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"Coastal erosion – Evaluation of the need for action"
Directorate General Environment
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Living with coastal erosion in Europe: Sediment and Space for Sustainability

Guidelines for incorporating coastal erosion issues into Environmental Assessment (EA) procedures

Final version – 20 May 2004

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1. INTRODUCTION TO ENVIRONMENTAL ASSESSMENT

1.1 Introduction

The objective of these guidelines is to provide general advice on how to address the potential impact of certain public and private projects, plans or programmes on coastal erosion processes. The need for such guidelines has been highlighted in the framework of the EUROSION project (service contract B4-3301/2001/329175/MAR/B3: "Coastal erosion – Evaluation of the need for action") whose major findings clearly show that existing Environmental Impact Assessment (EIA) procedures have failed in Europe to efficiently incorporate the impact of projects – be it urban, industrial or recreational - on shoreline stability into the projects' design.

1.2 European legislation on Environmental Assessment (EA)

Environmental Assessment (EA) is a key instrument of European Union environmental policy for assessing the effects of certain public and private projects, plans and programmes on the environment. This has been reflected by two directives: the Directive 85/337/EEC (amended in 1997) on the assessment of the effects of certain public and private projects on the environment (*Environmental Impact Assessment - EIA Directive*) and the Directive 2001/42/EC on the assessment of certain plans and programmes on the environment (*Strategic Environmental Assessment - SEA Directive*).

1.2.1 THE EIA DIRECTIVE

The EIA Directive on the assessment of the effects of public and private projects on the environment was introduced in 1985 and was amended in 1997. Member States had to transpose the amended EIA Directive by 14 March 1999 at the latest.

> Article 2 of the Directives requires that *"Member States shall adopt all measures necessary to ensure that, before consent is given, projects likely to have significant effects on the environment by virtue, inter alia, of their nature, size or location are made subject to a requirement for development consent and an assessment with regard to their effects."* Article 8 then requires that *"The results of consultations and information gathered pursuant to* [the EIA procedure] *must be taken into consideration in the development consent procedure"*.

The EIA Directive outlines which project categories shall be made subject to an EIA, which procedure shall be followed and the content of the assessment. Member State EIA procedures vary considerably in their details but the practical stages in most systems are generally those illustrated in Figure 1. The highlighted steps in Figure 1 are governed by the terms of the Directive. The other steps are part of good practice in EIA and some have been adopted in some Member States, but not in all.

1.2.2 THE SEA DIRECTIVE

EIA Directive has been completed in 2001 with the SEA Directive 2001/42/EC. The purpose of the SEA Directive is to ensure that environmental consequences of certain plans and programmes are identified and assessed during their preparation and before their adoption. The public and environmental authorities can give their opinion and all results are integrated and taken into account in the course of the planning procedure. After the adoption of the plan or programme the public is informed about the decision and the way in which it was made. SEA will contribute to more transparent planning by involving the public and by integrating environmental considerations. This will help to achieve the goal of sustainable development. Member States have to transpose the amended SEIA Directive by 21 July 2004 at the latest.

Key Stages	Notes
Project Preparation	The developer prepares the proposals for the project. This is only a first draft of the design and location of the project.
Notification to Competent Authority	In some MS there is a requirement for the developer to notify the CA in advance of the application for development consent. The developer may also do this voluntarily and informally
Screening	The CA makes a decision on whether EIA is required. This may happen when the CA receives notification of the intention to make a development consent application, or the developer may make an application for a Screening Opinion. The Screening decision must be recorded and made public (Article 4 of the Directive 97/11/EC).
Scoping	The Directive provides that developers may request a Scoping Opinion from the CA. The Scoping Opinion will identify the matters to be covered in the environmental information. It may also cover other aspects of the EIA process (see the guidance on Scoping in EIA). In preparing the opinion the CA must consult the environmental authorities (Article 5(2)). In some MS Scoping is mandatory.
Environmental Studies	The developer carries out studies to collect and prepare the environmental information required by Article 5 of the Directive (see Appendix A) and ascribed in the Scoping Opinion.
Submission of Environmental Information to Competent Authority	The developer submits the environmental information to the CA together with the application for development consent. If an application for an Annex I or II project is made without environmental information the CA must screen the project to determine whether EIA is required (see above). (Articles 5(1) and 5(3)). In most MS the environmental information is presented in the form of an Environmental Impact Statement (EIS).
Review of Adequacy of the Environmental Information	In some MS there is a formal requirement for independent review of the adequacy of the environmental information before it is considered by the CA. In other MS the CA is responsible for determining whether the Information is adequate. The guidance on EIS Review is designed to assist at this stage. The developer may be required to provide further information if the submitted information is deemed to be inadequate.
Consultation with Statutory Environmental Authorities, Other Interested Parties and the Public	The environmental information must be made available to authorities with environmental responsibilities and to other interested organisations and the general public for review. They must be given an opportunity to comment on the project and its environmental effects before a decision is made on development consent. If transboundary effects are likely to be significant other affected MS must be consulted (Articles 6 and 7).
Consideration of the Environmental Information by the Competent Authority before making Development Consent Decision	The environmental information and the results of consultations must be considered by the CA in reaching its decision on the application for development consent (Article 8).
Announcement of Decision	The decision must be made available to the public including the reasons for it and a description of the measures that will be required to mitigate adverse environmental effects (Article 9).
Post-Decision Monitoring if Project is Granted Consent	There may be a requirement to monitor the effects of the project once it is implemented.

Figure 1-1. The Environmental Impact Assessment Process. The highlighted steps must be followed in all Member States under Directives 85/337/EC and 97/11/EC. Scoping is not mandatory under the Directive but Member States must establish a voluntary procedure by which developers can request a Scoping Opinion from the CA if they wish. The steps, which are not highlighted form part of good practice in EIA and have been formalised in some Member States but not in all. Consultations with environmental authorities and other interested parties may be required during some of these additional steps in some Member States. The blue box indicates the contents of these guidelines for an EIA in the coastal zone. Abbreviations CA = Competent Authority; MS = Member State.

> Article 5 of the SEA Directive requires *"the adoption of environmental assessment procedures at the planning and programming level should benefit undertakings by providing a more consistent framework in which to operate by the inclusion of the relevant environmental information into decision-making. The inclusion of a wider set of factors in decision-making should contribute to more sustainable and effective solutions."*

Strategic environmental assessment, by its nature, covers a wider range of activities or a wider area and often over a longer time span than the environmental impact assessment of projects. Strategic environmental assessment might be applied to an entire sector (such as a national policy on energy for example) or to a geographical area, (for example, in the context of a regional development scheme). The basic steps of strategic environmental assessment are similar to the steps in environmental impact assessment procedures (Figure 1-1), but the scope differs. Strategic environmental assessment does not replace or reduce the need for project-level environmental impact assessment, but it can help to streamline the incorporation of environmental concerns (including coastal erosion) into the decision-making process, often making project-level environmental impact assessment a more effective process.

In line with EUROSION findings, Strategic Environmental Assessment may constitute a far more efficient tool to anticipate the impact of future investments on shoreline stability as coastal erosion often results from the cumulated effect of many individual projects which, taken separately, do not have a significant impact on coastal erosion processes.

1.3 How to use these guidelines

These guidelines are designed principally for use by competent authorities, developers and EIA practitioners in the European Union Member States and Accession Countries, see Box 1-1. It is hoped that it will also be of interest to academics and other organisations who participate in EIA training and education and to practitioners from across Europe.

These guidelines aim to provide these target groups of readers an outline of the key concepts and management questions supporting a correct incorporation of coastal erosion related issues into Environmental Assessment exercises and within the design of projects, plans and programmes susceptible to impact the shoreline stability.

They more specifically focus on four critical phases related to both EIA and SEA processes:

- The screening phase which aims at determining which projects or developments require a full or partial impact assessment study;

- The scoping phase which aims at identifying which potential impacts are relevant to assess, and to derive terms of reference for the impact assessment;

- The conduct of Environmental Impact Studies (EIS) which aims at predicting and quantifying the likely environmental impacts of a proposed project or development taking into account inter-related consequences of the project proposal;

- The identification of mitigation measures (including not proceeding with the development, finding alternative designs or sites which avoid the impacts, incorporating safeguards in the design of the project, or providing compensation for adverse impacts);

- The environmental monitoring and evaluation of the development activities, predicted impacts and proposed mitigation measures to ensure that unpredicted impacts or failed mitigation measures are identified and addressed in a timely fashion;

These guidelines have been designed to be useful across Europe but it cannot reflect all the specific requirements and practice of EIA in different countries. There are a variety of different approaches to EIA legislation (screening and scoping stage and consultation amount) amongst the Member States.

As for SEA legislation, there are few practical experiences about it as the official deadline for transposing the Directive into national legislation is July 2004.

Box 1-1 Users of this Guidance

Competent Authorities

- Competent authorities may be involved in EIA either as participants in a mandatory EIA process or in response to a request for a EIA Opinion from a developer. Their role may be to actually undertake the EIA and issue the EIA to the developer or to comment on and agree a EIA Report prepared by the developer.
- The competent authority may undertake EIA on its own or it may be advised by an independent body such as an EIA Commission.

Developers and EIA Teams

- Like competent authorities, developers may be involved in EIA either as part of a mandatory EIA system or voluntarily by requesting a EIA Opinion from the competent authority. In this role they may either prepare a draft EIA Report for comment by the competent authority and consultees or they may just provide information to the competent authority for the authority to carry out EIA.
- However, good practice also requires that EIA should be an integral part of any EIA. Developers and their EIA Teams should undertake EIA at an early stage to ensure that the environmental studies address all the relevant issues, irrespective of any legal requirement to undertake EIA.

Consultees

- The Directive requires competent authorities to seek advice from relevant environmental authorities prior to giving a EIA Opinion. In many cases other interested parties and the general public are also given an opportunity to comment. Consultees will therefore be involved in commenting on issues to be addressed in EIA.
- When EIA is carried out by a developer or an EIA Team, either under a legally established system or as part of good practice in EIA, environmental authorities and other interested parties and the public should also be consulted. The value of public participation in the EIA process is increasingly being recognised by competent authorities and other participants in the EIA process within Member States. Early consultation with interested parties can be very valuable in avoiding later delays if new issues emerge from consultation only after the EIS is submitted.

These guidelines are organized as follows:

- **Chapter 1** provides an introduction to the European Union environmental assessment legislation and how these guidelines get connected to it
- **Chapter 2** provides an overview of coastal erosion processes and its natural causes
- **Chapter 3** reviews the potential impacts of projects, plans and programmes of the factors which exacerbate coastal erosion
- **Chapter 4** provides an overview of the information required to make appropriate decisions during screening, scoping, EIS and monitoring phases of project/plan/programme design and implementation.
- **Chapter 5** proposes a list of possible measures to mitigate the effects of projects, plans or programmes on shoreline stability

2. THEORETICAL BACKGROUND OF COASTAL EROSION

2.1 Definition of the coastal zone

A good understanding of the coastal zone begins with a definition of the coastal zone. An integrated approach of the coastal zone is not only the beach (see Figure 2-1) but also a part of the coast with all its natural processes related to the coast and the human interference with the coast, like municipalities, recreation, industry and infrastructure.
The definition of the "coastal zone" should encompass the following:

- those areas visually connected to the shoreline and those areas that form an integral part of the coastal landscape, such as sea cliffs, dune fields, lagoons, marches and estuaries;
- the transitional area between coastal waters and terrestrial systems in which there are physical features, ecological or natural processes that affect, or potentially affect the coast or coastal resources; and
- areas utilised or likely to be utilised for human activity related to the coast.

The coastline is a series of interlinked physical systems, comprising both offshore and onshore processes. Sediment (clay, silt, sand and gravel) is moved around the coast by waves and currents in two directions: long-shore and cross-shore units.

Long-shore units or '*coastal sediment cells*' are defined as lengths of the coastline and associated nearshore areas where movement of coarse sediment (sand and gravel) is largely self-contained. They are defined as coastal process units where the physical processes are relatively independent of those operating in adjacent areas. Each cell comprises an arrangement of sediment sources (like eroding cliffs, rivers, the sea bed), areas where sediment is moved by coastal processes and sediment stores or sinks (like beaches, estuaries or offshore sinks).

A cross-shore coastal unit can be seen as a cross-shore beach profile in Figure 2-1. Important terms describing a beach profile are:

- *Offshore*: The portion of the beach profile extending seaward from beyond the nearshore (where the waves are breaking) to the edge of the continental shelf.
- *Nearshore*: The region in which the waves arriving from offshore become unstable and break. In general the depth limit for this zone is 10-20 m. On a wide, flat beach, secondary breaker zones may occur where reformed waves break for a second time. In this zone longshore bars and troughs exist.
- *Foreshore*: the sloping portion of the beach profile lying between a berm crest (or in the absence of a berm crest, the upper limit of wave swash at high tide) and the low-water shoreline.
- *Backshore*: The zone of the beach profile extending landward from the sloping foreshore to the point of development of vegetation or change in physiography (sea cliff, dune field, etc.).

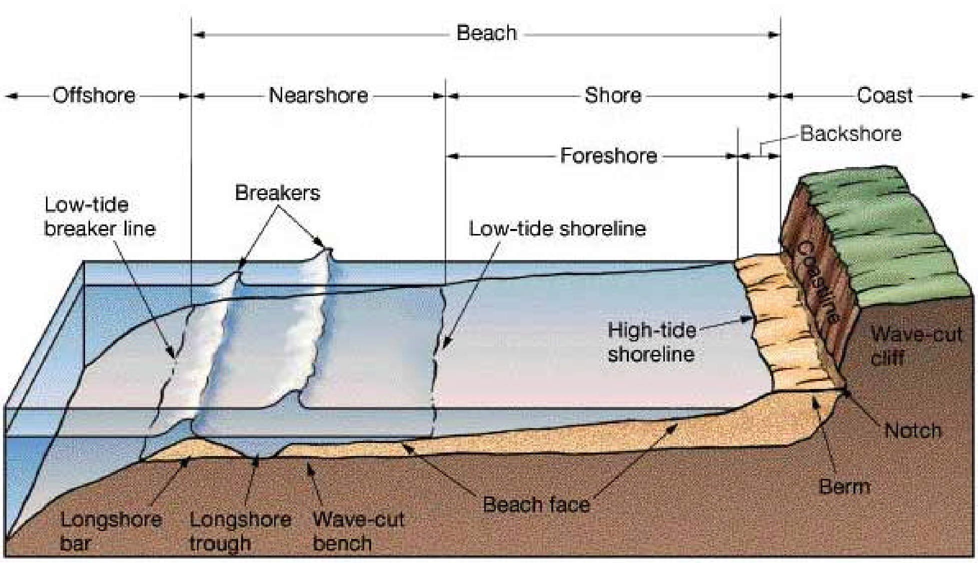


Figure 2-1. Terminology to describe the cross-shore beach profile, which is a part of the coastal zone.

2.2 Causes of coastal erosion

When dealing with erosion problems on a regional/national (policy) scale or on a local/regional scale (technical measures) a profound knowledge of the geo-morphological processes and causes of erosion is fundamental to a sound choice for a policy option and any related measures.

In relation to the type of erosion two components can be distinguished: structural and acute erosion. In some areas structural and acute erosion cause problems, while in other areas clearly one type of erosion is of main importance.
In case of structural erosion it is of importance to understand the relationship between the total availability of sediment and the forcing of the erosion (sea level, waves, tides). Sediments are delivered to the coast by the rivers due to erosion of the hinterland. Undercutting and collapse of soft coastal cliffs is another natural source of sediment for the coastal area. Coastal erosion may originate due to a reduction in the availability of sediment, instead of a change in forcing. Moreover, episodic events to the delivery of sediments (particularly for deltas) can be of importance. A further complication arises when the land is sinking (due to isostatic change brought about by tectonic effects, due to water abstraction or reduced precipitation, or because of sediment consolidation).

In relation to the main causes of erosion distinction can be made between *natural* and *human* causes. Examples of natural causes are relative sea level rise and storms and human causes are for example river damming, hard defences and urbanisation. These will be explained below.
Coastal erosion induced by human activities have surpassed in Europe coastal erosion driven by natural factors. Human-induced coastal erosion mainly proceeds from the cumulative and indirect impacts of small and medium size projects, as well as from river damming. However, little attention is being paid yet to these impacts by project developers, Environmental Impact Assessment (EIA) practitioners and competent authorities.

When considering causes of erosion, the dominant time and spatial scale of the underlying processes have to be taken into account. It's meaningless to discuss erosion without pointing out the scale considered. When managing erosion problems, the coastal system to be considered is mostly larger than the area in which erosion takes place. A coastal system should be considered with coherent and large enough time- and spatial scale.

With a few exceptions, coastal erosion can never be attributed to one single cause – be it natural or human-driven – but to a combination of various factors which all together create the conditions for erosion to take place. These factors operate on different time and spatial scales, which results in certain factors to stay "hidden" from coastal engineers for decades before there are finally evoked and their impact quantified. Major among these factors are:

- Waves. Waves are generated by offshore and near-shore winds, which blow over the sea surface and transfer their energy to the water surface. As they move towards the shore, waves break and the turbulent energy released stirs up and moves the sediments deposited on the seabed. The wave energy is a function of the wave heights and the wave periods. As such the breaking wave is the mechanical cause of coastal erosion in particular on open straight coasts.

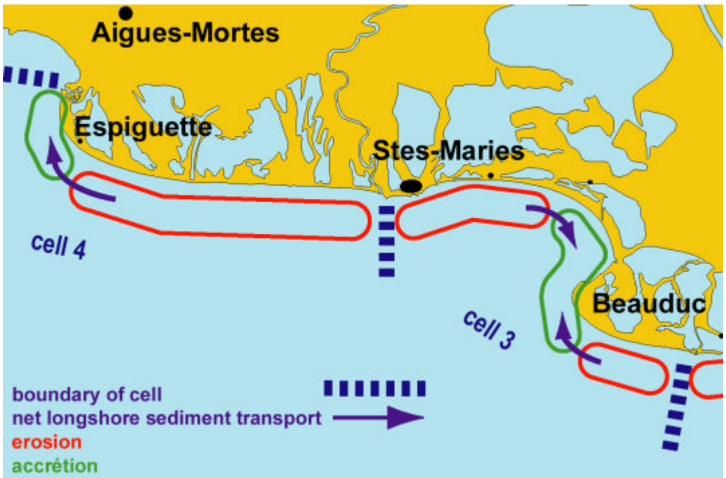
- Winds. Winds act not just as a generator of waves but also as a factor for sand transport, called Aeolian transport. *Aeolian* transport is an important process for soil erosion, dune formation and alteration, and re-deposition of soil particles. Dune formations (see Figure 38) established with dune vegetation is an important defence system for low lying sandy coasts like the Netherlands, Germany, Denmark and France. When the sand transport to the dunes is interrupted by objects or by a shortage of sand, the maintenance of the dunes is hindered.

Box 2-2. Two examples of coastal erosion in Europe

Example of coastal cliff erosion

The municipality of Happisburg is a located in the county of North Norfolk (UK). Sediments are removed from the cliffs under the action of the waves and are transported southwards where they supply the beach of Sea Palling with "fresh" sediments. The two aerial photographs on the left depict the situation of the area of Beach Road in Happisburg, in 1992 and 1999 respectively. Coastal erosion mainly affected the south-east part of Beach Road, and coincides with the destruction of the wooden defences originally located upfront the cliff.

Example of coastal plain erosion



Camargue, located in the Rhone delta, is a typical example of a coastal plain. It developed thanks to the sediments supplied by the Rhone over the past 2000 years. Coastal erosion has been observed since the 1900's and is deemed to be due to the recent rise in sea level, long-shore drift, storms and reduced sediment supply from the Rhone. The photograph above depicts fruitless efforts at Espiguette to stop coastal erosion via coastal defences (already submerged by the sea), while the picture on the right illustrates the effect of a storm on coastal dunes. At the long run, coastal erosion threatens the saltpans located behind the coastal dune of the risk of coastal flooding.

- Tides. Tides results in water elevation to the attraction of water masses by the moon and the sun. During high tides, the energy of the breaking waves is released higher on the foreshore or the cliff base (cliff undercutting). Macro-tidal coasts (i.e. coasts along which the tidal range exceeds 4 meters), all along the Atlantic sea are the more sensitive to tide-induced water elevation than meso- or micro-tidal coasts (i.e. tidal range below 1 meter). The tide is moving in a counter-clock-wise wave propagation along the coasts and causes perpendicular ebb- and flood-currents. The net sediment transport direction is the same as the flood-current direction, because the flood-current is stronger than the ebb-current at most places.

- Near-shore currents. Sediments scoured from the seabed are transported away from their original location by currents. In turn the transport of (coarse) sediments defines the boundary of coastal sediment cells, i.e. relatively self-contained system within which (coarse) sediments stay. Currents are generated by the action of tides (ebb and flood currents), waves breaking at an oblique angle with the shore (long-shore currents), and the backwash of waves on the foreshore (rip currents). All these currents contribute to coastal erosion processes in Europe.

- Storms. Storms result from raised water levels (known as storm surge) and highly energetic waves induced by extreme winds. Combined with high tides, storms may result in catastrophic damages such as along the North Sea in 1953. Beside damages to coastal infrastructure, storms cause beaches and dunes to retreat of tenths of meters in a few hours, or may considerably undermine cliff stability. In the past 30 years, a significant number of cases have reported extreme historical storm events that severely damaged the coast. Most of the sediment transport along the coast occurs during storms.

- Sea level rise. The profile of sedimentary coasts can be modelled as a parabolic function of the sediment size, the sea level, the wave heights and periods, and the tidal range. When the sea level rises, the whole parabola has to rise with it, which means that extra sand is needed to build up the profile. This sand is taken from the coast (Bruun rule). Though more severe in sheltered muddy areas (e.g. Essex estuaries), this phenomenon has been reported as a significant factor of coastal erosion in all regional seas.

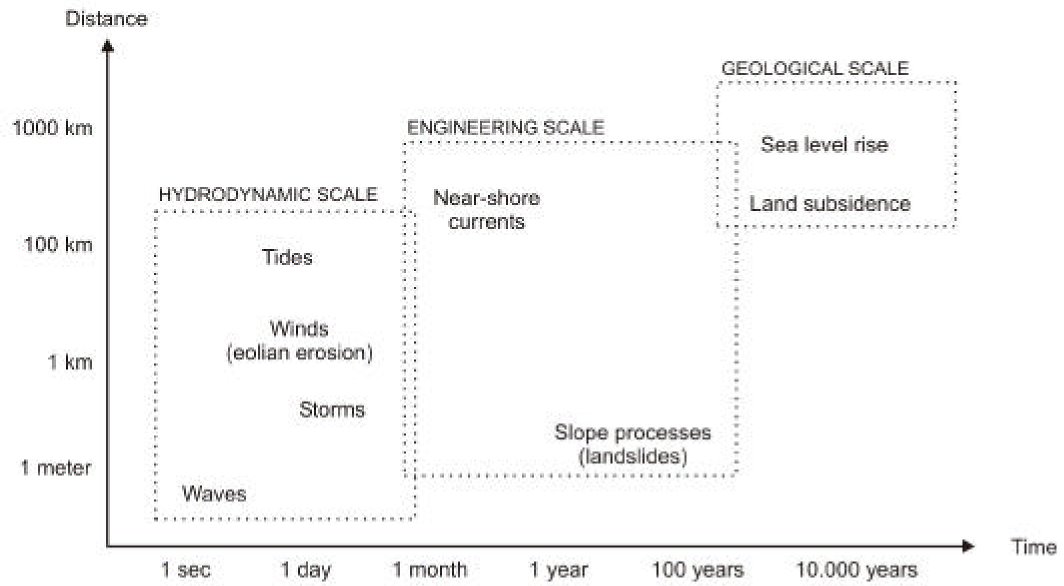


Figure 2-2. Time and space patterns of *natural factors* of coastal erosion. Note that "distance" has to be understood as the geographical extent within which the factor operates with a relatively constant intensity. "Time" reflects the temporal extent within which the factor occurs and causes erosion.

- Slope processes. The term "slope processes" encompasses a wide range of land-sea interactions which eventually result in the collapse, slippage, or topple of coastal cliff blocks.

These processes involve on the one hand terrestrial processes such as rainfall and water seepage and soil weathering (including alternating freeze/thaw periods), and on the other hand the undercutting of cliff base by waves.

- Vertical land movements. Vertical land movement – including isostatic rebound, tectonic movement, or sediment settlement – may have either a positive of negative impact on coastline evolution. If most of northern Europe has benefited in the past from a land uplift (e.g. Baltic sea, Ireland, Northern UK), this trend has stopped (with exception of the coast of Finland), such as in Donegal and Rosslare, and even reversed (e.g. Humber estuary). Along these coasts, the sea level induced by climate change rises faster than the sea, which results in a positive relative sea level rise.

3. REVIEW OF IMPACTS ON COASTAL EROSION PROCESSES

3.1 Typology of projects and impacts

Human activities may impact coastal erosion processes in a variety of ways. In all cases, changes take place whenever one or more of the above mentioned natural causes of coastal erosion are modified. From a generic point of view, a project is deemed to impact coastal erosion processes whenever it results in:

- **Impact 1**: modification of near-shore bathymetry and wave propagation patterns
- **Impact 2**: disruption of long-shore drift currents
- **Impact 3**: removal of sediment from the sediment system
- **Impact 4**: reduction of river debits
- **Impact 5**: reduction of volume of tidal basins
- **Impact 6**: modification of near-shore vegetation
- **Impact 7**: modification of soil weathering properties
- **Impact 8**: modification of Aeolian transport patterns
- **Impact 9**: land subsidence

A wide range of projects is concerned with such modifications. They can be grouped in 6 categories:

- **Category 1**: Land reclamation projects
- **Category 2**: River water regulation works
- **Category 3**: Sediment extraction projects
- **Category 4**: Construction of tourism and leisure facilities
- **Category 5**: Coastal defence works
- **Category 6**: Hydrocarbon and gas mining activities

Table 3.1 provides an overview of how above mentioned projects impact coastal erosion processes.

Table 3.1. Typology of projects having an impact on coastal erosion processes

IMPACTS PROJECTS	Modification of bathymetry and/or wave propagation patterns	Disruption of long-shore currents	Removal of sediment from the sediment system	Reduction of river debits	Reduction of volume of tidal basins	Modification of near-shore vegetation	Modification of soil weathering properties	Modification of Aeolian transport patterns	Land subsidence
Land reclamation									
• Harbour/airport extension	✓	✓			✓				
• Energy production plants (e.g. windfarms)	✓	✓			✓				
• Recreational parks	✓	✓			✓				
River regulation works									
• River damming			✓	✓					
• Irrigation systems				✓					
Sediment dredging									
• Channel dredging for navigation	✓		✓			✓			
• Aggregate extraction for construction	✓		✓			✓			
• Sand extraction for nourishment	✓		✓			✓			
Construction of tourism/leisure facilities									
• Marinas	✓	✓							
• Hotel resorts		✓							
• Recreational parks including golf amenities							✓	✓	
Coastal defence									
• Cross-shore hard defence including groins, breakwaters and jetties	✓	✓	✓						
• Alongshore hard defence including seawalls, bulkheads and revetments		✓	✓						
• Beach nourishment (see sediment extraction)	✓		✓			✓			
Hydrocarbon/gas mining									✓

3.2 Review of project impacts on coastal erosion processes

This section reviews and discusses the impacts of human activities on coastal erosion processes.

3.2.1 LAND RECLAMATION PROJECTS

Throughout history, land has been reclaimed from the sea for different purposes: urban expansion, agriculture, industry, nature or safety. Although its rate has decreased over time, reclamation is still considered nowadays in Europe especially when the lack of space hampers key developments. This is epitomized by a number of projects undergoing or foreseen in the Netherlands such the extension of Rotterdam harbour (Maasvlakte project) or the construction of an offshore airport island to decongestion Schiphol airport (project Flyland temporarily abandoned), which foresee the reclamation of tens of hectares from the sea. Below is a review of impact associated with land reclamation projects as far as coastal erosion is concerned.

Modification of near-shore bathymetry and wave propagation patterns

Land reclamation projects primarily modify the position of the coastline and its near-shore bathymetry, as well as its orientation relatively to the wave front direction. Consequences of these modifications are particularly severe on the behaviour of waves propagating in the neighbourhood of reclaimed areas and particularly on wave refraction.

Wave refraction is the bending of the wave front because of varying water depths underneath. The part of a wave in shallow water moves slower than the part of a wave in deeper water. So when the depth under a wave crest varies along the crest, the wave bends. This occurs when waves approach a straight shoreline at an angle: the part of the wave crest closer to shore is in shallower water and moving slower than the part away from the shore in deeper water. The wave crest in deeper water catches up so that the wave crest tends to become parallel to the shore (see Figure 3-1). Wave refraction also occurs when waves approach complex coastline made of headlands and bays or around islands.

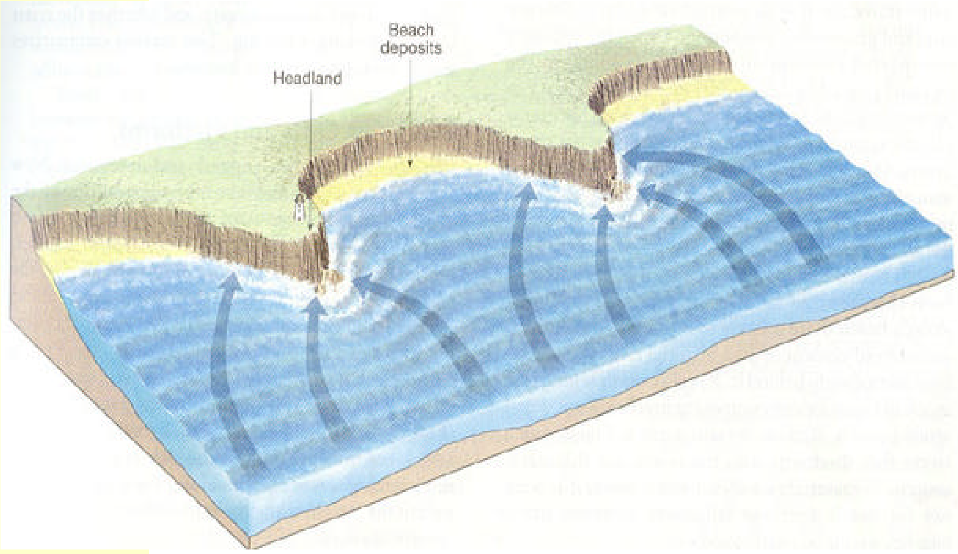
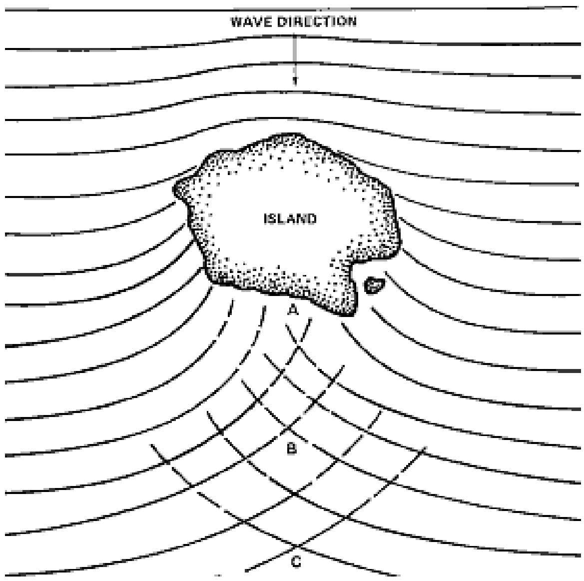


Figure 3-1. As waves get close to the shore, their front bend as a result bathymetrical changes and tends to become parallel to the shore. In the case of a complex coastline made of headlands and embayments, the waves energy concentrates at the level of headlands resulting in increased erosion and decreases in bays resulting in sedimentation. Because this process remains in most cases incomplete, the waves arrive and break on the shore at a certain angle generating a long-shore current. Beside natural processes, the geometry of the coastline, especially within bays, basins or estuaries may be artificially re-shaped by land reclamation.

Modification of wave refraction patterns, in turn, may modify the angle and the energy with which the waves break along the parts of the coastline, which are outside the reclaimed area. Some parts of the coastline may receive more energy than before resulting in increased erosion, while other parts may receive less energy resulting in less erosion. In some particular situations, the angle at which waves break along the coastline may be reversed resulting in a change of long-shore drift direction.

Figure 3-2 shows how waves are bent around an island, which should be at least 2-3 wavelengths wide in order to offer a wave shadow zone. It causes immediately in the lee of the island (A) a wave shadow zone but further out to sea a confusing sea (B) of interfering but weakened waves which at some point (C) focuses the almost full wave energy from two directions, resulting in accelerate coastal erosion when point C is situated in the surf zone.



Disruption of long-shore drift

A land reclamation project, especially adjacent to the shoreline, interrupts the currents generated by the wave breaking on the shore at an angle. These currents – known as long-shore currents - are responsible for transporting sediments along-shore. Disruption of long-shore sediment transport causes sediments to accumulate up-drift the cross-shore structure and erosion downdrift. This process is more founded with figures in paragraph 3.2.4.

Reduction of the volume of tidal basins

Within tidal basins, bays and estuaries, where land reclamation projects are most easy to undertake, land reclamation may result in substantial hydrodynamic and morphological changes. Reclamation of lands, which were originally devoted to tidal waters results in a decrease of the tidal influence, which often heralds a switch from tide to river domination of processes. Diminished ebb-activities may lead to the break-up of the pre-existing ebb delta, with the dispersal of much of this material onto the adjacent shore forming a substantial outgrowth of new beach ridges and maybe dunes. This redistribution of sediments may in turn result into a modification of the bathymetry and wave propagation patterns following the same patterns described in the previous section. By way of illustration, the piecemeal reclamation of many estuaries in eastern Ireland and the Netherlands has induced some interesting changes in the shoreline, often over a long time scale (10-100 years).

3.2.2 RIVER WATER REGULATION WORKS

River water regulations works can diminish sediment supplies to the shore in two ways: (1) by trapping sediment behind the dams and (2) by reducing peak river flows that transport sand

Removal of sediment from the sediment system

By trapping sand and gravel in reservoirs, dams deprive downstream reaches of their normal sediment load and release sediment-starved, or *hungry water*, which tends to erode its bed and banks unless the dam has reduced flood magnitude so much that sediment accumulate on the bed instead. In

Europe damming has intensively sealed water catchments locking up millions of tons of sediments per year which were initially meant to reach the coastal sediment cell and be-redistributed alongshore and cross-shore. For some southern European rivers (e.g. Ebro, Douro, Urumea, Rhone), the annual volume of sediment discharge represents less than 10% of their level of 1950 (e.g. the Ebro) resulting in a considerable sediment deficit at the river mouth, and subsequent coastal erosion downstream. Sediments result from soil erosion in water catchments and are transported to rivers by water run-off. In spite of a wide range of measures to empty dams from sedimentation, sediment flushing remains a delicate operation since: (i) the release of sediments downstream increases turbidity of rivers and jeopardizes fisheries and leisure activities, (ii) sediments accumulated in river bed for a long time show higher contamination rate than continuously flowing sediments.

Finally, if the impact of one river dam may reduce but not disrupt sediment transport, the cumulated impact of several dams on the same river may result in a reduction up to 95% of the sediment load.

Reduction of river debit

Beside the locking-up of thousands of tons of sediments, dams are also responsible for reducing water flow velocity. As a consequence of this reduction, the water flow is not sufficient to put sediments in motion, and sediments remain deposited in the riverbed. However it is worth mentioning that reduction of water debit does not just affect dammed rivers: it also affects river basins characterised by irrigation works. Irrigation consists in removing water from a natural water system to artificially drain other areas by the way of canals and pumping systems. By doing so, the debit of the original water systems is reduced and so is the ability of the system to transport sediments. Paradoxically, irrigation may result in increased soil erosion in the newly drained area, however these sediments do rarely reach the coastal cell and remain deposited in the riverbed.

3.2.3 SEDIMENT EXTRACTION

Dredging activities have intensified in the past 20 years for navigational purposes (the need to keep the shipping routes at an appropriate water depth), construction purposes (an increasing amount of construction aggregates comes from the seabed), and since the 1990's for beach and underwater nourishment. Sediment dredging occurs either offshore or inland (in river beds).

Removal of sediment from the sediment system

Just like dams, dredging activities remove sediment from the sediment system. This creates a sediment starvation that the sediment system "tries" to compensate by increasing erosion of underwater sand banks and the shoreline. This builds upon the observation that a number of coastal sediment systems are "in balance", i.e. at any given place, the amount of incoming sediments compensates exactly the amount of outgoing sediments. When dredging in the riverbed or the near-shore area results in a "hole" (site with an increased water depth), this "hole" creates an imbalance, which will be progressively filled up by incoming sediments. If sediment transport is oriented towards the shore, the filling up of dredged sites results in a deficit of sediment along shore and therefore coastal erosion.

In some cases, dredging may result in a considerable amount of materials, which provide natural protection against wave assaults to be removed. In this case, the coastline remains undefended again the turbulence generated by waves breaking on the shore and increased erosion. By way of illustration, it is estimated that 50% of the total volume of the protective pebbles (3 millions cubic meters) has been extracted from the chalk cliff of Normandy (France) since the early 1900's.

Modification of near-shore bathymetry

By modifying the water depth, dredging modifies the wave propagation patterns as described in the case of land reclamation. Wave refraction induced by bathymetrical changes may in turn alter the angle and energy with which the waves break on the shore.

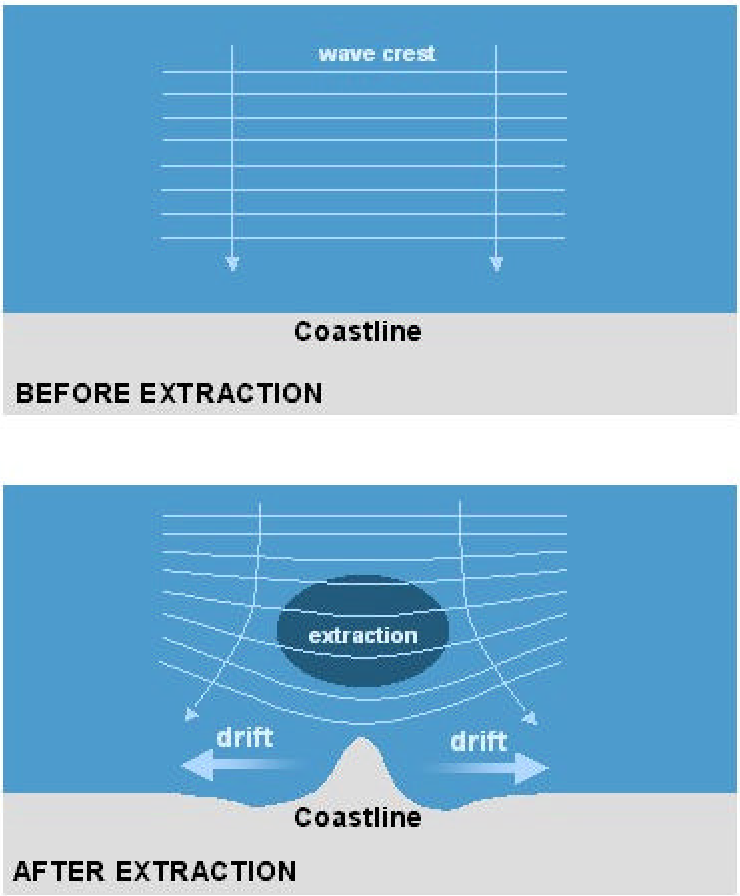


Figure 3-3. In this particular example, the wave front arrives, before extraction, at no angle to the shore. After extraction, the bathymetry of the near-shore has deepened and causes the wave front to be refracted. Waves arrive with an angle and a decreased energy resulting in a slight long-shore drift. A tombolo is being formed as a result of reduced wave energy.

It is assumed that the influence of the bathymetry on wave propagation starts as soon as the water depth (d) gets shallower than half of the wave length (L), i.e. when d=0,5.L. The transition from deep-water waves to shallow water waves is known as shoaling processes. Wave refraction occurs within the shoaling process area.

Modification of near-shore vegetation

In a number of ecosystems, seagrass plays an important role in absorbing the energy of incoming waves resulting in less energetic waves to reach the coast. This natural protection helps control the extent of coastal erosion especially in the Mediterranean Sea. However, this sea-grass is particularly vulnerable to activity disturbing the sea bottom, as this is the case for dredging activities. Damage to sea-grass communities may subsequently result in increased coastal erosion. For that reason, some countries like Spain have severely limited dredging operations susceptible to alter *Posidonia* communities along the coast of Spain. This example however remains limited in Europe.

3.2.4 CONSTRUCTION OF TOURISM AND LEISURE FACILITIES

In most European countries, tourism and leisure projects have become the first source of investment in the coastal zone both in number and amounts of investments. An outstanding part of the economy of southern European countries is derived from such projects. However, these projects also tend to become number one in terms of modification of coastal processes and coastal erosion. The major impacts of tourism projects are described hereunder.

Disruption of long-shore drift

The construction of marinas, jetties or any perpendicular structure from the shoreline (*cross-shore structure*) interrupts the currents generated by the wave breaking on the shore at an angle. These currents – known as long-shore currents - are responsible for transporting sediments along-shore.

Disruption of long-shore sediment transport causes sediments to accumulate up-drift the cross-shore structure and erosion downdrift. The seaward advance of the shoreline up-drift the cross-shore, for example the jetties providing protection to a marina entrance, and the landward retreat down-drift take place until the coastline geometry reaches an equilibrium status.

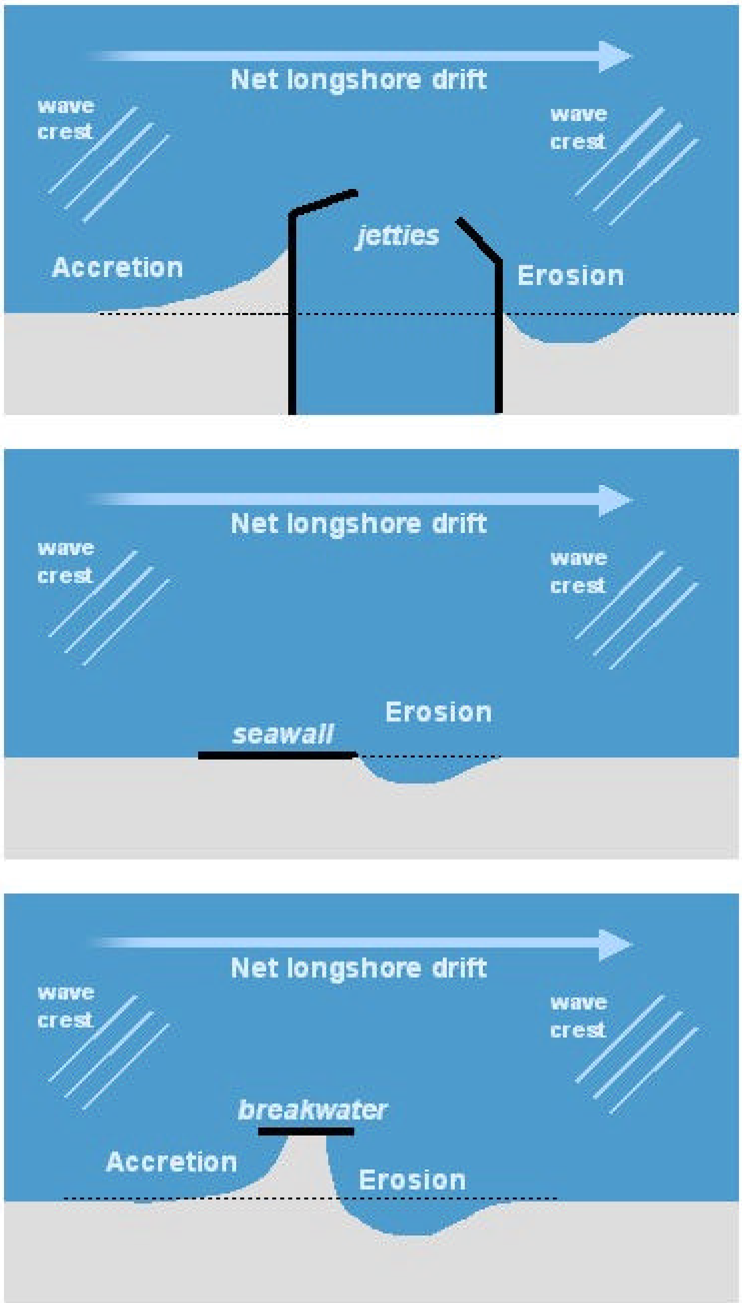


Figure 3-4. Cross-shore and long-shore structures result in sediments to be trapped up-drift long-shore structures (e.g. jetties) or behind cross-shore structures (e.g. seawall) and therefore in coastline retreat down-drift. In the case of submerged breakwaters, the sediments are not effectively trapped, but the breakwater generates a "shadow zone" which at the long run developed in a tombolo (= outgrowth of sand from the shoreline to the off-shore structure)

Beside cross-shore structures, sediment transport may also be disrupted by along-shore structure when such structures are built within the foreshore or the backshore, i.e. within the area, which interacts with coastal sediment processes. This is the case for an increasing number of seawalls, bulkheads or breakwaters meant to protect hotel resorts or tourism amenities invested along the coastline. Such long-shore structures do not trap sediments being transported by long-shore currents but lock-up sediments deposited behind the cross-shore structure and potentially acting as a sediment sources for coastal processes.

Modification of wave propagation patterns

Beyond their effect on long-shore sediment transport, hard structures associated with tourism amenities may also result in wave diffraction, which is the alteration of the wave crest direction due to the vicinity of surface piercing structures (such as jetties or breakwaters). This alteration results in wave energy to be either diluted in some places (less impact on the coastline) or concentrated in some other places (more impact on the coastline and subsequent erosion).

Figure 3-5. The harbour of Breskens is located in the province of Zeeuws-Vlaanderen in the Netherlands illustrates the case of sand trapping by jetties. This photograph clearly shows the accumulation of sand behind the jetties meant to protect the entrance of the marina. This sand accumulation up-drift, results in a sediment deficit down-drift.

Modification of soil weathering properties

Shoreline vegetation protects property naturally, effectively and inexpensively. Erosion can result where vegetation has been damaged or removed by construction, herbicide application, or wave action. Trees offer excellent erosion control because of their deep roots, which bind the soil and their leaves, which intercept rain before it impacts, and erodes the soil. In spite of this, some investments consisting in the construction of recreational parks are being consented right behind the coastline. These investments generally require clearing or modifying the original vegetation for building purposes. As a result of reduced vegetation, which acts as a factor of soil cohesion, the soil stability is undermined and more exposed to landslide events, especially along cliffs. Landslide may occur as a result of a six-step processes described hereafter.

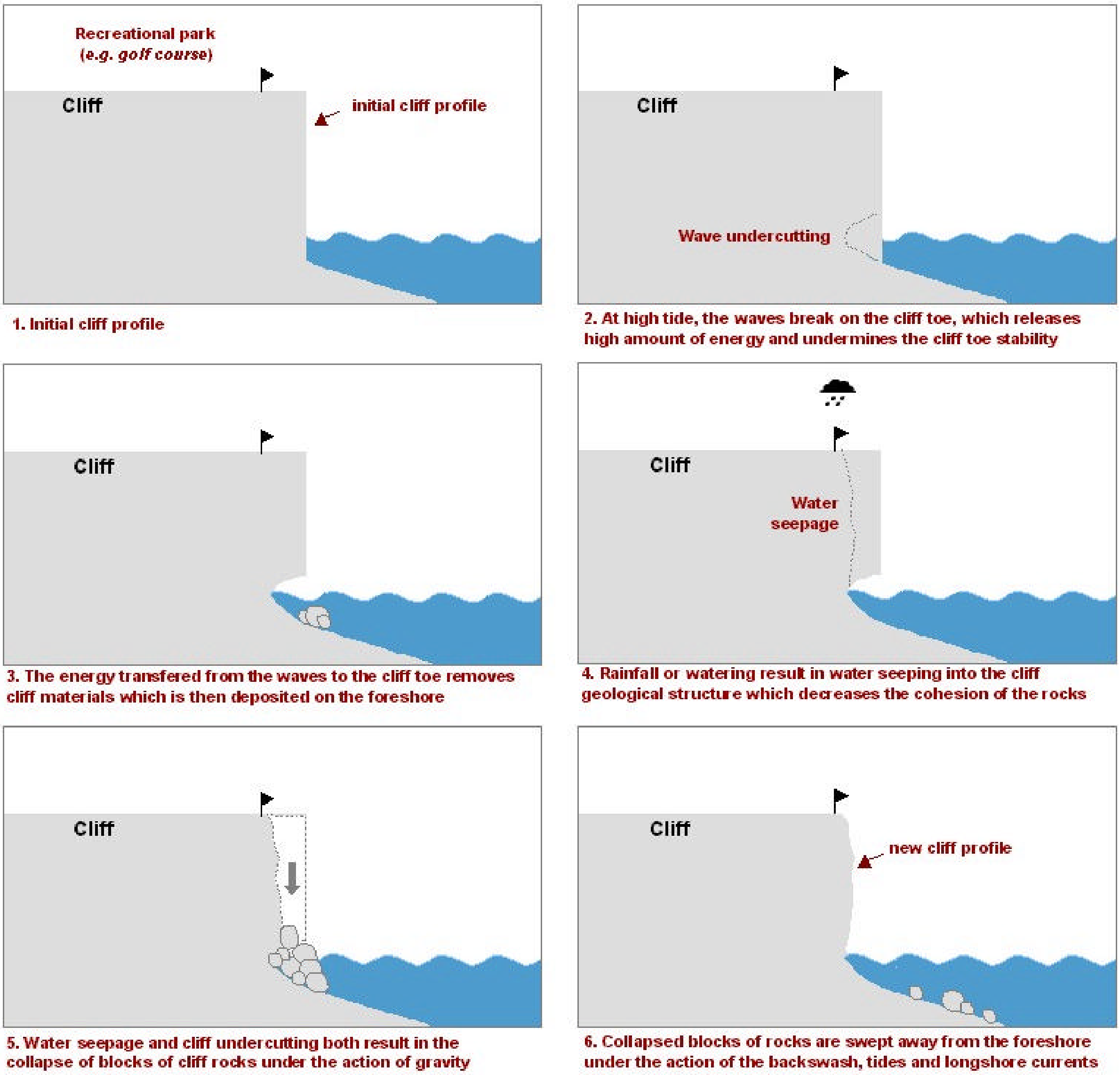


Figure 3-6. Coastal landslide

Figure 3-7. The Golf course of Vale do Lobo (Portugal) illustrates the impact of tourism activities on landslide processes. Excessive soil watering to maintain the golf vegetation results in water seepage and undermining of the slope stability

Modification of Aeolian transport patterns

Finally, clearing of vegetation for recreational purposes may alter wind transport patterns as vegetation acts as an Aeolian trap and helps the re-deposition of sand particles transported by the wind. This is particularly the case in coastal dune areas. Figure 3-8 below provides an illustration of dune formation and movement caused by the wind transport.

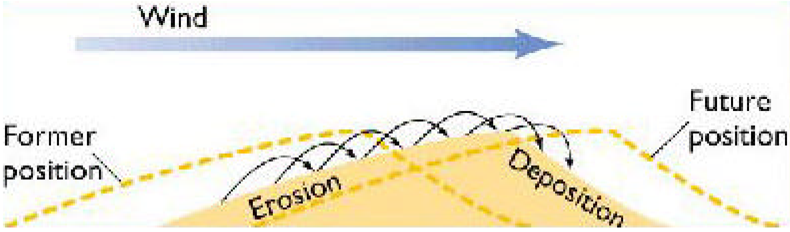


Figure 3-8. Wind plays an important in the dynamic of coastal dunes. By modifying the process of sand transportation-re-deposition (for example, by clearing or damaging the vegetation of dunes whose aerial part acts as a sediment trap), the sand is dispersed in the air and the dunes progressively.

3.2.5 COASTAL DEFENCE PROJECTS

Paradoxically, coastal defence projects meant to counteract the adverse impact of coastal erosion may prove to have counterproductive effects if not appropriately designed. These effects are described below.

Disruption of long-shore sediment transport

Already mentioned in the previous section, the use of long-shore and cross-shore hard and rock-armoured structures to provide protection to the assets located along the coastline disrupt the sediment transport processes either by trapping sediments being transported by long-shore currents or by preventing sediments locked up behind the hard structure to participate to sediment processes.

Figure 3-9. The picture illustrates the extent of coastal erosion in Vagueira, located 9 km south of Aveiro habour entrance. Sediments carried along the coast by longshore currents are partly trapped by the harbour's breakwater, which results in a sediment deficit downdrift and coastal erosion. In the case of Vagueira, the coastal section protected by a rocky structures protudes of about 30 to 50 meters (with an average rate of 4 meters / year) compared with the non-protected sections.Without protection, the first line of buildings would have collapsed.

Modification of wave propagation patterns

In addition, the use of large protective vertical seawalls may hamper wave energy dissipation and augments turbulence from interfering waves. This in turn scours and lowers the foreshore upfront the seawall and undermines the foundations of the seawall. After a few years, the seawall is finally swashed away and coastline retreat starts again at this location.

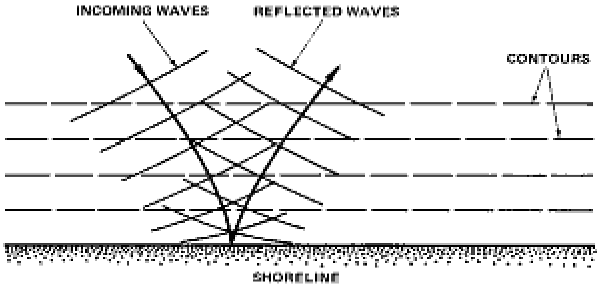


Figure 3-10. Reflection occurs when incoming waves cannot break and dissipate their energy because the foreshore slope is too steep or the waves encounter a vertical structure (e.g. a seawall). In that case, the waves are reflected away from the shoreline where they interfere with incoming waves. Interference causes waves in the foreshore to be energetic and generating more turbulence. In turn, this turbulence is responsible for scouring sand deposited on the

Modification of near-shore bathymetry

Since the 1990's, beach nourishment schemes have been intensively used throughout Europe to combat coastal erosion without disrupting long-shore sediment transport. However, beach nourishment requires huge amounts of sediments, which can only be supplied through dredging. As previously mentioned, dredging activities may impact coastal processes either by modifying the near-shore bathymetry, by removing quantities of sediment from the sediment systems, or by modifying the near-shore protective vegetation, thus exacerbating coastal erosion.

Removal of sediment from the sediment system.

See above.

Modification of near-shore vegetation.

See above.

3.2.6 HYDROCARBONS AND GAS MINING

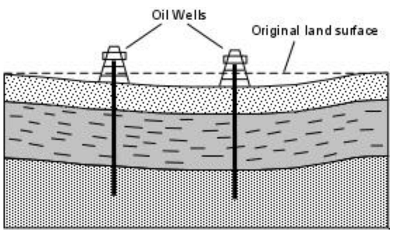


Figure 3-11.

Oil and Natural gas are both fluids that can exist in the pore spaces and fractures of rock, just like water. When oil and natural gas are withdrawn from regions in the Earth near the surface, fluid pressure provided by these fluids is reduced. With a reduction in fluid pressure, the pore spaces begin to close and the sediment may start to compact resulting in subsidence of the surface. In a number of sites where gas or oil has been extracted, as significant increase of sea level rise relatively to land has been observed (e.g. the North Sea). This "apparent" sea level rise is in fact mainly due to the subsidence of the land. In turn, land subsidence causes the sediment system to readjust to a new equilibrium characterized by a constant water depth: this can be achieved by "filling in" the sea bottom with sediment potentially taken from the coastline causing coastal erosion. To a certain extent, the impact of land subsidence is equivalent to sea level rise induced by climate change.

Although this phenomenon seems to have a limited geographical scope in Europe, its effects are irreversible and can be quite significant. With new techniques of mining in the near future, the land subsidence can be minimized.

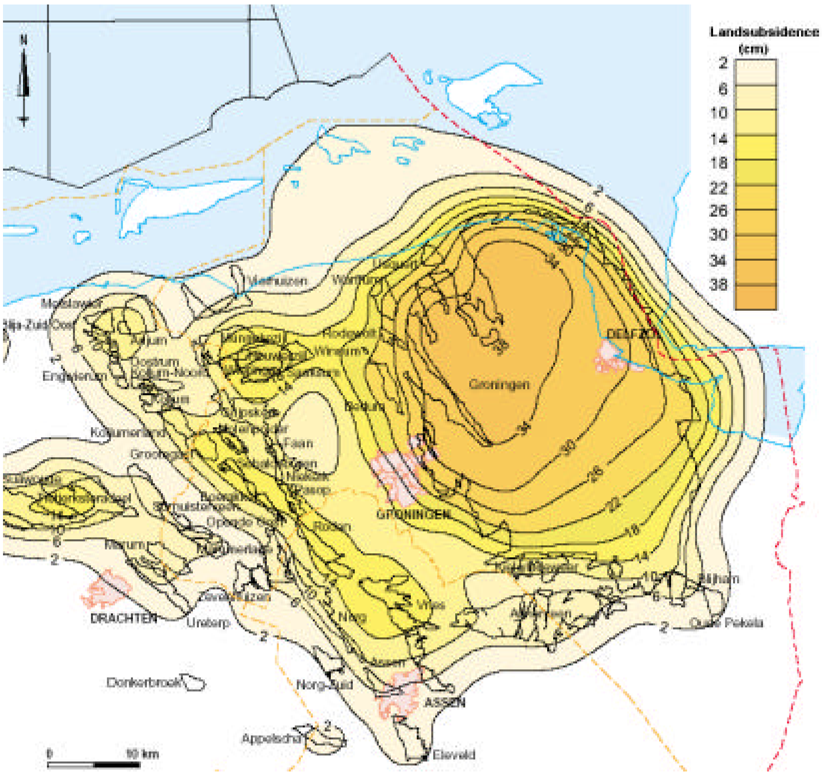


Figure 3-12. Land subsidence in the northern provinces of the Netherlands and Wadden Sea due to gas mining.

4. INFORMATION REQUIREMENTS

4.1 Introduction

This section provides an overview of data and information needed to assess the impact of projects on coastal erosion processes and design appropriate measures and monitor the effectiveness of these measures. More precisely:

- During the screening and scoping phases, data are needed to decide whether the project, programme or plan requires an Environmental Impact Assessment (EIA) or a Strategic Environmental Assessment (SEA) focusing on coastal erosion. (See Figure 4.1)
- During the Environmental Impact Studies (EIS), data are needed to quantify the impact and design appropriate mitigation or compensation measures. (See Figure 4.2)
- During the implementation of the project, programme or plan, data are needed to ensure that mitigation measures have expected results and if not, provide the basis for corrective actions (Environmental monitoring system). (See Figure 4.3)

This can be best summarized by the following three diagrams which highlights the linkage between the project development (in grey), the key management questions related to environmental issues (in white) and the need for data (in yellow):

Figure 4-1.

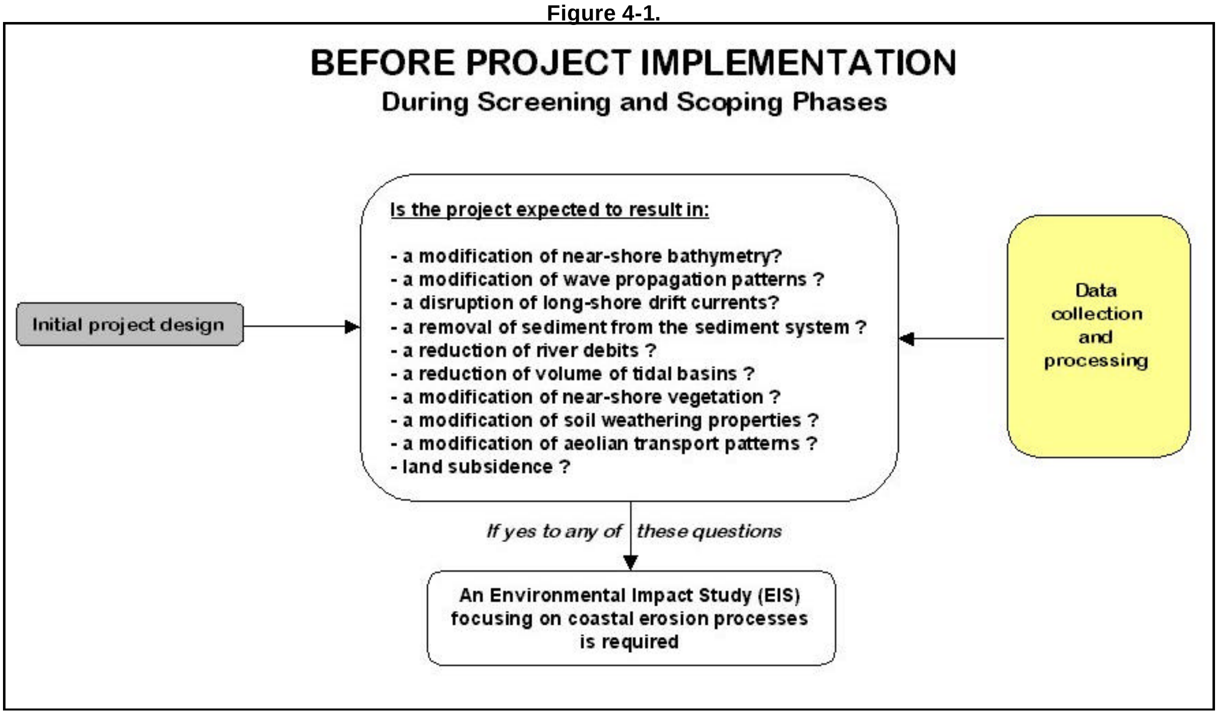


Figure 4-2.

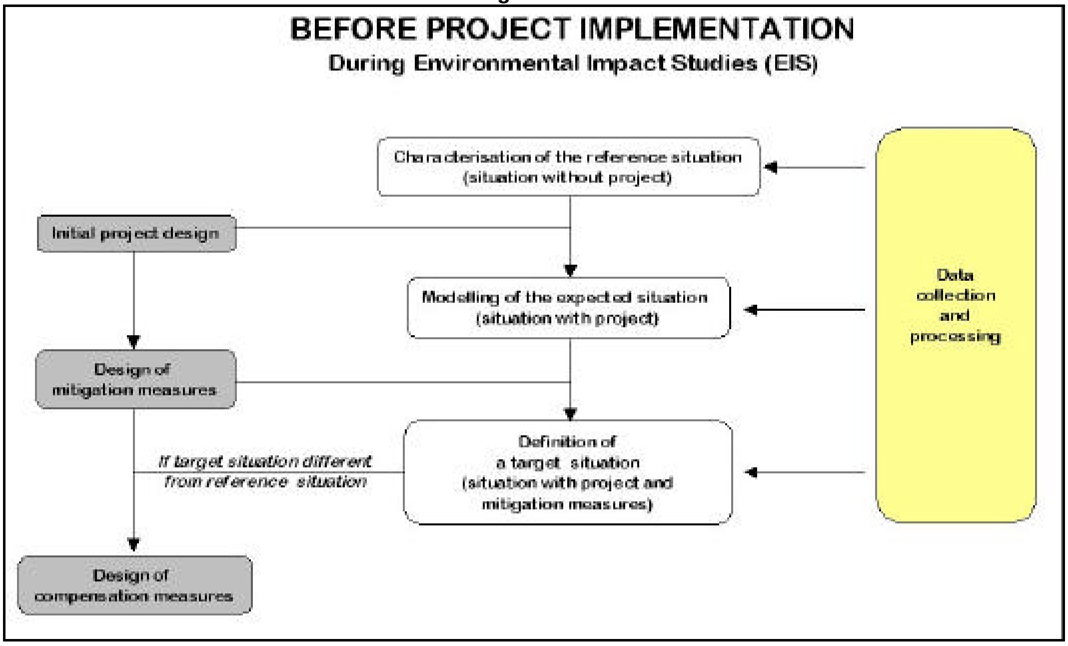
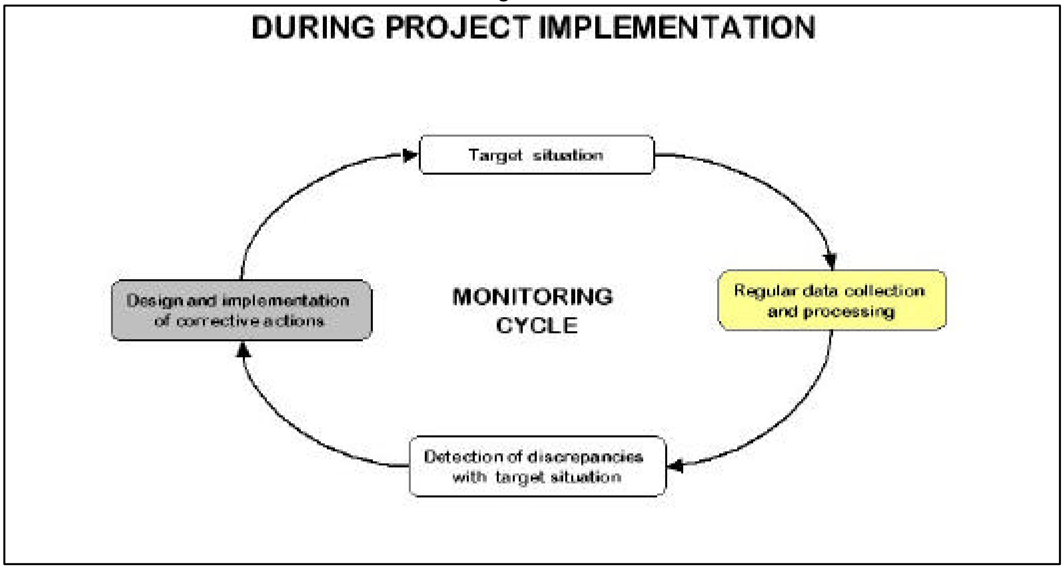


Figure 4-3.



4.2 Overview of the information requirements

In line with Figures 4.1, 4.2 and 4.3, information is needed at different steps of project design and development to trigger appropriate decisions, and more particularly with the objectives to:

- characterise the reference situation (or reference shoreline evolutionary trend), i.e. the "natural" evolution of the shoreline without the project. This evolutionary trend can be established through the collection of baseline data.
- quantify the project effects on the shoreline stability (or evolutionary trends). This is achieved though of use of appropriate models.
- detect any discrepancy between the target situation negotiated during the EA procedure (for example, "no coastline retreat tolerated" or "no more than 2 metres retreat at any given place"), and the effective impact of the project activities in the fields. Regular collecting and processing monitoring data through surveying techniques best achieves this.

Table 4.1. provides an extensive overview of data, model, and surveying techniques requirements either existing or to be developed in Europe to support the above-mentioned objectives.

Table 4.1. Matrix of information requirements

Impacts	Data requirements for characterising the reference situation.	Model requirements for quantifying the potential impact of a project design on the reference situation	Data requirements for monitoring the impact of project implementation on the target situation
Modification of near-shore bathymetry	▪ Aerial photography and/or orthophotographs to provide an accurate position of the coastline. Historical photographs can give an overview of the situation of the shoreline in time. ▪ Satelite images for an overview of the coastline for larger areas. E.g. LANDSAT images of 60x60 km. ▪ Airborne surveying with laser altimetry called LIDAR. Particularly efficient for near-shore areas as it can 'sense' the elevation for both terrestrial and underwater areas. ▪ Another method for underwater measurements is echo-sounding of the seafloor with dGPS on a ship.	▪ The limit boundary of the zone of extreme bottom changes for quartz-sand beaches is given with the closure depth, calculated with a formula of Hallermeier (1981). ▪ UNIBEST-DE is the module to compute the cross-shore profile developments during storm conditions of a coast consisting of loose material. In addition to large wave attack, these conditions are characterised by a considerable rise of the mean water level (storm surge). Especially relevant for applications as dune erosion and beach profile change under extreme conditions and design of beach nourishments.	▪ ARGUS: a serie of video cameras watching the foreshore. Elevation can be deduced with overlapping photo's (photogrammetric techniques). ▪ WESP (Water and Beach Profiler) echo-sounding: the beamer is mounted on a mobile crane able to move on the back- and foreshore. ▪ Echo-sounding in combination with GPS from a ship
Modification of wave propagation and breaking patterns	▪ Current wave regime: waveheight, -period and –direction. Measurements for wave height are wave gauges which measure the vertical displacement of the waterlevel or High Frequency Doppler radars (HF radars) which can measure the wave height and propagation. ▪ Current propagation regime: Refraction, diffraction and reflection patterns and breaking patterns can be measured with HF radars or determined from aerial photographs or satellite images.	▪ SWAN (Simulating *WA*ve *N*earshore) models the energy contained in waves as they travel over the ocean surface towards the shore. Wave change height, velocity and direction are input data to model the wave transfer. ▪ MIKE 21BW is used to study wave dynamics in ports and harbours and in small coastal areas. ▪ MIKE 21 PMS models refraction, shoaling, diffraction and reflection of waves on gently sloping bathymetry. ▪ SBEACH (Storm-induced BEAch CHange Model) is a model developed by the US Army's Corps of Engineers to simulate cross-shore beach, berm, and dune erosion produced by storm waves and water levels. The latest version allows simulation of dune erosion in the presence of a hard bottom. ▪ GENESIS is a model for calculating shoreline change caused by wave action. The effect of coastal defence works can be added to the model.	▪ Changing propagation regime: Refraction, diffraction and reflection patterns and breaking patterns can be measured with HF radars or determined from aerial photographs or satellite images.
Disruption of long-shore drift currents	▪ Current direction of the long-shore drift. Can be measured with Electromagnetic Current Meters, Acoustic Doppler Current Profiles (ADCP) with ultrasonic pulses, GPS-drifters (buoys) or with hydraulic tracers. ▪ Sediment properties. Data of grain size, particle fall velocity and bottom roughness are measured by sediment collection via grab samplers or sediment cores and calculations. Density of the sediment is determined via Rapid Sediment Analysers. ▪ Sediment transport is made of two components : bedload and suspendend load transport. Measuring these transport can with bedload samplers, suspended sediment traps and optical sensors (OBS) for suspended sediment. ▪ Wave and tidal data from gauges and HF-radar.	▪ Transport formulas from Bijker (1971), Van Rijn (1984), Engelund-Hanssen (1971). They are a function of the deep water wave height, period and angle, current velocity, grain size and density, particle fall velocity and bottom roughness. ▪ UNIBEST -CL+ is a sediment balance model for computing longshore transport what can be translated into shoreline migration and evolution also around coastal defence works. Sediment sources and sinks, sea level rise, artificial sand bypass can be defined. ▪ MIKE 21-ST is designed for the assessment of sediment transport rates and related initial rates of bed level changes of non-cohesive sediment due to currents or combined wave-current flow. ▪ MIKE 21-MT is designed to calculate mud transport rates and can be applied for engineering	▪ Modification of nearshore or backshore. Measured with ARGUS, WESP or echo-sounding (see nearshore bathymetry). ▪ Changed sediment transport patterns. Measuring these transport can via bedload samplers, suspended sediment traps and optical sensors (OBS) for suspended sediment. ▪

Impacts	Data requirements for characterising the reference situation.	Model requirements for quantifying the potential impact of a project design on the reference situation	Data requirements for monitoring the impact of project implementation on the target situation
		applications. ▪	
Removal of sediment from the sediment system	▪ Wave regime: transformation from offshore to nearshore, wave height, refraction pattern. ▪ Sediment transport pattern (see above) ▪ Nearshore and backshore bathymetry (see above)	▪ SWAN: models the transformation of the wave reflection pattern over the dredge pit. Wave change height, velocity and direction and water depth are input data to model the wave transfer. ▪ MIKE 21-MT is designed to calculate mud transport rates and can be applied for modeling dredging plumes. ▪ UNIBEST-CL+ for modeling longshore transport (see above) ▪ Delft3D-SED: The SED module of Delft3D can be applied to model the transport of cohesive and non-cohesive sediments, e.g. spreading of dredged materials, to study sediment/erosion patterns.	▪ Transformation of wave refraction pattern ▪ Changed sediment transport pattern ▪ Nearshore and backshore bathymetry changes
Reduction of river debits	▪ Amount of sediment transport entering the sea at the mouth of the river. Measuring the transport can via bedload samplers, suspended sediment traps and optical sensors (OBS) for suspended sediment. ▪ Current velocity and discharge of the river. Current velocity be measured with Electromagnetic Current Meters, Acoustic Doppler Current Profiles (ADCP) with ultrasonic pulses, GPS-drifters (buoys) or with hydraulic tracers. Discharge of the river is the mean current velocity times the cross section of the river.	▪ Delft3D-FLOW: The FLOW module of Delft3D is a multi-dimensional (2D or 3D) hydrodynamic (and transport) simulation program which calculates non-steady flow and transport phenomena resulting from tidal and meteorological forcing on a curvilinear, boundary fitted grid. And can be applied for river flow simulations and fresh water river discharges in bays. ▪ Delft3D-SED: The SED module of Delft3D can be applied to model the transport of cohesive and non-cohesive sediments.	▪ Changed amount of sediment transport entering the sea at the mouth of the river. Measuring the transport can via bedload samplers, suspended sediment traps and optical sensors (OBS) for suspended sediment.
Reduction of volume of tidal basins	▪ Tidal prism (the amount of water flowing into or out of a tidal basin in one flood or ebb period). The prism is calculated with data of current velocity and water depth over time at the entrance of the basin. Needed data is current velocity, water depth and cross sectional inlet area (see river debits) ▪ Sediment transport into and out of the basin over time (ebb/flood, springtide/neaptide cycle). Measuring the transport can via bedload samplers, suspended sediment traps and optical sensors (OBS) for suspended sediment. ▪ Bathymetry of tidal basin. (see nearshore bathymetry)	▪ ASMITA is a morphological model to assess the influence of the sand demand of a flood basin of the Wadden Sea on the behaviour of the North Sea coastal zone. ▪ MORRES is a conceptual sand balance model of a flood basin - outer delta system and gives an estimate of a disturbance in this system on the sand demand of the North Sea shore and the shoal area in the flood bowl. ▪ ESTMORF (ESTuary MORphology) is a physical model for tidal flow in a network of tidal channels (estuaries, tidal basins) , in which the area bathimetry and the tidal flow patterns can be simulated accurately.	▪ Change in tidal prism ▪ Change in sediment transport ▪ Changed bathymetry and possible erosion or accretion areas.
Modification of near-shore vegetation	▪ Sampling benthic flora and fauna using grabs and/or collecting cores, which have to be analysed in a lab. ▪ Measuring the amount of sunlight penetrating the seawater and reaching the bottom.	▪ MIKE 21-MT is designed to calculate mud transport rates and can be applied for engineering applications, like the effect of dredging plumes.	▪ Sampling benthic flora and fauna using grabs and/or collecting cores, which have to be analysed in a lab. ▪ Measuring the amount of sunlight penetrating the seawater and reaching the bottom.
Modification of soil weathering properties	▪ Weathering processes: - Coastline geology from Eurosion Database. The classification of sediment rocks/metamorphic/volcanic etc. gives the resistence of the rocks against erosion processes. - Morphology of the coastline in terms of erosion forms (gullies), ground failure, scars.	▪ Simulation model of Armstrong (1976) or Ahnert (more complex). Modelling of sequential erosion slope profiles with the opportunity to model undercutting of a cliff by waves or streams. ▪ …	▪ Morphology of the coastline in terms of erosion forms (gullies), ground failure, scars and probably changed vegetation patterns on the cliff. ▪ Slope transport rate. With aerial photographs or a Digital Terrain Model (DTM) over time, the

Impacts	Data requirements for characterising the reference situation.	Model requirements for quantifying the potential impact of a project design on the reference situation	Data requirements for monitoring the impact of project implementation on the target situation
	- Vegetation cover from CORINE ▪ Slope transport rate. With aerial photographs or a Digital Terrain Model (DTM) over time, the rate of cliff retreat can be categorised. ▪ Marine Transport:. - Wave attack: energy of the waves which undermine a cliff. Needing maximum waveheights during normal and storm conditions. Measured with Wave gauges or High Frequency Doppler radars. - Longshore transport rates: amount of removed sediment from under a cliff (see disruption of longs.tr.)		rate of cliff retreat can be categorised. ▪ Changed wave attack induced by project what increases erosion of the cliff (undercutting speed). ▪ Or changed longshore transport pattern.
Modification of aeolian transport patterns	▪ Wind regime: wind speed and direction can be measured with scatterometers or anonometers, but data is mostly available at weather centres. ▪ Sedimentology of the beach: grain size, shear stress, threshold wind speed (ua=u*/k ln(z/z0), where k=0.4) ▪ Amount of Aeolian transport can be measured with sediment traps ▪ Cross-shore beach profile including dune systems with DGPS or if possible an DTM with airborne surveying LIDAR.	▪ Bagnold formula (1936): calculation of the amount of Aeolian transport. ▪ Wilson formula (1972): development and origin of ripples, dunes and megadunes. ▪ Aeolus II: An interactive program for a 2D/3D simulation of Aeolian sediment transport with optional selection of different formulas/models. ▪ HYSPLIT_4 (HYbrid Single-Particle Lagrangian Integrated Trajectory) model is a complete system for computing simple trajectories to complex dispersion and deposition simulations using either puff or particle approaches.	▪ Amount of Aeolian transport can be measured with sediment traps ▪ Changes in cross-shore beach profile including dune systems with DGPS
Land subsidence	▪ Nearshore bathymetry. With airborne surveying: LIDAR or ship-borne surveying: Sonar. ▪ Waterdepth and wave characteristics especially wave height transformation and refraction. Measured from water gauges and HF-radar.	▪ Bruun rule (1962). Estimates the response of the shoreline profile to sea level rise. Parameters are only mean water level and sand grain size. ▪ UNIBEST-CL+ for modeling longshore transport (see above)	▪ Nearshore bathymetry. With airborne surveying: LIDAR or ship-borne surveying: Sonar. ▪ Relative sea-level rise due to land subsidence with water gauges

5. SURVEY OF MITIGATION RESPONSES

Below is a suggestion of mitigation measures which can be included in a project design depending on the type of impacts this project will have on coastal erosion pressure factors. They can be used simultaneously or alternatively. This survey includes two parts:

- primary measures which will act directly on the pressure factors responsible for coastal erosion
- additional measures which can be taken to counteract the local effects of coastal erosion in case primary measures are not sufficient to prevent erosion

5.1 Primary mitigation measures

Primary mitigation measures are particular arrangements, which may be integrated directly in the project design the limit as much as possible the modification of the features, which are directly responsible for coastal erosion (the *pressure factors*). In that sense, these primary mitigation measures aim at preventing human induced coastal erosion to occur instead of combating it. They may take the form of a variety of forms, which are briefly discussed hereafter.

5.1.1 MODIFICATION OF NEAR-SHORE BATHYMETRY

- Avoiding dredging operations in shallow waters. Ideally, dredge areas should be located offshore the shoaling zone, i.e. the zone where waves interact with the sea bottom. In practice, the shoaling zone starts at a water depth d given by:

  $$d = \frac{g.T^2}{4p}$$ where T taken as the peak period of incoming waves

  Depending on areas, this minimum depth for dredging operations ranges from 15 to 20 metres. However dredging in deeper waters requires specialised equipments different from shallow waters.

- Adopting for the dredge area appropriate size, shape and depth, i.e. which minimize the effect of wave refraction on the shore. As waves propagate over a dredge area, they undergo modifications, which depends on the size, shape and depth of the dredge area. Simulations using computer models like SWAN (Delft Hydraulics), UNIBEST (Delft Hydraulics), MIKE (Danish Hydraulics Institute), SBEACH (US Army Corps of Engineers) may help to make the choice between different scenarios.

5.1.2 MODIFICATION OF WAVE PROPAGATION PATTERNS

- Adopting for surface piercing structures shapes which control wave diffraction. By acting on the groin shape design it is possible to limit the diffraction of surface piercing structures (like groins, breakwaters or harbour jetties) responsible for wave diffraction. S–shaped or T-shaped groins as well as circular breakwaters provides interesting design for that purpose.

- Preferring sloping seawalls to vertical seawalls. Vertical seawalls are responsible for wave reflection, which in turn exacerbates erosion in front of the seawall and undermines its foundations. By adopting a sloping design for the seawall, wave reflection can be reduced and wave energy can be better dissipated. The appropriate slope is a function of wave height and period, and seawall revetment roughness. It must be noted that the cost of sloping seawalls is significantly higher as they occupies a large volume.

5.1.3 DISRUPTION OF LONG-SHORE SEDIMENT TRANSPORT

- Limiting the seaward extent of cross-shore structures. Long-shore sediment transport mainly occurs in the area lying from the breaker line (i.e. the water depth at which the waves break) and the shoreline. By limiting the seaward extent of cross-shore structures like groins or jetties, the long-shore sediment transport is not entirely disrupted and continues to transport sediment along shore.

- Sand by-passing. Sand by-passing consists in artificially taking sand accumulated up-drift cross-shore structure and moving this sand down-drift, thus restoring long-shore sediment transport. This can be done either by sucking up the sand via pumping devices, trucks or hopper dredges. A hopper dredge is a propelled floating plant, which is capable of dredging material, storing it onboard, transporting it to the disposal area, and dumping it.

- Using materials dredged from navigation channels to restore sediment budget along-shore. Alternatively to sand by-passing, the sediment budget may be restored by taking sand from inlets or harbour entrances which need to be regularly dredged to facilitate navigation. A particular attention should be paid however to the level of contamination of sediments extracted from navigation channels and inlets which may be significantly higher than the near-shore seabed.

5.1.4 REMOVAL OF SEDIMENTS FROM THE SEDIMENT SYSTEM

- Limiting the amount of aggregates to be extracted. Conservative measures may be taken in order to make sure that a certain volume of aggregate extraction, expressed in cubic meters, will not be exceeded. This maximum volume depends on the sediment economy within the sediment system. If the sediment system already suffers from sediment shortage, the authorised amount of extraction should be all the more limited.

- Adding sediments to the sediment budget. When removal of sediments from the sediment system is the main cause of coastal erosion, the possibility to identify strategic sediment reservoirs, which can be used to compensate the sediment deficit may be considered. This can include identifying offshore sand banks, which are not active (i.e. not contributing significantly to the sediment transport patterns), or sediment sources inland (e.g. quarry). Sediments identified in sediment reservoirs should have the same characteristics as the sediments removed from the sediment system (size, roughness, structure, texture). Other critical questions relating to the addition of sediments to the sediment budget are where and when this addition should take place (e.g. within rivers, along the beaches, underwater). Careful studies should be conducted in that respect.

5.1.5 REDUCTION OF RIVER DEBITS

Hydraulic measures to deal with sedimentation problems in reservoirs have proved to be very effective, provided sufficient water and adequately sized outlets are available. Among the different measures are:

- minimizing deposition in reservoirs through sluicing or venting of density currents. Sluicing makes it possible to avoid sedimentation within dam reservoirs, but is to a large extent limited to fine particles as silt and clay. The throughput of coarse sediments depends on the technical characteristics of the dams.

- removing accumulated sediments from the reservoir through flood flushing. Flushing consists in simulating an artificial flood by releasing huge amounts of water from dam reservoirs. The water flow velocity flushes sediments deposited on the riverbed. The efficiency of flushing depends however on a number of logistical constraints. For the most part, the reservoir has to be small and narrow and the discharge has to be large enough to carry bed-load downstream. For larger reservoirs, the sediments that accumulate near the outlet at the dam tend to be fine and are potentially more destructive to downstream aquatic life than they are beneficial.

- controlling the location of sediment deposition in the reservoir for later excavation. Sediment scouring is then achieved either via underwater pumping or during maintenance works, which require drying out the dam reservoir.

The first two measures are costly in terms of water, and effective reservoir management requires mathematical modelling tools that provide detailed predictions of the effectiveness of these hydraulic measures. In addition, sediments deposited in the riverbed or within the dam reservoir for long period show a higher rate of contamination to nitrogen and metals than flowing sediments.

5.1.6 REDUCTION OF THE VOLUME OF TIDAL BASINS

- Replacing reclaimed area by creating new wetlands. When land reclamation results in a significant reduction of the tidal prism (i.e. the volume of the tidal basin), the area which is lost may be compensated by new areas which are transformed into wetlands. This compensation aims at keeping the tidal prism as well as the tidal influence constant. However, this compensation may not be applicable everywhere, especially in those areas where lack of space is critical. As well, maintaining the tidal prism constant may not prevent local modifications or redistribution of sediments within the estuary, tidal basins or the bay.

5.1.7 MODIFICATION OF THE NEAR-SHORE VEGETATION

- Including buffer zones between the project site and settlement ponds, marine plants and tidal lands. Accurate mapping of sea-grass habitats and knowledge on currents' velocity are a prerequisite to any activity susceptible to impact the integrity of the seafloor, and constitute the knowledge base for delineating buffer zones. Buffer zones should be wide enough to avoid the impact of increased turbidity induced by the project activities on sea-grass communities. This can range from 100 metres to several kilometres depending on the magnitude of underwater currents (notably near-bed currents).

- Avoiding operations at certain periods. Period to avoid are periods of rapid water movements (stormy conditions), seagrass flowering periods, or spawning and migration seasons.

- Reducing turbidity induced by the project activities by placing "curtains" or any other measures able to limit the lateral movement of turbid waters. This also includes a careful maintenance of equipment to avoid leakage or spillage. This will avoid excessive spoil dispersion susceptible to damage sea-grass communities located in the neighbourhood.

- Limiting the frequency of underwater activities. This can be done for example by forbidding repetitive operations in the same areas (e.g. navigational channels) causing damages to the sea-grass communities. In the case of navigational dredging, it may be appropriate to dredge to a slightly greater depth than absolutely necessary to avoid too frequent maintenance dredging. The period between consecutive operations should be long enough to ensure that the damaged ecosystem will recover a status close to the status of undisturbed conditions. Appropriate monitoring programmes could help determine this period.

- Rehabilitating natural habitat after operations. This include for example re-profiling bed and banks to their initial shape or replanting sea grass communities which may have been damage during operations.

5.1.8 MODIFICATION OF SOIL WEATHERING PROPERTIES

- Establishing setback lines to limit the clearing of shoreline vegetation. Since vegetation constitute an efficient, natural and un-expensive defence to prevent coastal landslide and control erosion, it is important to reduce the clearing of vegetation along the shoreline. This can be done by establishing a setback line, i.e. a buffer zone within, which such activities as vegetation clearing is forbidden. The width of the setback line may vary from a 100 metres to several kilometres depending on existing erosion rate (if any) and the soil and geological properties of the shoreline.

- Rehabilitating natural vegetation. If shoreline vegetation is damaged by the project activities, programmes to restore the initial vegetation could be implemented whenever possible. As the vegetation grows, roots act as a factor of soil cohesion and the stability of the shoreline is increased. This measure may be applied in the case of dunes, bluffs with a gentle slope, and in some cases of high cliffs. (see also *modification of Aeolian transport patterns*)

- Re-profiling of the shoreline vegetation via bioengineering techniques. When rehabilitation of vegetation is not possible because of steep bluffs, bioengineering techniques may be used. These include planting vegetation on slopes stabilized with blankets made of special, biodegradable fibres, transplanting trees into stone or riprap (known as "joint planting"), planting freshly cut willow limbs in the ground (known as "willow staking"), and laying interlocking blocks with gaps designed to promote plant growth.

5.1.9 MODIFICATION OF AEOLIAN TRANSPORT PATTERNS

- Reducing soil erodibility via vegetation planting. In the case of eroding dunes or other coastline highly exposed to wind stress, vegetation may help to increase the soil cohesion and therefore upgrade their resistance to wind actions. In addition, vegetation also act as windbreaks (see below).

- Windbreaks planting. A windbreak is a barrier or baffle that causes the wind to slow down. When wind speed is decreased, the load carried by the wind is dropped. Fences and plants are often used as windbreaks.

5.1.10 LAND SUBSIDENCE

- Limiting the volume of materials extracted. Severe subsidence may be prevented or controlled by leaving some material behind for support, i.e. maintaining a residual pressure which will prevent the land from subsiding.

- Re-pressurizing the extraction site. Alternatively, subsidence may be prevented by totally refilling mined out volumes with fluids such as water. This results in a re-pressurization of the area. Recent experiments suggests that carbon dioxide can also be used under certain conditions to re-pressurize depleted gas reservoirs thus contributing to both carbon sequestration and reduction of land subsidence.

5.2 Additional mitigation measures

Unlike primary mitigation measures, additional mitigation measures are not meant to limit the factors responsible for coastal erosion, but to counteract their effects locally (i.e. coastal erosion). They should be considered only in those cases where primary mitigation measures fail to avoid coastal erosion. An overview of these measures is presented in the next table. A distinction is generally made between hard techniques which rely on heavy and non-easily removable materials (such as concrete or rock armoured structured) and soft techniques which build upon sand and natural processes.

Table 5.1. Additional mitigation measures to counteract coastal erosion locally

TECHNIQUES	*PRINCIPLES*	*LIMITS OF APPLICATION*
HARD TECHNIQUES		
Breakwater	Breakwaters are protective structures placed offshore, generally in hard materials such as concrete or rocks, which aim at absorbing the wave energy before the waves reach the shore.	Breakwaters reflect or diffract wave energy in destructive ways or concentrate it in local hot spots. Erosion problems and the scouring effects of the misdirected energy lead to the loss of beach / coastline and undermine the structures that were meant to be protected.
Gabion	The gabion is a metal cage filled with rocks, about 1 metre by 1 metre square. Gabions are stacked to form a simple wall.	They are used to protect a cliff or area in the short term only, since they are easily damaged by powerful storm waves and the cages tend to rust quite quickly. Gabions have the advantage of ease of use and are relatively cheap but their life span is short.
Geotextiles	Geotextiles are permeable fabrics which are able to hold back materials while water flows through. Geosynthetic tubes are large tubes consisting of a woven geotextile material filled with a slurry-mix. The mix usually consists of dredged material (eg. sand) from the nearby area but can also be a mortar or concrete mix.	Geotextiles are relatively recent but provided good results to prevent beach from retreating. Plus they are very flexible and can be re-arranged if their configuration does not provide good results.
Groin fields	Groins are structures that extend perpendicularly from the shore. Usually constructed in groups called groin fields, their purpose is to trap and retain sand, nourishing the beach compartments between them. Groins may be made of wooden or rocky materials. They interrupt the longshore transport of littoral drift. When a well designed groin field fills to capacity with sand, longshore transport continues at about the same rate as before the groins were built, and a stable beach is maintained.	Sand accumulated between groins contributes to a sediment deficit down-drift. Coastal erosion problems are then shifted to other locations. Thus, to be effective, groins should be limited to those cases where longshore transport is predominantly in one direction, and where their action will not cause unacceptable erosion of the downdrift shore.
Revetments	Revetment is a sloping feature which breaks up or absorbs the energy of the waves but may let water and sediment pass through. The older wooden revetment consists of posts fixed into the beach with wooden slats between. Modern revetments have concrete or shaped blocks of stone laid on top of a layer of finer material. Rock armour or riprap consists of layers of very hard rock with the largest, often weighing several tonnes, on the top. Riprap has the advantage of good permeability and looks more natural.	Revetments are adapted to foreshore with a gentle slope. It has the same adverse effect as seawalls though with a reduced intensity. It also results in changing the nature of the sea frontage which may lead to further changes in the foreshore ecosystems.
Seawall	Bulkheads and seawalls protect banks and bluffs by completely separating land from water. Bulkheads act as retaining walls, keeping the earth or sand behind them from crumbling or slumping. Seawalls are primarily used to resist wave action. Design considerations for these types of structures are similar. These structures do not protect the shore in front of them, however.	When bulkheads and seawalls are used in areas where there is significant wave action, they may accelerate beach erosion (much of the energy of the waves breaking on the structure is redirected downward to the toe). Bulkheads and seawalls are most appropriate where fishing and boating are the primary uses of the shore, and gently sloping areas for sunbathing or shallow-water swimming are not essential. They are also critical when risks associated to coastal erosion are imminent.
SOFT TECHNIQUES		
Artificial reef creation	Building an artificial reef which absorbs the wave energy (thus providing coastal defence), while providing a natural habitat for marine biodiversity and opportunities for recreational activities	Only few examples of artificial reef creation exist in Europe (in Sea Palling, UK mainly), but seems to provide good results.
Beach drainage	Beach drainage decreases the volume of surface water during backwash by allowing water to percolate into the beach, thus reducing the seaward movement of sediment. Beach drainage also leads to drier and "gold" coloured sand, more appreciated for recreational activities.	The technique is relatively new and experience lacks to assess its performance. It has to be noted however that beach drainage is adapted when erosion mainly occurs cross-shore (non significant long-shore drift)
Sand supply or nourishment	Artificial increase of sand volumes in the foreshore via the supply of exogenous sand. Sand supply may be achieved through the direct placement of sediment on the beach, through trickle charging (placing sediments at a single point), or through pumping. It can be also take	Beach and underwater nourishment as been very popular in the North because of the availability of sediments which has similar properties as the beach sediment. When sediment is not available and has to be imported from another region, beach

TECHNIQUES	PRINCIPLES	LIMITS OF APPLICATION
	place in the emerged part of the foreshore (“beach nourishment”) or under the water line (“underwater nourishment”) which is generally cheaper.	nourishment may not be the best decision. Nourishment schemes have also to be carefully designed as they may alter the biota (both on the beach and in the dredging area).
Beach scraping	Artificial re-profiling of the beach when sediment losses are not severe enough to warrant the importation of large volumes of sediments. Re-profiling is achieved using existing beach sediment	Beach scraping is among the cheapest techniques as it does not require importing sand. However, the process may have to be carried out several times before the right profile is found. It is also restricted to those beaches where cross-shore erosion is dominant and storms not heavy.
Cliff drainage	Reduction of pore pressure by piping water out of the cliff and therefore preventing accumulation of water at rock boundaries	May not be applicable for all types of cliffs.
Cliff profiling	Change of cliff face angle to increase cliff stability. The angle at which cliff become stable is a function of rock type, geologic structure and water content.	May not be applicable for all types of cliffs, and the techniques requires a fairly good knowledge of the cliff geologic structure and watering process.
Cliff toe protection	Protection of the cliff base by placing blocks at the foot of potential failure surface.	This technique is easy to achieved but do not stop erosion completely. It may therefore be adapted in those case where further loss of lands is still acceptable
Creation of stable bays	Increasing the length of the coastline to dilute wave energy per unit length of coast. While some coastline segments are protected, erosion continues between these hard points leading to the formation of embayments	This technique is almost not used in Europe and is still experimental. However, it has been envisaged for a number of sites (especially the Holland coast)
Dune regeneration	Wind blown accumulation of drifted sand located in the supra-tidal zone. Wind velocity is reduced by way of porous fences made of wood, geo-textile, plants, which encourages sand deposition	Adapted for those cases where wind plays an important role
Marsh creation	Planting of mudflats with pioneer marsh species, such as *Spartina sp*. Marsh vegetation increases the stability of sediment due to the binding effects of the roots, increasing shear strength and decreasing erodability. Marshes also provides cost-effective protection against flooding by absorbing wave energy.	Marsh creation is particularly popular in United Kingdom. However, the technique may be jeopardized by accelerated sea level rise. In this case, the accumulation of fine sediments necessary to the marsh creation may not occur in the proper way and the marsh finally collapse.
Mudflat recharge	Supply of existing mudflats with cohesive sediments. This is achieved via trickle charging (see beach feeding), rainbow charging, and polders	Such as marsh creation, mudflat recharge may be jeopardized by accelerated sea level rise.
Rock pinning	Prevention of slippage in seawards dipping rocks by bolting layers together to increase cohesion and stability. Does not prevent wave attack at the cliff base, but does reduce the threat of mass movement and thus reduces net erosion rates.	May not be applicable for all types of cliffs.
sand by-passing	Reactivation of sediment transport processes by pumping sediments accumulated up-drift by coastal infrastructure normal to the coastline and injecting them down-drift. A variant of sand by-passing is to use materials dredged for navigational purposes to reactivate the sediment transport.	This technique has been implemented by a number of harbour authorities (or dams authorities) in Europe as volumes of sand trapped by harbour breakwaters (resp. dams) are generally considerable. When sediments are trapped by a series of groins (or consecutive dams) the technique might not be cost effective anymore. It has to be noted that in the case of dams, accumulated sediment may be contaminated may not be re-injected in the sediment transport system.
Vegetation planting and/or stabilisation	Colonisation of coastal soils by vegetation whose roots bind sediment, making it more resistant to wind erosion. Vegetation also interrupt wind flow thus enhancing dune growth. As for cliffs, vegetation increases cohesion of surface soils on cliff slopes to prevent downhill slumping and sliding	Vegetation adapted to dune (eg. Marram grass) is generally very fragile and require integral protection and daily care to the dune system.

APPENDIX A

PROJECTS LISTED IN ANNEX I OF DIRECTIVE 97/11/EC WHICH MAY IMPACT COASTAL EROSION PROCESSES

Article 4(1) of Directive 97/11/EC requires that the following types of projects must be subject to EIA. Only those, which have an impact on coastal erosion processes have been highlighted.

Annex I Projects

1. Crude-oil refineries (excluding undertakings manufacturing only lubricants from crude oil) and installations for the gasification and liquefaction of 500 tonnes or more of coal or bituminous shale per day.

2. Thermal power stations and other combustion installations with a heat output of 300 megawatts or more, and nuclear power stations and other nuclear reactors including the dismantling or decommissioning of such power stations or reactors (except research installations for the production and conversion of fissionable and fertile materials, whose maximum power does not exceed 1 kilowatt continuous thermal load).

3. (a) Installations for the reprocessing of irradiated nuclear fuel
   (b) Installations designed:
   • for the production or enrichment of nuclear fuel,
   • for the processing of irradiated nuclear fuel or high-level radioactive waste,
   • for the final disposal of irradiated nuclear fuel,
   • solely for the final disposal of radioactive waste,
   • solely for the storage (planned for more than 10 years) of irradiated nuclear fuels or radioactive waste in a different site than the production site.

4. a)Integrated works for the initial smelting of cast-iron and steel
   (b)Installations for the production of non-ferrous crude metals from ore, concentrates or secondary raw materials by metallurgical, chemical or electrolytic processes.

5. Installations for the extraction of asbestos and for the processing and transformation of asbestos and products containing asbestos: for asbestos-cement products, with an annual production of more than 20 000 tonnes of finished products, for friction material, with an annual production of more than 50 tonnes of finished products, and for other uses of asbestos, utilization of more than 200 tonnes per year.

6. Integrated chemical installations, i.e. those installations for the manufacture on an industrial scale of substances using chemical conversion processes, in which several units are juxtaposed and are functionally linked to one another and which are:
   (i) for the production of basic organic chemicals;
   (ii) for the production of basic inorganic chemicals;
   (iii) for the production of phosphorous-, nitrogen- or potassium-based fertilizers (simple or compound fertilizers);
   (iv) for the production of basic plant health products and of biocides;
   (v) for the production of basic pharmaceutical products using a chemical or biological process;
   (vi) for the production of explosives.

7. Construction of lines for long-distance railway traffic and of airports (1) with a basic runway length of 2 100 m or more;
   (b) Construction of motorways and express roads (2);
   (c) Construction of a new road of four or more lanes, or realignment and/or widening of an existing road of two lanes or less so as to provide four or more lanes, where such new road, or realigned and/or widened section of road would be 10 km or more in a continuous length.

8. **(a) Inland waterways and ports for inland-waterway traffic which permit the passage of vessels of over 1 350 tonnes;**
   (b) Trading ports, piers for loading and unloading connected to land and outside ports (excluding ferry piers) which can take vessels of over 1 350 tonnes.

9. Waste disposal installations for the incineration, chemical treatment as defined in Annex IIA to Directive 75/442/EEC (3) under heading D9, or landfill of hazardous waste (i.e. waste to which Directive 91/689/EEC (4) applies).

10. Waste disposal installations for the incineration or chemical treatment as defined in Annex IIA to Directive 75/442/EEC under heading D9 of non-hazardous waste with a capacity exceeding 100 tonnes per day.

11. Groundwater abstraction or artificial groundwater recharge schemes where the annual volume of water abstracted or recharged is equivalent to or exceeds 10 million cubic metres.

12. (a) Works for the transfer of water resources between river basins where this transfer aimsmat preventing possible shortages of water and where the amount of water transferred exceeds 100 million cubic metres/year;
(b) In all other cases, works for the transfer of water resources between river basins where the multi-annual average flow of the basin of abstraction exceeds 2 000mmillion cubic metres/year and where the amount of water transferred exceeds 5 % of this flow. In both cases transfers of piped drinking water are excluded.

13. Waste water treatment plants with a capacity exceeding 150 000 population equivalent as defined in Article 2 point (6) of Directive 91/271/EEC (5).

14. Extraction of petroleum and natural gas for commercial purposes where the amount extracted exceeds 500 tonnes/day in the case of petroleum and 500 000 m3/day in the case of gas.

15. Dams and other installations designed for the holding back or permanent storage of water, where a new or additional amount of water held back or stored exceeds 10 million cubic metres.

16. Pipelines for the transport of gas, oil or chemicals with a diameter of more than 800 mm and a length of more than 40 km.

17. Installations for the intensive rearing of poultry or pigs with more than:
(a) 85 000 places for broilers, 60 000 places for hens;
(b) 3 000 places for production pigs (over 30 kg); or
(c) 900 places for sows.

18. Industrial plants for the
(a) production of pulp from timber or similar fibrous materials;
(b) production of paper and board with a production capacity exceeding 200 tonnes per day.

19. Quarries and open-cast mining where the surface of the site exceeds 25 hectares, or peat extraction, where the surface of the site exceeds 150 hectares.

20. Construction of overhead electrical power lines with a voltage of 220 kV or more and a length of more than 15 km.

21. Installations for storage of petroleum, petrochemical, or chemical products with a capacity of 200 000 tonnes or more.

APPENDIX B

PROJECTS LISTED IN ANNEX II OF DIRECTIVE 97/11/EC

Article 4(2) of Directive 97/11/EC requires that the following types of projects must be subject to EIA if it is determined, either by case-by-case examination or on the basis of thresholds and criteria set by the Member State, that they are likely to have significant effects on the environment. Only those, which have an impact on coastal erosion processes, have been highlighted.

Annex II Projects

1. Agriculture, silviculture and aquaculture
   (a) Projects for the restructuring of rural land holdings;
   (b) Projects for the use of uncultivated land or semi-natural areas for intensive agricultural purposes;
   (c) Water management projects for agriculture, including irrigation and land drainage projects;
   (d) Initial afforestation and deforestation for the purposes of conversion to another type of land use;
   (e) Intensive livestock installations (projects not included in Annex I);
   (f) Intensive fish farming;
   (g) Reclamation of land from the sea.

2. Extractive industry
   (a) Quarries, open-cast mining and peat extraction (projects not included in Annex I);
   (b) Underground mining;
   (c) Extraction of minerals by marine or fluvial dredging;
   (d) Deep drillings, in particular:
   • geothermal drilling,
   • drilling for the storage of nuclear waste material,
   • drilling for water supplies, with the exception of drillings for investigating the stability of the soil;
   (e) Surface industrial installations for the extraction of coal, petroleum, natural gas and ores, as well as bituminous shale.

3. Energy industry
   (a) Industrial installations for the production of electricity, steam and hot water (projects not included in Annex I);
   (b) Industrial installations for carrying gas, steam and hot water; transmission of electrical energy by overhead cables (projects not included in Annex I);
   (c) Surface storage of natural gas;
   (d) Underground storage of combustible gases;
   (e) Surface storage of fossil fuels;
   (f) Industrial briquetting of coal and lignite;
   (g) Installations for the processing and storage of radioactive waste (unless included in Annex I);
   (h) Installations for hydroelectric energy production;
   (i) Installations for the harnessing of wind power for energy production (wind farms).

4. Production and processing of metals
   (a) Installations for the production of pig iron or steel (primary or secondary fusion) including continuous casting;
   (b) Installations for the processing of ferrous metals:
      (i) hot-rolling mills;
      (ii) smithies with hammers;
      (iii) application of protective fused metal coats;
   (c) Ferrous metal foundries;
   (d) Installations for the smelting, including the alloyage, of non-ferrous metals, excluding precious metals, including recovered products (refining, foundry casting, etc.);
   (e) Installations for surface treatment of metals and plastic materials using an electrolytic or chemical process;
   (f) Manufacture and assembly of motor vehicles and manufacture of motor-vehicle engines;
   (g) Shipyards;
   (h) Installations for the construction and repair of aircraft;
   (i) Manufacture of railway equipment;
   (j) Swaging by explosives;
   (k) Installations for the roasting and sintering of metallic ores.

5. Mineral industry
(a) Coke ovens (dry coal distillation);
(b) Installations for the manufacture of cement;
(c) Installations for the production of asbestos and the manufacture of asbestos-products (projects not included in Annex I);
(d) Installations for the manufacture of glass including glass fibre;
(e) Installations for smelting mineral substances including the production of mineral fibres;
(f) Manufacture of ceramic products by burning, in particular roofing tiles, bricks, refractory bricks, tiles, stoneware or porcelain.

6. Chemical industry (Projects not included in Annex I)
(a) Treatment of intermediate products and production of chemicals;
(b) Production of pesticides and pharmaceutical products, paint and varnishes, elastomers and peroxides;
(c) Storage facilities for petroleum, petrochemical and chemical products.

7. Food industry
(a) Manufacture of vegetable and animal oils and fats;
(b) Packing and canning of animal and vegetable products;
(c) Manufacture of dairy products;
(d) Brewing and malting;
(e) Confectionery and syrup manufacture;
(f) Installations for the slaughter of animals;
(g) Industrial starch manufacturing installations;
(h) Fish-meal and fish-oil factories;
(i) Sugar factories.

8. Textile, leather, wood and paper industries
(a) Industrial plants for the production of paper and board (projects not included in Annex I);
(b) Plants for the pre-treatment (operations such as washing, bleaching, mercerisation) or dyeing of fibres or textiles;
(c) Plants for the tanning of hides and skins;
(d) Cellulose-processing and production installations.

9. Rubber industry - Manufacture and treatment of elastomer-based products.

10. Infrastructure projects
(a) Industrial estate development projects;
(b) Urban development projects, including the construction of shopping centres and car parks;
(c) Construction of railways and intermodal transshipment facilities, and of intermodal terminals (projects not included in Annex I);
(d) Construction of airfields (projects not included in Annex I);
(e) Construction of roads, harbours and port installations, including fishing harbours (projects not included in Annex I);
(f) Inland-waterway construction not included in Annex I, canalisation and flood-relief works;
(g) Dams and other installations designed to hold water or store it on a long-term basis (projects not included in Annex I);
(h) Tramways, elevated and underground railways, suspended lines or similar lines of a particular type, used exclusively or mainly for passenger transport;
(i) Oil and gas pipeline installations (projects not included in Annex I);
(j) Installations of long-distance aqueducts;
(k) Coastal work to combat erosion and maritime works capable of altering the coast through the construction, for example, of dykes, moles, jetties and other sea defence works, excluding the maintenance and reconstruction of such works;
(l) Groundwater abstraction and artificial groundwater recharge schemes not included in Annex I;
(m) Works for the transfer of water resources between river basins not included in Annex I.

11. Other projects
(a) Permanent racing and test tracks for motorised vehicles;
(b) Installations for the disposal of waste (projects not included in Annex I);
(c) Waste-water treatment plants (projects not included in Annex I);
(d) Sludge-deposition sites;
(e) Storage of scrap iron, including scrap vehicles;
(f) Test benches for engines, turbines or reactors;
(g) Installations for the manufacture of artificial mineral fibres;
(h) Installations for the recovery or destruction of explosive substances;
(i) Knackers' yards.

12. Tourism and leisure
(a) Ski-runs, ski-lifts and cable-cars and associated developments;
(b) Marinas;
(c) Holiday villages and hotel complexes outside urban areas and associated developments;
(d) Permanent camp sites and caravan sites;
(e) Theme parks.

13. Any change or extension of projects listed in Annex I or Annex II, already authorised, executed or in the process of being executed, which may have significant adverse effects on the environment; Projects in Annex I, undertaken exclusively or mainly for the development and testing of new methods or products and not used for more than two years

APPENDIX C

INFORMATION CHECKLIST FOR SCREENING DERIVED FROM ANNEX III OF DIRECTIVE 97/11/EC

Article 4(3) of Directive 97/11/EC requires that Competent Authorities must take into account the selection criteria set out in Annex III of the Directive when making screening decisions on a case-by-case basis and when setting thresholds and criteria for projects requiring EIA.

1. Contact Details of the Developer

- Name of the company.
- Main postal address, telephone, fax and e-mail details for the company.
- Name of the main contact person and direct postal address, telephone, fax and e-mail details.

2. Characteristics of the Project

- Brief description of the proposed project.
- Reasons for proposing the project.
- A plan showing the boundary of the development including any land required temporarily during construction.
- The physical form of the development (layout, buildings, other structures, construction materials, etc).
- Description of the main processes including size, capacity, throughput, input and output.
- Any new access arrangements or changes to existing road layout.
- A work programme for construction, operation and commissioning phases, and restoration and after-use where appropriate.
- Construction methods.
- Resources used in construction and operation (materials, water, energy, etc.)
- The relationship with other existing/planned projects.
- Information about alternatives being considered?
- Information about mitigating measures being considered.
- Other activities, which may be required as a consequence of the project (*eg* new roads, extraction of aggregate, provision of new water supply, generation or transmission of power, increased housing and sewage disposal).
- Details of any other permits required for the project.

3. Location of the Project

- Maps and photographs showing the location of the project relative to surrounding physical, natural and man-made features.
- Existing land-uses on and adjacent to the site and any future planned land uses.
- Zoning or land-use policies.
- Protected areas or features.
- Sensitive areas.
- Details of any alternative locations, which have been considered.

4. Characteristics of the Potential Impact

A brief description of the likely impacts of the project considering the following factors:

- Impacts on people, human health, fauna and flora, soils, land use, material assets, water quality and hydrology, air quality, climate, noise and vibration, the landscape and visual environment, historic and cultural heritage resources, and the interactions between them.
- Nature of the impacts (*i.e.* direct, indirect, secondary, cumulative, short, medium and long-term, permanent and temporary, positive and negative).
- Extent of the impact (geographical area, size of the affected population/habitat/species).
- Magnitude and complexity of the impact.
- Probability of the impact.
- Duration, frequency and reversibility of the impact.
- Mitigation incorporated into the project design to reduce, avoid or offset significant adverse impacts.
- Transfrontier nature of the impact.

APPENDIX D

ENVIRONMENTAL INFORMATION REQUIREMENTS SET OUT IN ANNEX IV OF DIRECTIVE 97/11/EC

Article 5(1) of Directive 97/11/EC requires the Developer to provide to the Competent Authority the information set out below in so much as the information is relevant to the given stage of the consent procedure and to the specific characteristics of the project and of the environmental features likely to be affected, and the developer may reasonably be required to compile the information having regard *inter alia* to current knowledge and methods of assessment.

Environmental Information Requirements for EIA

1. Description of the project, including in particular:
   - a description of the physical characteristics of the whole project and the land-use requirements during the construction and operational phases,
   - a description of the main characteristics of the production processes, for instance, nature and quantity of the materials used,
   - an estimate, by type and quantity, of expected residues and emissions (water, air and soil pollution, noise, vibration, light, heat, radiation, etc.) resulting from the operation of the proposed project.

2. An outline of the main alternatives studied by the developer and an indication of the main reasons for this choice, taking into account the environmental effects.

3. A description of the aspects of the environment likely to be significantly affected by the proposed project, including, in particular, population, fauna, flora, soil, water, air, climatic factors, material assets, including the architectural and archaeological heritage, landscape and the inter-relationship between the above factors.

4. A description of the likely significant effects of the proposed project on the environment resulting from:
   - the existence of the project,
   - the use of natural resources,
   - the emission of pollutants, the creation of nuisances and the elimination of waste, and the description by the developer of the forecasting methods used to assess the effects on the environment.

5. A description of the measures envisaged to prevent, reduce and where possible offset any significant adverse effects on the environment

6. A non-technical summary of the information provided under the above headings.

7. An indication of any difficulties (technical deficiencies or lack of know-how) encountered by the developer in compiling the required information.

APPENDIX E

GLOSSARY OF TERMS

Term	Explanation
Accession Countries	Countries which are seeking to become Members States of the European Union.
Competent Authority (CA)	Those which the Member States designate as responsible for performing the duties arising from the Directive.
Developer	The applicant for authorisation for a private Project or the public authority which initiates a Project.
Development Consent	The decision of the Competent Authority or Authorities which entitles the Developer to proceed with the Project.
Effect/Impact	Any change in the physical, natural or cultural environment brought about by a development Project. Effect and Impact are used interchangeably.
EIA Team	The team which carries out the Environmental Studies and prepares the Environmental information for submission to the Competent Authority
Environmental Impact Assessment (EIA)	A term used in this document to describe the procedure which fulfils the assessment requirements of Directive 97/11/EC.
Environmental Impact Statement (EIS)	In many but not all EIA Regimes, the Environmental Information provided by the Developer to the Competent Authority is presented in the form of an Environmental Impact Statement. This is a document or documents containing the Environmental Information required under Article 5 of Directive 85/337/EEC as amended by Directive 97/11/EC. The abbreviation EIS is used in the guidance to cover both Environmental Impact Statements and other formats in which environmental information is provided.
Environmental Information	The information provided by a Developer to a Competent Authority on *inter alia* the Project and its environmental effects. The requirements for this information are set out in Article 5 and Annex IV of the Directive (see Environmental Impact Assessment).
Environmental Studies	The surveys and investigations carried out by the Developer and the EIA Team in order to prepare the Environmental Information for submission to the Competent Authority.
Exclusion List	A list of thresholds and criteria for specified categories of projects defining those projects for which EIA is not required because they are considered to be unlikely to have significant effects on the environment. An exclusive list may be over-ridden by other requirements e.g. that EIA is required for projects in certain locations.
Impact	see Effect.
Mandatory List	A list of thresholds and criteria for specified categories of projects defining those projects for which EIA is always required because they are considered to be likely to have significant effects on the environment.
Member States	Countries which are united in the European Union.
Negative list	See Exclusion List
Positive List	See Mandatory List
Project	The execution of construction works or of other installations or schemes and other interventions in the natural surroundings and landscape including those involving the extraction of mineral resources.
Review	The process of establishing whether an EIS is adequate for the Competent Authority to use it to inform the decision on Development Consent. It is important to note that the decision will usually involve consideration of other information in addition to the environmental information, but the aim of review is to check that the environmental information is adequate.
Screening	The process by which a decision is taken on whether or not EIA is required for a particular Project.
Scoping	The process of identifying the content and extent of the Environmental Information to be submitted to the Competent Authority under the EIA procedure.
Strategic Environmental Assessment (SEA)	A term used in this document to describe the procedure which fulfils the assessment requirements of Directive 2001/42/EC.