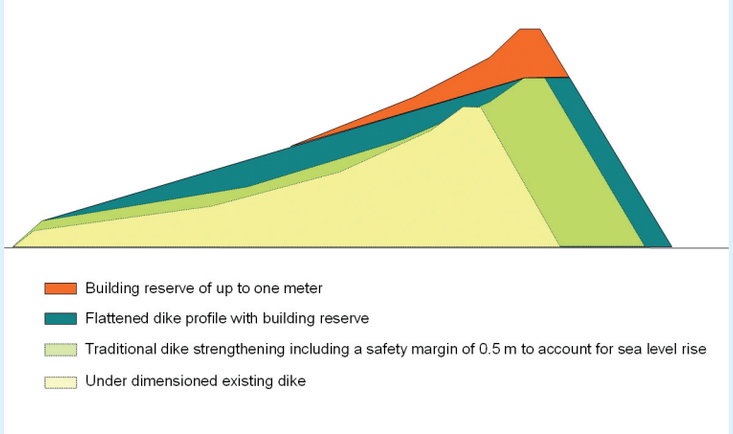
In 2007, the Dutch Government established an independent Delta Commission with a remit to evaluate and recommend possible flood risk adaptation strategies and measures to counteract climate change (Delta Commissie 2008). The main recommendations of the Commission concerned the movement of sand in, so far, unknown quantities:

In order to make the sandy coasts more resilient against sea level rise, an increase in the annual sand nourishment to about 85 million m^3 was recommended. By doing this, it is expected that an annual sea level rise of about 12 mm can be balanced and the coast may even extend in a seaward direction (as a climate buffer).

In high risk areas with high concentrations of inhabitants like South and North Holland, the safety standard should be increased by a factor of 100. To achieve this, construction of so-called delta dikes was recommended. These dikes are so high, broad or strong that a breach is seen as impossible. As they can be several hundred m wide, multi-functional uses can be considered.

In Hamburg, an extensive new building area in front of the main dike line (in the harbour area) is being formed, using the so called dwelling mound concept. This means that the whole area is raised (by moving sand) to such a level that it seems hardly possible for future storm surges to flood the area. Further measures (evacuation routes, flood-proof housing) are implemented to reduce the remaining risks.

Finally, in Schleswig-Holstein, the uncertainty with respect to the actual amount of future sea level rise is anticipated by the concept of re-profiling to create building reserves for future dike strengthening (Figure). Dike strengthening measures include a safety margin of 0.5 m in order to balance sea level rise. In addition, the strengthening efforts include a re-profiling of the outer dike slopes to allow for later height adjustments of a further meter if necessary (i.e., when sea level rise becomes more than 0.5 m). Hence, in two strengthening campaigns (by moving sand), a total sea level rise of 1.5 m can be balanced.



3. Raising

Heightening is the usual way to strengthen dikes. Heightening provides coastal defence, but without integrated development or a combination of functions.

It is recommended that the three steps are considered sequentially. If a spacing solution is not possible, then broadening should be examined and, if that is not practicable (for instance because space is limited or for socio-economic reasons) raising may be explored.

In dealing with flood risk in the abstract, three components can be moved: water, sand and people. These may be defined as Guiding Principles for spatial planning in coastal flood-prone areas.

Moving water

Where a region has to deal with surpluses of water, it is generally moved out of the area. During times of heavy rain, water is pumped off the land into the sea. Keeping sea water out of areas where it does not belong is also a form of moving water. - in the case of sea level rise this task becomes more difficult. If water is allowed into the area it will affect people or sand movements.

Moving sand

Another option is to move sand. Too much water results in flooding, both from inland sources and from the sea - this hazard can be countered by moving sand. If lower parts of the terrain are raised with sand the probability of flooding is reduced. The same goes for the coast: if the flood defence zone (e.g. dikes, dunes, wetlands) is raised with sand or other sediments the probability of flooding is minimised.

Moving people

The third possibility to reduce the impacts of floods is to move people. If an area is under (high) risk of flooding, the evacuation of the population reduces the vulnerability. The same applies to assets (economic, property, infrastructure) in the flood-prone area. Keeping people out of a flood prone area is also a form of moving people and also an opportunity to reduce vulnerability.

Generally, the situation demands a balanced combination of moving water, sand and, finally, people. If the natural conditions are suitable to discharge water, moving water seems to be the best alternative. If moving water becomes more difficult, moving sand or even moving people comes into consideration. Conversely, if the sand and/or people are moved, it then becomes possible to let water in from the sea, increasing natural resilience.

A general overview of a typical coastal zone includes the elements in Figure 12. Moving water, sand and people can be applied to these elements, depending on the situation.

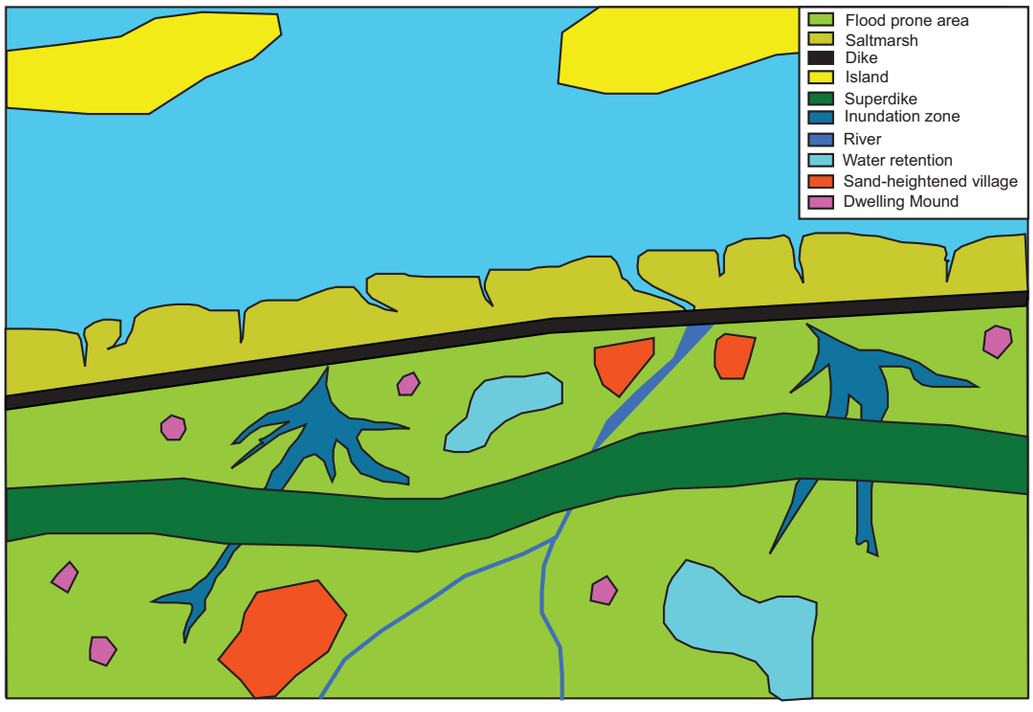


Figure 12: Schematic overview of typical coastal zone elements.

4.3.3 Spatial planning instruments and coastal defence

Zoning

CPSL II recommended the establishment of coastal regional plans with defined buffer zones and flood hazard zones.

Buffer zones are defined as:

Coastal buffer zones, defined by setback lines in spatial plans, may provide protected zones between the sea and the hinterland, where human land-use and development are tightly restricted. As the term "buffer" implies, this measure provides a spatial buffer zone between the sea and the coastal hinterland, which may either allow for erosion or safeguards space for necessary coastal defence measures. Several categories of buffer zones may be defined, e.g., from zones where all human activities are prohibited to zones where certain time-limited activities/investments and easily removed properties are allowed. The zones may be included in all spatial plans and programs, e.g. local building plans, regional plans or (inter)national programs. Buffer zones are long-term planning measures which have to be considered by planning authorities decades before they might actually fulfil their function.

Coastal flood hazard zones are areas potentially endangered by storm surges. If no coastal defences existed, these coastal lowlands would probably be inundated during such surges. Coastal flood hazard zones may be defined in several categories, e.g., low, middle and high probability of flooding or low to high vulnerability as in the EC-Flood Directive. For different zones, different regulations may be defined in spatial plans.

For example, Schleswig-Holstein is considering identifying areas of preference and areas of reservation for coastal protection on the basis of flood hazard maps and flood risk management plans prepared for the EC Flood Directive. These are included in future state development plans and regional plans. The suggestion here would be to include those areas that are referred to in the management plans as necessary for coastal protection as areas of preference and all other areas identified in the flood hazard maps as areas of reservation.

The areas of preference for coastal protection would be larger than the areas now needed for dikes etc and this will ensure that additional space-oriented solutions can be applied. In these areas, other uses can be introduced only where they don't interfere with coastal protection.

In the areas of reservation for coastal protection some settlement may be allowed, but the special risks and demands of flooding need to be borne in mind.

Regulatory Measures

In 4.2 it was shown that there are possibilities for using buffer and preference areas, for example in the Ribe marsh area where conditions are applied to new buildings and structures. Several examples are given below of regulations and prescriptions relating to coastal risk management. These may be incorporated via regional plans in local building plans, and to which spatial planning possibilities should be extended.

These regulations should be seen as possibilities and opportunities for use, where appropriate, in a particular spatial plan or spatial planning instrument.

- Designate areas of preference for coastal flood defence and, if necessary and appropriate, also further inland;
- Strict restrictions on new building areas in high hazard zones (e.g. the lowest areas in a polder, exposed areas without flood defences);
- A ban on new building areas in buffer zones;
- Raise new building areas and critical infrastructure above storm flood level (Halligwarften, Hafencity Hamburg, Vinexterp);
- Extra heightening of existing urban concentrations and infrastructure with sand up to a level above storm surges, bearing in mind the rising sea level (Figure 13). Since this is a long-term process, it should be initiated in good time;
- Construction of super-dikes. Super-dikes (Figure 14) are extra broad dikes, which cannot be breached, although water may overtop the dike;
- Erect/maintain second dike lines in order to reduce the area of flooding and as evacuation roads (compartmentalization). Compartments and self-supporting cells aim to create smaller compartments in order to confine the effects of a flood to a small area. If, in addition to the compartments, self-supporting cells are created where people gather in case of a flood, the damage can be kept to a minimum;
- Build or raise roads to a higher level in order to limit flood areas and for use as evacuation routes based on flood risk maps This requires very close cooperation with coastal flood risk managers;
- Flood-proof housing (i.e. guidelines in regional plans and prescriptions in local

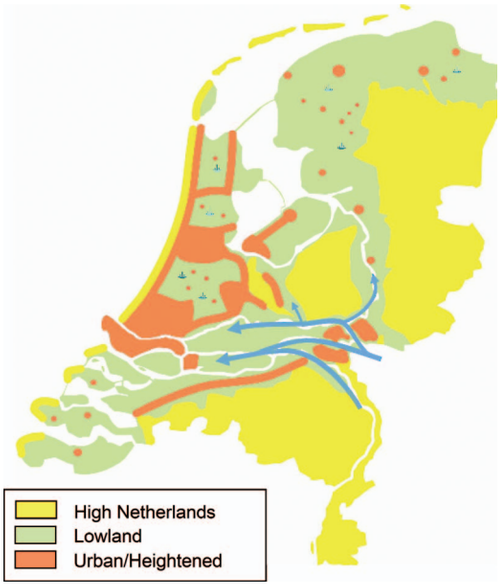


Figure 13: Extra heightening of existing urban concentrations and infrastructure with sand. Source: Aerts et al., 2008.

building plans). Examples are shelter rooms, houses which float, regulation of hazardous facilities, restrict living to upper floors (see figure 15);
- Flood-proof construction of the infrastructure;
- Include guidelines for contingency planning in regional plans for flood-prone areas, incl. evacuation routes, rendezvous points, evacuation exercises and information campaigns;
- Establish the right of compulsory acquisition for coastal defence purposes in buffer zones;
- Designate areas of preference for the extraction (from outside the Wadden Sea sand-sharing system, see 5.3.3) and nourishment of sand for coastal defence purposes
- Designate areas of preference (preferably inland) for the extraction of clay for dike strengthening;
- Designate areas of preference for natural dynamics (aeolian processes, overwash, salt marsh accretion) to balance sea level rise.
- Designate areas with high flood hazards and low damage expectation, in which coastal defence measures may be reduced or abandoned, providing opportunities for natural dynamics and/or recreation.

4.3.4 Spatial planning based on physical boundaries

The guiding principles (4.3.2) illustrate that different natural characteristics can be managed differently. In an area influenced largely by the sea, it is clear that the sand guiding principle is able to define spatial measures and structures. The same goes for the mainland, governed by the

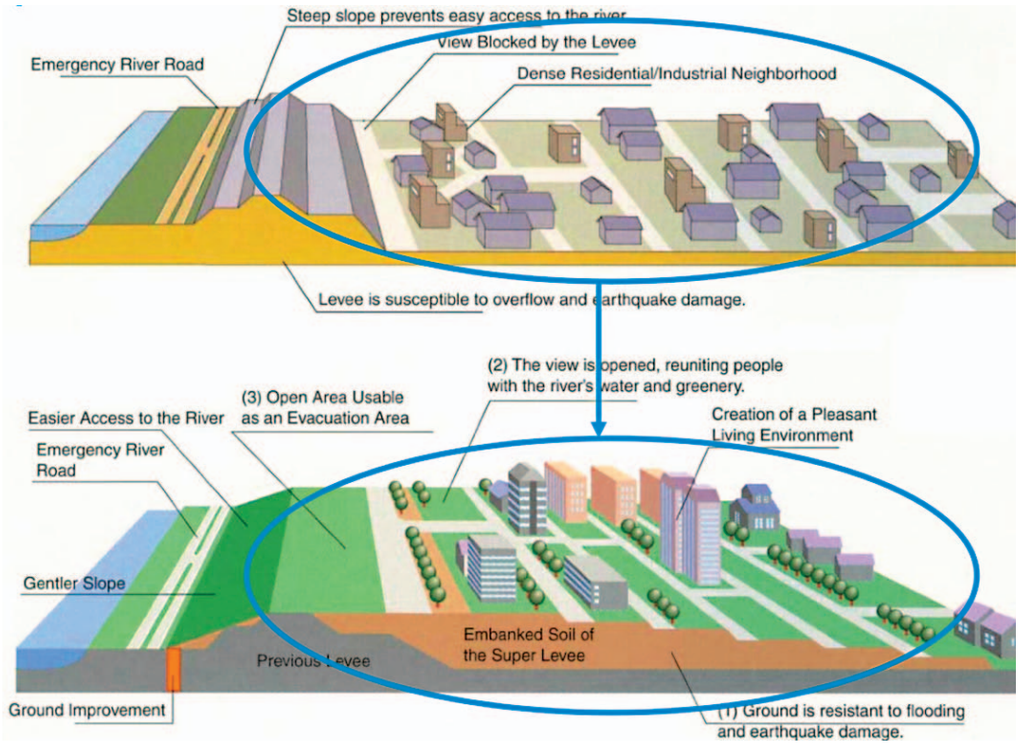


Figure 14: Super dike. Comparison of classical dike (top) with super dike (bottom). Source: Stalenberg, 2008.

water guiding principle and the flood prone area governed by sand and water at the same time. If these differences are taken as leading principles for spatial planning, it becomes possible to develop spatial plans, with their boundaries between the differing areas. Since the new spatial law in the Netherlands came into force, mandatory plans can be developed for areas across several administrative units. It is also now possible to forge agreements on elements that are to be achieved in the plan over a period of more than the traditional 10 years, for example 40 or 50 years.

Especially in coastal areas, these changes are profitable. From a coastal point of view, the characteristics are more often based on the different physical components than on municipal boundaries. Sea level rise, which has specific impacts on different administrative authorities, can be tackled better by plans which focus on physical attributes. The new planning system makes it possible to develop a spatial plan for a flood prone area, for example (see Figure 16). In this plan, agreements can be made and policies can be described for this specific zone, enhancing improved and defined policies for the area in the longer term. Assuming a greater sea level rise in the next decades, the plan for the flood prone area can stipulate the measures that need to be implemented in the next 10, 20, 30 or 40 years in order to stay up to date. The final advantage of this new planning approach is the stimulation of

Figure 15: Summer houses in the port area of Rømø. The lower floor may not be used for living in, since the height from ground to first floor is insufficient for use as living space. Source: Flemming Kondrup.

cooperation between authorities. They must work together on the integral safety of all their communities and benefits (including financial) resulting from the plan also need to be shared.

If such a planning approach is used, the aim must be to develop an integrated flood prone area structure vision. In this structure vision the process needs to start with an analytical phase in which all functions, policies and problems for the area are examined. Based on this analysis, a program needs to be developed in order to define the goals for the area, both quantitative and qualitative, and also to define the relevant functions, policies and problems. Once this program has been developed, the plan can be designed and an integrated vision for the area and its future established. In this vision, measures for both the short term as

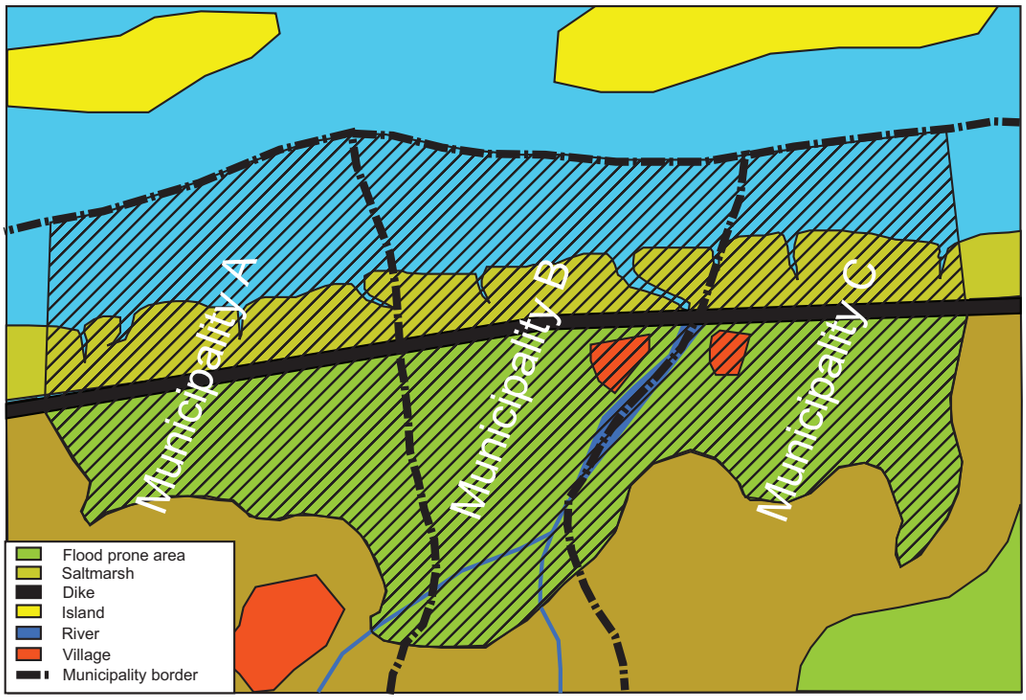


Figure 16: Spatial planning on the basis of physical boundaries. The shaded area is the area covered by the Integrated Flood Prone Area Structure Vision.

well as for the longer term can be defined. Since this structure vision is integratesd, all relevant functions will be part of the plan. The final phase is to define the manner of planning and funding delivery of the plan.

4.3.5 Coastal defence in a wider spatial and functional perspective

The growing awareness of the urgency of coastal defence, prompted mainly by the projections of greater sea level rise, has led to a general consensus in The Netherlands that strengthening of just one dike alone is not enough to keep safety levels high enough. An unclear future with large areas of uncertainty has given rise to a search for robust solutions (e.g. Delta Commission, 2008). This has led to many innovative solutions.

In the boxes below, several examples of projects from the Dutch Wadden Sea coast are presented, which aim to illustrate

1. coastal defences, arranged in such a way that resilience of the coastal zone is enhanced,
2. multifunctional developments in which several defence measures are integrated.

Such plans bring together coastal defence, habitat restoration, regional economic development,and fresh water management and require comprehensive spatial planning with a long-term perspective.

Box 6: Climate buffers

In the coastal zone, sea level rise has a huge impact on the ability to protect land behind the dikes. In addition, discharge of river-water to the sea is hindered. Moreover, saline seawater penetrates deeper into the land by inlets and groundwater flows. Finally, the salt water quality decreases because the supply of fresh water is hindered by sudden fluctuations, due to the increase of extreme peak showers. At the same time less sediment is available because the balance between river and sea is broken and the sea level rises faster (Bureau Stroming, 2006).

If climate buffers are installed, these areas would once more be able to keep up with sea level rise. To make this possible, the areas need to gain net sediment, for example by the introduction of dynamic coastal management, the restoration of tidal functions or the creation of new dunes. Between the dunes a plain emerges, where the sediment is able to accrete and a coastal zone develops instead of a coastline. Opening the coastline enhances the supply of sand and clay and therefore the land is raised where the sea level is rising. If housing is required here, it needs to be built on dwelling mounds. A spin-off of thinking in terms of a coastal zone is that the strict separation between salt and fresh water is lost and a rich variety of brackish habitats will emerge. Fresh water can be stored in fresh water basins in the dunes and can be transported to end-users by means of a ditch system.

The Wadden Sea already functions more or less as a climate buffer. However, Bureau Stroming states that the conditions for sedimentation in the Wadden Sea need to be improved. This can be done by restoring salt marshes, improving conditions for the development of sea-grass fields, mussel and cockle beds and enhancing sand transport on the islands.

Changing like this, the Wadden Sea area is capable not only of keeping up with the changes in climate but also able to improve safety at the same time.

Box 7: Climate-proof Eemsdelta

Several problems are concentrated In the Eemsdelta area: It is the weakest point in the Groningen coastal defence, the population is shrinking while the economy is growing, as at Eems harbour. Climate adaptation measures may be the key to mitigate the impact of falling populations (Wit, 2008). If the coastal zone is developed in an integrated manner, the area can be made more attractive. If new houses need to be built, they could be located in a unique landscape, created by the need to adapt to climate change. A broad coastal zone can be introduced where seawater can enter the hinterland, providing a new and dynamic environment for housing. If the sea is allowed controlled access to the hinterland, the landscape will be able to rise with the sea level and people living in the area will become accustomed to water in their environment. Resilience is thus increased (and vulnerability decreased) if the population becomes used to water in their environment and is not taken by surprise by a disaster, e.g. a breach in a raised dike. Moreover, this flexible and multifunctional zone provides an attractive landscape.

Eemsdelta as a dynamic coastal zone (Roggema et al., 2006)

The city of Delfzijl could transform itself into a unique town in the Eems. If the building and demolition of houses is planned in such a way that a compact walled fortress emerges, water could be stored in compartments around the town (figure below). Some compartments would contain sea water, while others would hold temporary surpluses of rainwater. In the future, the city of Delfzijl could become an island in the Eems.

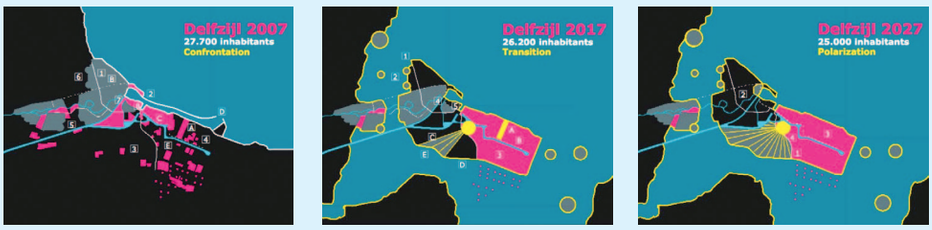
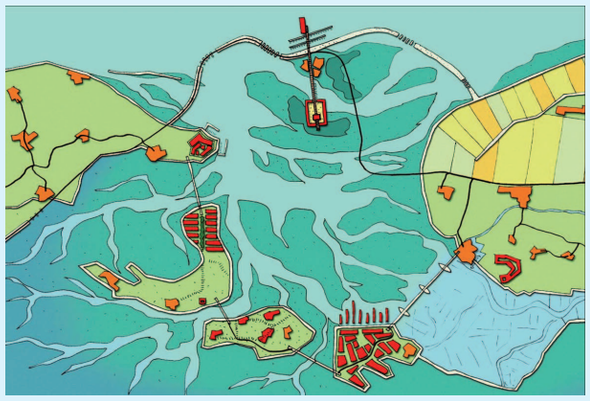


Image transition in phases: from the existing Delfzijl to Delfzisland (Klap, 2008)

Box 8: Lauwers Lake

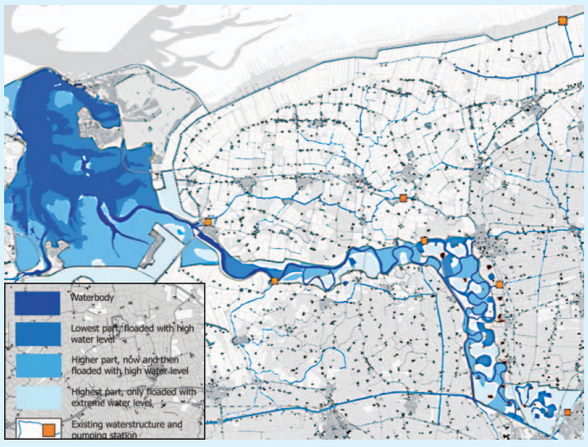
The Lauwers Lake plays a key role in water management in Northern Netherlands. Large amounts of water are discharged through the lake. The concentration on discharge leads to a static water system in the lake. There are other proposals, in which the area is seen as a more dynamic and naturally functioning system.

Within the Grounds for Change project the Lauwers Lake is seen as energy supplier (Roggema et al. 2006).
In this plan, the dike is dismantled and tidal functions return to the area. Energy is produced through a tidal plant (at the site of the old dike) and an osmosis plant constructed upstream, where salt and fresh water meet. The natural dynamics return and the Lauwers Lake area functions as a climate buffer with enhanced biodiversity. Additionally, unique housing is made possible in the newly developed dynamic tidal landscape.



Lauwers Lake as an energy supplier and under the influence of tides (Roggema et al., 2006).

In a design by Meliefste (2008) a fresh water reservoir is created by raising the existing dike. More water can be stored (figure below), which is required for winter periods when greater precipitation is expected. The extra stored water can be used in the drier summer periods. Moreover, a higher water level enhances the wildlife of the upstream Reitdiep area. The water in the Reitdiep sometimes reaches the edge or overtops the dikes. Wet grasslands and large water bodies appear in the area in the winter.



Lauwers Lake as a fresh water reservoir (Meliefste et al., 2008).

5. Compensation of sediment deficits

5.1 Introduction

In its second report (CPSL, 2005), the CPSL group concluded that sand nourishment successfully balances coastal erosion along the outer edges of the barriers. They may also contribute to the compensation for sediment deficits resulting from sea level rise, although the ecological effects are still unclear. Under the Terms of Reference for CPSL III the group was invited to investigate the possibilities of a study on the feasibility and effects of sand nourishment to balance the sediment deficit of the Wadden Sea in the face of increased sea level rise. On this basis, the following possible research questions have been defined.

This chapter starts with a short description of the role of sediments in the Wadden Sea in the context of climate change. Next, the compensation for sediment deficit due to climate change, like sediment sources, transport mechanisms and sinks, together with ecological considerations are discussed. For each of these topics, gaps in knowledge are identified. The chapter ends with a list of possible research questions that could be included in a feasibility study. A broad description of sand nourishment, including various national policies and practices, is given in CPSL (2005).

5.2 The role of sediment in the Wadden Sea

The Wadden Sea represents a huge body of sediments that accumulated during the Holocene transgression. In its present state, the Wadden Sea is characterized by 33 adjacent tidal inlet systems which comprise distinct morphological features such as barrier islands, tidal flats and tidal gullies. A comprehensive description of these features is given in CPSL (2001). Each tidal system can be considered as a sand-sharing system (Fig. 17) (Dean, 1988).

The elements of a sand-sharing system are linked and can be in, or strive to achieve, a dynamic equilibrium with the hydrodynamic conditions. For example, a particular tidal volume will create a corresponding cross-sectional area for a tidal gully. Changes in any part of the system will be compensated primarily by sediment transport to or from other parts of the same system. When changes are temporary and limited, the original dynamic equilibrium will eventually be restored. For example, a moderate increase in sea level rise induces a greater accumulation on tidal flats and salt marshes as a result of longer tidal inundation (i.e. the sediment has more time to settle). As a result, the level of the flats and salt marshes increases and the period of tidal inundation decreases again, and the former dynamic equilibrium is restored. If changes are more permanent or extreme, e.g. the "Afsluitdijk", a new equilibrium will be established with sediment being imported from or exported to areas beyond the sand-sharing system (CPSL, 2005; Dastgheib et al., 2008).

In response to the observed sea level rise, sediment accumulates in the Wadden Sea by several hydromorphological and biological mechanisms (see 5.3.1). In this way, the same average topographic situation with regard to sea level is maintained or, in other words, the dynamic equilibrium between hydrology and morphology is maintained. In the long term, most of the (abiotic) sediments are derived from the shore faces, beaches and

Figure 17:
Sand sharing-system.
Source: Louters and Gerritsen, 1994.

dunes of the barriers islands as well as from western Jutland and northern Holland. The North Sea bed beyond 10 to 15 m below MSL is not seen as a significant natural sediment source.

These factors demonstrate that the resilience of the Wadden Sea ecosystem with respect to climate change is heavily dependent on sediment, i.e., its availability and redistribution potential. In general, a stronger sea level rise will increase the demand for sediment from (limited) external sources in order to maintain its present dynamic equilibrium. If sea level rise becomes too great, sediment availability and/or the capacity for sediment transportation may be insufficient. As a consequence, greater water depth would allow higher wave energy (higher and longer waves) to reach the mainland and, in the long-term, dike strengthening campaigns may become necessary. In which case, the continuing extraction of sediments from the Wadden Sea increasingly becomes counter-productive.

It is interesting to note that hardly any scientific information is available about the volume of sediment needed to stabilize the Wadden Sea under given rates of sea level rise. Regional studies have been conducted, mostly based on semi-empirical models such as ASMITA (Stive et al., 1998; Kragtwijk et al., 2004). It is probable that, in the course of sea level rise, material will not be evenly distributed in the Wadden Sea. Some features, such as gullies, might even erode due to stronger currents, if tidal volume increases as a result of lower tidal flats. Sediment budget analyses for the last century in Schleswig-Holstein support this hypothesis (Hofstede, 1999). Many questions about the quantification of sediment redistribution patterns and processes, as well as about regional differences among sand sharing systems (CPSL, 2001), remain to be answered. Further research on this topic is strongly recommended.

5.3 Methods to combat sediment deficit as a result of climate change

5.3.1 Natural sediment transport into the Wadden Sea

Several natural processes lead to a net transfer of sediments towards the back-barrier part of the Wadden Sea and may thereby help in balancing sea level rise.

Due to tidal asymmetry, settling and scour lag processes as well as sediment trapping (e.g. by vegetation), more sediment enters the back-barrier basins during flood tide than leaves during ebb tide via the tidal inlets (Postma, 1961; Oost, 1995) - the net result is accumulation. Largely as a result of these processes, the Wadden Sea ecosystem has been able to balance a sea level rise of several metres over the last 5,000 years or so. Although regional gross sediment budget analyses are available (e.g., Hoselmann and Streif, 1998), quantification of the respective sediment redistribution potentials of the processes remains a research challenge. Progress is achieved by applying semi-empirical models like ASMITA.

Aeolian and overwash processes lead to a net sediment transport on and even over the barrier islands. With regard to aeolian processes in the dunes, hardly any firm figures have been collected on the rates of transport, but local deposition is known to be up to 1 m p.a.. Overwash processes and their effects on barrier stabilization remain poorly understood. Rough estimates for the Dutch barrier islands suggest that sedimentation rates over larger areas may amount to several dm/century.

The first and potentially the most sustainable option to combat sediment deficits due to climate change is the enhancement of the natural processes described above. Where appropriate and if permissible within national policies, options include to protect/create sediment traps (salt marsh vegetation, mollusc beds, sea-grass beds, etc.), and to allow/create more overwash and aeolian transport on the barriers. So far, only limited research has been conducted on this topic, for instance on the erection of brushwood groins as artificial sediment traps in front of salt marshes (Dijkema et al., 1990).

5.3.2 Artificial sediment input into the Wadden Sea

Artificial deposition of sand on strategic locations is another option to avoid sediment deficits. In the Wadden Sea area, nourishment is presently being applied in three situations:

- In the dunes, to maintain the flood defence function of the dunes;
- On the beaches to balance structural coastal erosion. To establish the volumes needed, the erosion is normally measured by reference to an established base-line or a minimum sand volume in a control area;
- On the foreshore, nourishment has the same aim as on the beach. However, the volumes may be greater since the costs per m^3 are lower and the effects appear to last longer.

In Table 3 an overview is presented of sand nourishment since 2000.

In the long term, beach and foreshore nourishment also help to stabilize the back-barrier basins. The fed areas are eroded and the material is transported – by the mechanisms described in Section 5.3.1 – into the basins and along the shoreline. However, little is known about the morphological behaviour of the nourishment, and about transport routes, volumes and terminal sinks of the nourished material.

Apart from the source areas (see below), ecological impacts of nourishment occur in all three deposition sites. Although adapted to high natural dynamics, the biota may be influenced by burial, changes in grain size and nutrient composition. On a larger scale there is a question about to what extent the dumping of sand leads to an increase in grain size locally and in the Wadden Sea as a whole, in particular the possible effects on morphology and biota

Acknowledging that the Wadden Sea is a sand-sharing system with permanent sediment redistribution from one element to another (CPSL 2001), several research questions arise about optimal locations, volumes, timing and grain size of the nourishment.

5.3.3 Sediment sources

In order to balance additional sediment demands resulting from sea level rise, the sediment should be taken from outside the Wadden Sea sand-sharing system. The seaward limit of this system is between 10 and 15 m deep. Thus, sediment imported from below that depth may be considered to feed the Wadden Sea system. Sedimentary morphological investigations at an extraction site in about 15 m of water showed no interference with sediment transport patterns on the foreshore (Zeiler et al., 2004).

From recent studies on the ecological effects of sand extraction from the floor of the North Sea, it appears that there are pros and cons for local deep dredging as well as for shallow extraction over wide areas. Local deep drilling limits the ecological effects but may cause long-lasting (> 100 years) negative biological disturbances, whereas, in the case of shallow extraction, biotopes may be restored after a few years. Disturbance, however, occurs over much wider areas. For example, Schleswig-Holstein favours deep dredging; other countries carry out shallow mining. Which method should be applied may depend upon the distribution and characteristics of the sediment, on the volumes needed as well as on other, as yet unknown, aspects. A comparison of national approaches and conducted EIAs is desirable.

Region	NL	NdS	SH	DK
2000	2.59	0.31	1.67	0.12
2001	0.50		1.03	
2002	1.00		0.97	
2003	1.50		0.94	
2004	5.40		1.02	
2005	1.21		1.14	0.08
2006	1.43		1.17	
2007	2.64	0.30	1.43	
2008	0.39		1.24	
2009			1.10	
Sum	**16.66**	**0.61**	**11.71**	**0.20**

Table 3: Volumes of sand (Mm^3) nourished on the Wadden Sea barrier islands.

5.4 Research questions

As a first step, desk studies should be carried out to gather and compare existing information about sand nourishment in the Wadden Sea, including extraction sites as well as morphological and ecological impacts of extraction and dumping. In addition, in connection with the above topics, the CPSL group formulated a number of research questions, listed below and these could be incorporated in a feasibility study. However, it should be noted that this list is not exhaustive.

Sources

- Beyond what water depth should sand preferably be mined for nourishment and is there a regional variation in this depth?
- How much sediment is needed to counteract particular rates of sea-level rise along the outer coasts and for the Wadden Sea as a whole? Are there functional relationships?
- Are the available amounts of sand sufficient for the future and which grain sizes are available?
- What kind of dredging (volumes, form, timing and frequency) results in minimal morphological effects?
- What kind of dredging (volumes, form, timing and frequency) results in minimal ecological effects?

Transport agents

- Can import and trapping mechanisms be improved?
- Quantification of (natural) sediment sources?
- Can main/major sediment transport mechanisms, routes and volumes be defined?

Sinks

- Where are the optimal locations for artificial sediment-deposition to balance sea-level rise in the Wadden Sea?
- What are the morphological impacts?
- What are the ecological impacts?
- What happens to the deposited sediments?
- Which grain size and quantities are optimal?
- What kind of nourishment techniques should be used?

6. Conclusions and recommendations

In this chapter conclusions are listed, as well as recommendations based upon these conclusions. The conclusions and recommendations must be seen in combination with, and as an update to, the conclusions and recommendations from the earlier CPSL reports (CPSL 2001, 2005).

Conclusions

Spatial Planning

- Coastal defence is a major element in the management of coastal risks which aims to reduce the hazards from storm surges to people and their assets. The other elements in the management cycle are prevention, preparedness, emergency response, recovery and review (Section 4.1, Fig. 7).
- Prevention and limitation of coastal risks by appropriate spatial planning constitutes the first step in a sustainable coastal risk management cycle in that it reduces and controls the vulnerability of coastal regions.
- Spatial planning can contribute significantly to improving the resilience of the coastal system against climate change. The current spatial planning instruments, however, need to be further developed in order to cope fully with anticipated impacts of climate change.
- Designation of hazard zones in coastal regions is an efficient spatial planning option since it allows for the prescription and implementation of tailor-made and proportionate regulations for the use of coastal lowlands.
- Spatial planning, based on physical instead of administrative boundaries, enables an efficient tackling of coastal challenges resulting from climate change in that it considers the physical characteristics as well as the guiding principles sand, water and people in coastal regions.
- Long-term impacts of climate change require extended planning horizons.

Sand Nourishment

- The Wadden Sea represents a huge body of sediments that accumulated during the Holocene transgression. A number of processes, such as tidal asymmetry, settling lag and overwash, determine the import and distribution of these sediments. In consequence, the future stability and integrity of the Wadden Sea region is determined by sediments; their availability and their ability to be redistributed. Consequently, sand (sediment) and water represent guiding principles in the Wadden sea region.
- The predicted sea-level rise may induce a sediment deficit in the Wadden Sea.
- Sediment deficits can be compensated by importing sand from outside the Wadden Sea sand sharing system (i.e., beyond the –10 to –15 m isobaths). Sand nourishment along the outer coastlines of the barriers successfully balances coastal erosion. Due to the processes described above, this replenishment may eventually contribute to the compensation of sediment deficits in the Wadden Sea tidal basins.
- For the large scale application of sand nourishment, information is needed regarding the sediment source areas and the optimal nourishment sites as well as the likely transport routes and sinks of the nourished material. For these issues, research questions are listed in Section 5.4.

Recommendations

Sand Suppletion

- A trilateral study on nourishment to combat negative effects of sea level rise in the Wadden Sea should be conducted on the basis of the defined research questions (Section 5.4). The trilateral cooperation should determine appropriate financing opportunities.

Spatial Planning

- Coastal buffer zones and coastal flood hazard zones should be implemented in spatial plans, including the application of regulatory measures within these zones (Section 4.3.3).
- Regulations, prescriptions and measures described in section 4.3.3 should be implemented in spatial and building planning, as well as in coastal risk management.
- If strengthening of the flood defence system becomes necessary due to climate change a Three Steps Strategy consisting of spacing, broadening and raising should be followed in spatial planning. (Section 4.3.2).
- The Guiding Principles of moving water, sand and people in an appropriate balance should be applied in spatial planning processes.
- Integrated coastal zone planning should be based upon physical characteristics defining the planning boundaries and involving multiple authorities, as well as the land and sea interface.
- In order to adapt to changing environmental circumstances the enhancement of additional

spatial initiatives, designs and ideas should be encouraged, because they can lead to new insights in dealing with these conditions.
- In order to adapt to the impacts of climate change an extended planning horizon (e.g. 50 years) should be introduced.
- The above recommendations should be tested by developing hypothetical spatial plans for pilot sites in the Wadden Sea region with the aim of developing a practicable methodology.

Other impacts of climate change, relevant to water management, such as drainage of fresh water, salt water intrusion and raising of the ground water table, have not been dealt with by CPSL. These are relevant to spatial planning and demand further consideration.

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Annex 1: Terms of Reference

Responsibility

The CPSL III Group acts under the responsibility of the Trilateral Working Group (TWG).

Composition

The CPSL III Group will consist of representatives of the responsible administrations (coastal defense, nature protection and regional planning). The secretarial work will be carried out by the Common Wadden Sea Secretariat.

Timetable

The work of the CPSL III group will start as soon as possible after the adoption of the Terms of Reference. The draft final report shall be submitted to the TWG early 2009.

Tasks

- to initiate a study on the feasibility of coastal spatial plans that consider climate change, in particular the establishment of buffer and coastal hazard zones. Using the CPSLII review as a starting point, this study should address the following elements:
  - a listing of possible ways to deal with coastal defense and climate change in coastal spatial planning in general;
  - provide advice on which of the possibilities under a. are most feasible for the Wadden Sea region;
- to investigate the possibilities of a study on the feasibility and effects of sand nourishment to balance the sediment deficit of the Wadden Sea tidal basins under increased sea level rise (e.g. volumes needed and costs, search for optimal sites, ecological impacts);
- to provide advice on the incorporation of the CPSLII recommendations in the revision of the Wadden Sea Plan;
- to prepare contributions for the 2009 update of the Quality Status Report, related to climate change and coastal protection;
- to participate (CPSL chairperson), upon request and as appropriate, in the TWG, to report on relevant developments of the CPSL group;
- to participate as observer in the Wadden Sea Forum (CPSL chairperson) with the aim of informing and advising the WSF about coastal protection and sea level rise matters.

Annex 2: CPSL II Members

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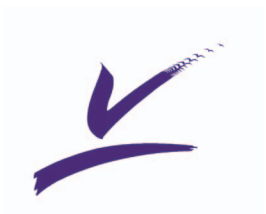

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