Coastal defence guide

to cope with erosion in the broader perspective of ICZM

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Summary

As with many countries in the world, India suffers from coastal erosion. This can have a considerable influence on both the natural and the socioeconomic systems of a country.

A coastal guide has been produced to help coastal managers identify what type of coastal measures they can take to reduce or arrest coastal erosion. The guide is general, not site specific in character and based on long term experiences. It discusses the entire spectrum of (hard and soft) coastal defence measures and the relationship to integrated coastal management. Three main types of response strategies to coastal erosion are distinguished. During the selection process determining the most appropriate measures, several assisting tools are available: Environmental Impact Assessment, Cost-Benefit Analysis and Multi-criteria analysis.

The criteria and indicators needed for selection, can also be used later for monitoring and evaluating the efficiency of the executed coastal protection measures. The Coastal Protection Guidelines has been made available as downloadable PDF report (see CCC V-1-1) and may be helpful for this process of selection.

1. Introduction

During missions of Dutch delegations to Tamil Nadu in India in the late nineties, the Dutch members were asked by representatives of several State institutions and the Central Water Commission of the Indian Ministry of Water Resources to assist and co-operate with research and management of the Indian coastal zone.
Coastal erosion is one of the severe problems along many stretches of the Indian coastline, both on sandy as well as on rocky cliff coasts. Considering the high population density and property values, efforts to stabilise the coast and protect its features are very important.

Within this framework of cooperation, a number of Indian-Dutch collaborative activities in the field of integrated coastal zone management were undertaken. One of these was a survey of Indian coastal protection strategies, which resulted in a ''Coastal Protection Guideline''. The Secretary to the Government of India, the Ministry of Water Resources, receiving the first copy (2001), considered this appreciated 'Coastal Protection Guideline', a step towards an Indian Policy Document on Coastal Strategies.

The guide is general in character and can be used in other States and countries with sandy coasts where erosion is prevalent. The entire Coastal Protection Guidelines can be downloaded free-of-charge, see this CCC Internet Publication V-1-1-1.

Severe Coastal erosion *affecting the coastal road, north of Chennai, Tamil Nadu, India. (photo: R. Misdorp)*

2. The coastal guide

The coastal guide discusses the entire spectrum of (hard and soft) coastal defence measures and highlights the relationship between integrated management and the various coastal protection options. The guide also contains some technical information and documentation on construction and maintenance of hard coastal protection solutions. This should be helpful to coastline managers who want to know what measures they can take to reduce or arrest coastal erosion.
The coastal zone is not only important to protect the hinterland; it also accommodates various human uses, such as fisheries, recreation, housing and transportation. Integrated Coastal Zone Management is extremely valuable in helping to deal with these different uses and to find the best solution based on a general coastal vision and on a solid consideration of effects and costs.
This is why the guide begins by discussing coastal vulnerability assessment as a first step towards Integrated Coastal Zone Management. .

3. Vulnerability assessment

The method of vulnerability assessment can be used to establish whether there is a serious threat to an area or region from erosion. This method, firstly described in IPCC-1991, is also helpful in finding solutions to erosion problems.
Coastal erosion influences both the natural and the socio-economic system. Identifying a number of response strategies enables the impact of erosion to be determined and using a standard policy analysis a choice is made between the various strategy options.
The *first step* is to delineate the area under study. The *second step* is to collect all relevant data, such as physical characteristics, habitats and species, socio-economic information and land use and values. The *third step* is to identify relevant development factors, both human-induced and natural. These may include the number of people present (or population density), land use and level of production activities, capital investment levels, natural values, morphological changes and human-induced subsidence. The *fourth step* is the most important phase of the vulnerability assessment and involves the identification of the physical changes and natural system responses. In *step five* a response strategy is choosen. An explicit assessment of the costs and benefits of each option should also be included. The final assessment of the vulnerability of a coastal region (*steps 6 and 7*) takes place in two stages. The first is a consideration of the susceptibility of the area to the physical changes imposed by erosion and the related, potentially adverse socio-economic and/or ecological impacts. The second stage is an assessment of the practical feasibility of response options.

It is wise to put measures for coping with erosion into the broader perspective of Integrated Coastal Zone Management by producing a National Coastal Zone Plan. However, even if no ICZM plan is yet available, it is still possible in the short term to weigh up measures for coping with erosion against other interests in the coastal zone. This can be achieved by following steps 5 to 7 of the process described above, which provide an insight into the likely impact of each policy or management reponse. The benefit of an ICZM plan is that it allows a balanced consideration of anti-erosion measures in the context of other interests and ensures attention to the coherence of the different activities in the coastal zone.

Questions	Answers, following questions and actions			
Delineation and collecting data	Definition of coastal features Special focus on coral coasts Special focus on mangroves and muddy coasts			
Relevant development factors	Coastal processes responsible for erosion Human use of the coastal zone; human-induced erosion			
What do I know about my coast?	*Are long-term coastal measurements available?*			
	NO:	Start measuring today	*How can I measure beach profiles and waves at low cost?*	
	YES:	Analyse data and determine problem	*Do I understand the processes causing the erosion on my coast?*	
			NO:	Study data and literature
			YES:	*Do I have acute erosion or chronic erosion?*
How can I preserve my coast and what solution to choose?			Study several alternative strategies and the different measures that can be taken Weigh alternatives in light of social-economic-environmental issues; choose most promising	
Needs and actions			Carry out maintenance and monitoring and evaluation on effectiveness	

Table 1: ***How to proceed from an erosion problem to a solution***

4. Strategies for coping with erosion

The following text describes how to proceed from problem to solution. The coastal guide provides more detailed information about each step.

Definition of coastal features

This step consists of describing the parts of the coastal zone, which contribute to the protection of the hinterland and of the natural forces that cause coastal change. In the case of the coastline of India, the existence of a monsoon system and the occurrence of cyclones are important factors. Wave action changes twice a year, which causes a seasonal fluctuation of the beaches. Cyclones cause large waves, but also raise the water level in the sea and in combination these usually causes acute coastal erosion. The mechanism involves sand transportation from the dry shore to a point just below the waterline. This sand may or may not be transported back to the beach. If not, it is carried away from the coast leaving it exposed to further erosion. There are many factors involved in determining whether this occurs or not.

Relevant development factors

Before undertaking any action to control coastal erosion, it is important to understand the processes that produce the problem. Most erosion is caused by changes in alongshore transport of sand by a combination of current and waves. Breaking waves generally create a current parallel to the coastline, and this transports sediment along the coast.

Because of a movement in alongshore sediment transport, the area just inside the line where waves break will become shallower (in case of accretion) or deeper (in case of erosion).
Where such a movement is absent, cross-shore transport is often part of the normal dynamics of the coast and usually nothing to worry about. During a storm, there will be some erosion of the upper beach and in the following calm season, the eroded sand will be transported from deeper water back onto the upper beach.
However, where there is an interruption in alongshore transport causing loss of sand, the area just inside the breaker line will become deeper. The consequence is that sand eroded from the upper beach during storms will be deposited in the hole created by the scour caused by the alongshore currents and is therefore not transported back during the following calm season. This means that the erosion of the upper beach will not be replaced by nature.

In practical engineering terms, this means that coastal erosion problems have to be solved by restoring the equilibrium profile in the breaker zone. Almost all the interruption in sediment supply and alongshore transport are human-caused for instance: river damming, sediment extraction in rivers, construction of harbours, dredging access channels, construction of breakwaters and groynes.
Apart from erosion due to sediment loss and interruption in alongshore transport, rising of sea levels also cause coastal erosion.

Solutions to choose
When the processes that can cause coastal erosion are known, information must be gathered about the amount of erosion and the (socio-economic) costs of all alternative solutions. There are three main types of response to coastal erosion:

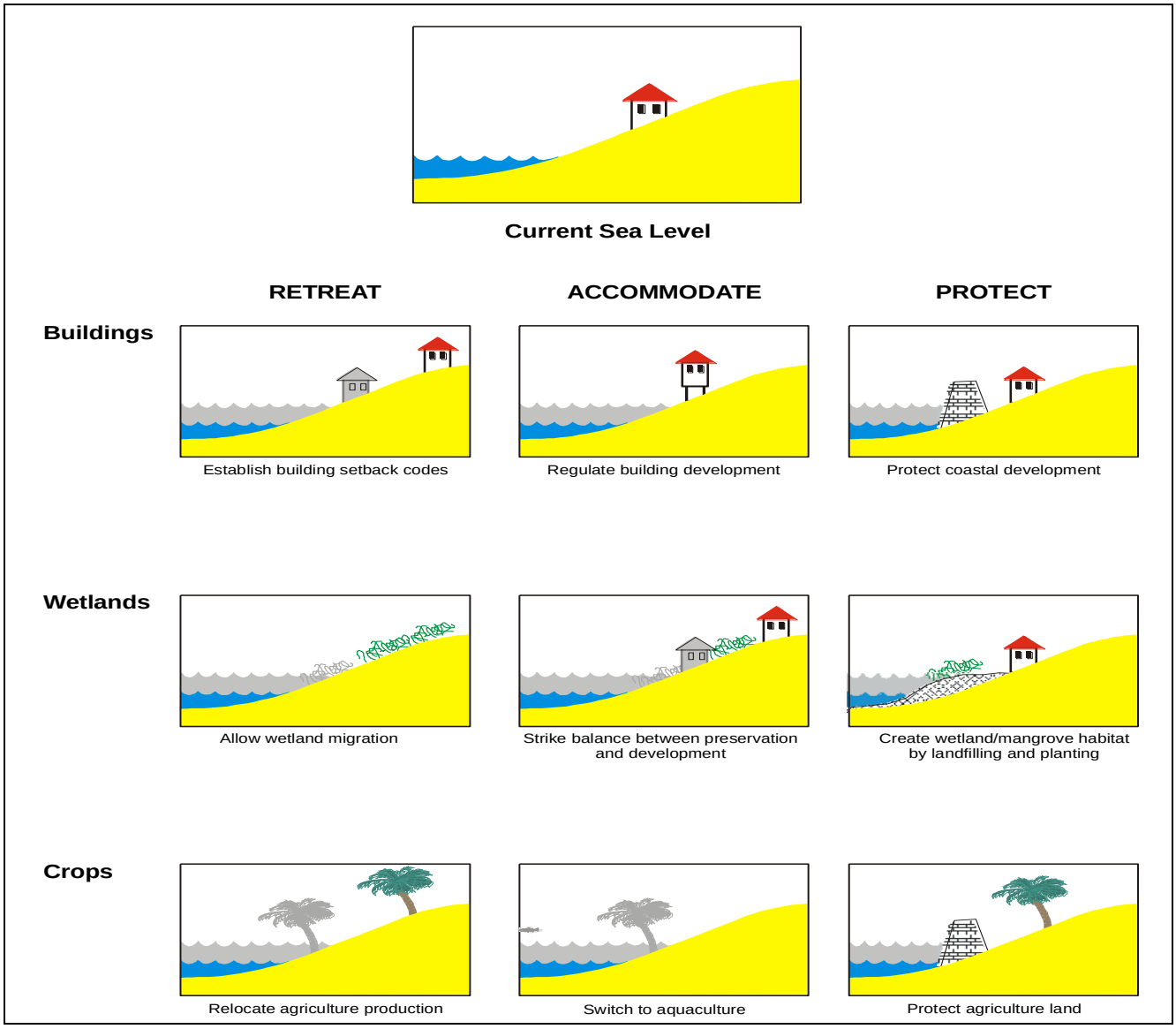


Figure 1: ***Summary of three main strategies*** *addressing coastal erosion (in this example forced by sea level rise; IPCC, 1992).*

1. ***Retreat***

This strategy is in fact not to combat the erosion as such, but only to set back and to undo its negative effects. It means that no important developments are allowed in the endangered area. In most cases this is the cheapest solution in the long run. However, it requires anticipation of the erosion, efficient coastal planning and compliance with government decisions and legislation by all those concerned.

Restrictions on land-use are often applied involving a system of setback lines (see Sri Lanka chapter CCC II-6-1) indicating where people are (or are not) allowed to undertake economic or house-building activities because of the danger of erosion. There is a difference between coasts suffering from acute erosion and those suffering from chronic erosion, they need different set-back regimes.

2. ***Accommodate***

This strategy is similar in that it does not try to stop the erosion, but aims to accommodate change. This allows the area to be flooded during cyclones, whilst precautions are taken to evacuate people and minimise damage, for example, by using cyclone shelters, introducing aquaculture and salt resistance strains of rice.

3. ***Protect***

Under this scenario attempts will be made to prevent erosion. This will be achieved either by "hard" or "soft" protection. Examples of *soft solutions to chronic erosion* are:

- Artificial beach nourishment. This involves man-made deposition of sand on the beach, which is reshaped to a natural profile by the forces of nature.
- Sand bypassing. This is a very efficient use of resources solving the erosion problem by dredging sand bar in a river mouth or lagoon outlet, serving navigation and recycling the dredged sand to the erosion zone.
- Gravel beaches. Instead of feeding the beach, it is possible to reduce the sediment transport capacity by replacing the sand by gravel. This will have the effect of changing the rate of transport capacity and - with the right design - will stop local erosion. However, it is important to remember that this can cause erosion on the downstream side of the protection.

The *soft solution to acute erosion* is to increase the amount of sand on the beach or in dunes protecting the hinterland.

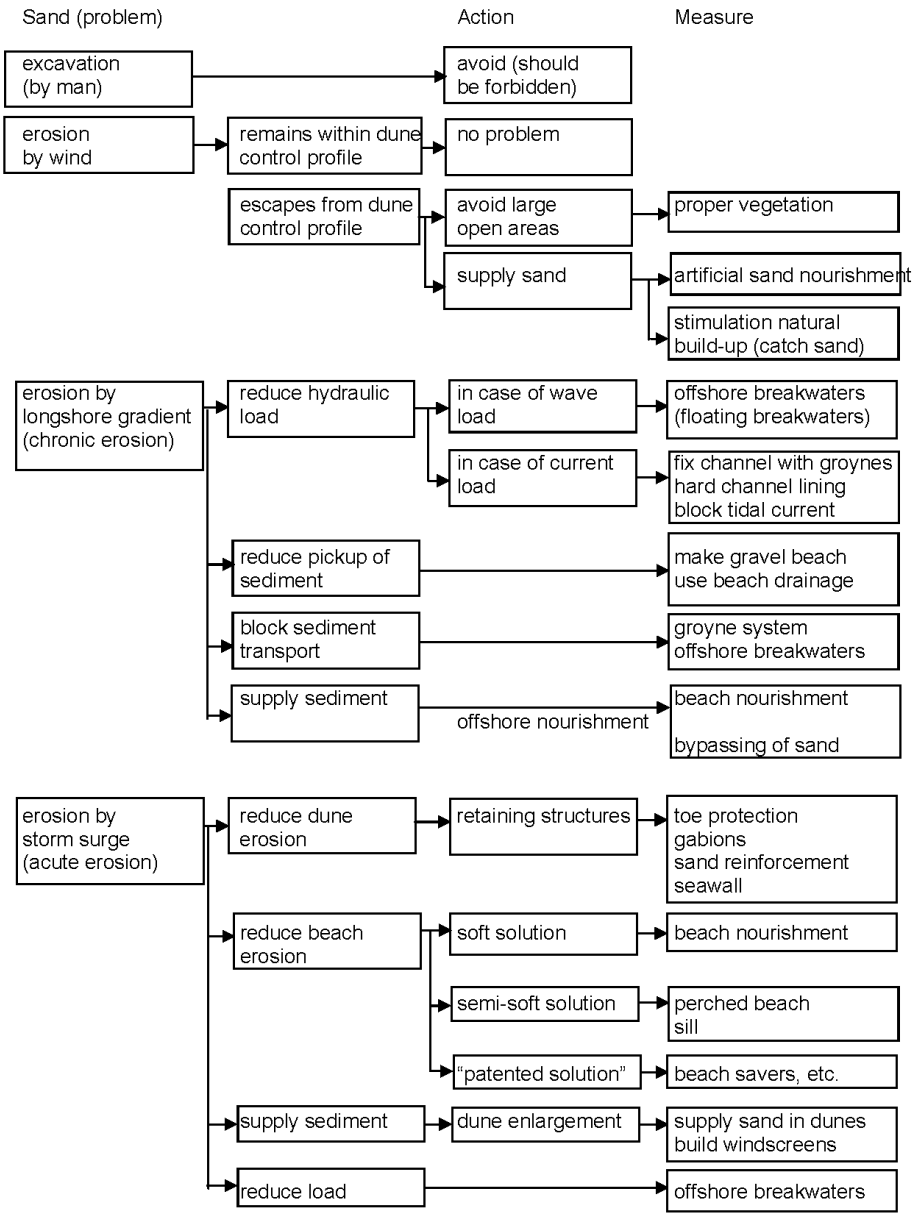
Hard solutions to chronic erosion may be considered if the coast downstream from the structure is of limited value and therefore expendable. Examples are a single long groyne, or multiple groynes and offshore breakwaters. The differences between these structures are mainly a matter of cost. From a morphological point of view, all these structures act in the same way and it is important to realise that also hard structures require maintenance and often shift erosion problems to another stretch of the coast.
Hard solutions to acute erosion require the construction of a rip-rap revetment, a (vertical) seawall, a sandbag protection, gabions or a dike-type protection. Often hard solutions (e.g. jetties) are used for protecting harbour areas and facilitating shipping.

5. Selection of alternative measures

Erosion is not only a technical problem, but a land-use problem as well. The best strategy to combat the adverse effects of erosion is to select from a range of options, weighing up human and ecological considerations as well as financial and technical ones.
An explicit and well-structured planning exercise based on participation of stakeholders and concise data collection and analysis is crucial to produce rational decisions in the complicated context of land-use planning and coastal zone management.

Environmental Impact Assessment

Once alternative actions or strategies have been specified, environmental impact assessments should be conducted to ensure that the relevant environmental consequences of the various alternatives are recognised early in the project cycle and taken into account in selection, planning and design. The process known as environmental impact assessment (EIA) is an important environmental tool for developers, decision makers and the public (see DR-EIA, chapter CCC III-3-2-5).



Flow chart for solving coastal problems

Figure 2: ***Every type of erosion requires a different type of measure****. Some of them are not very relevant to the situation in India, but they are included in order to make the overview more complete.*

Cost-benefit analysis

Extended analysis of the costs and benefits of different development alternatives may be used in decision-making. Although many environmental factors are difficult to express in monetary values, this approach has the advantage of representing results in the economic language familiar to decision makers. Cost-Benefit Analysis (CBA) is a tool to facilitate decision making by comparing the costs and benefits expressed in monetary terms, which can provide a greater insight into the relative value of the identified alternative solutions.

The different costs and benefits relate not only to the construction and maintenance of the coastal protection structure itself, but also to associated effects on its surroundings and to society

Multi-criteria analysis

There are limits, philosophical and/or practical, to the extent to which ecological and socio-cultural costs and benefits can be expressed in monetary terms. Economic cost-benefit analysis is therefore merely one input into balanced decision-making.

Impact assessment produces an overview of the expected impacts of the different alternative strategies. This includes quantitative and qualitative information on indicators or criteria related to the objectives of local, regional and/or national planning rules. In relation to the feasibility of implementation, reference should include social acceptability and institutional change. Scores for such indicators can be qualified in terms of 'high/low' or 'good/bad'.

A Multi-Criteria Analysis (MCA) helps in the evaluation of such multi-objective scores. In addition to *scoring*, the use of MCA requires *weighting,* e.g. putting different weights to different indicators.

6. Conclusions

Erosion can have considerable influence on both the natural and the socio-economic systems of a country. Vulnerability assessment helps establish whether an area has a serious erosion problems and to devise response strategies to combat them. The downloadable Coastal Protection Guidelines may be helpful for this process. It is advisable to put the anti erosion strategies into the broader perspective of Integrated Coastal Zone Management, by drawing an ICZM plan. In this way, their implementation can take account of other interests and ensuring coordination between different activities in the coastal zone, both in the short and long term.

7. References:

- **IPCC- IPCC-Intergovernmental Panel on Climate Change, Response Strategies Working Group, 1992:** *Global Climate Change and the Rising Challenge of the Sea;* Ministry of Public Works and Water Management, Directorate General Rijkswaterstaat, Tidal Water Division, the Netherlands

PDF Reports

- **IPCC-Intergovernmental Panel on Climate Change, 1991:** *Seven steps to the Assessment of the Vulnerability of Coastal Areas to Sea Level Rise, A Common Methodology;* IPCC - Working Group Coastal Zones, September 1991, Rijkswaterstaat, Ministry of Transport, Public Works and Water Management, The Hague, the Netherlands **;** see PDF reports: CCC V-1-3.

- **Coastal Protection Guidelines:** *A guide to cope with erosion in the broader perspective of Integrated Coastal Zone Management*; RIKZ/CZM-Centre 2001; to download: see training manuals: CCC V-1-1-1.