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IMPACT OF SEA-LEVEL RISE ON SOCIETY (ISOS): APPLICATION OF THE MODEL ON NILE DELTA

P. Schröder[1]

[1] Delft Hydraulics, Coasts & Offshore Division, AD Emmeloord, The Netherlands

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Abstract

Sea-level rise is inevitable. Some areas are more vulnerable than others. Some countries are already struggling. No coasts will be unaffected. But both the extent of sea-level rise and the magnitude of the impact to be expected are uncertain. Nonetheless, impacts will not be limited to coastal defence systems. The effects will go far beyond the immediate coastline and affect national economies and the social fabric.

Research into the aggregate macro-economic effects of global climate change is being carried out and is important. But there must be no delay in developing a pragmatig management approach to deal with sea-level rise impacts on a site specific basis. Response requirements will differ with impact sites, but the choice is the same: fight or flight. Preventive measures or a structured reaction plan must be designed.

1. Introduction

1.1 Event outline

Human interference with atmospheric processes and a lack of awareness of the long-term consequences has led, among other things, to an acceleration of an already slowly rising sea-level. Low-lying and already troubled coastal areas have become more vulnerable.

Coasts, rivers, infrastructure, ports, shipping, water resources, and environment will be affected. There will be an inevitable economic and social backlash. Responsible authorities must be enabled to take measures based on sound policy options (Fig. 1).

To do so there must be base-line information. Impact progression and efficacy of measures must be monitored, analyzed, interpreted and modeled. Responses must be generated, implemented, and checked. Staff must be trained, technologies mastered, and an administrative, organizational, and enforcement structure must be built up.

1.2 The Impact Management Unit (IMU)

Critical areas vulnerable to the impacts of sea-level rise are per definition low-lying, populated, fertile and productive, coastal zones, exposed to storms, cyclones, hurricanes or abnormal tidal amplifications. Impacts depend on the extent of sea-level rise. The effects of such impacts have a spatial character, i.e. they may extend over a smaller or larger area along the coast and inland. Once delineated, such space constitutes a typical impact management unit (IMU). This is a discrete unit area where the impact effects require management (Fig. 2).

For this purpose, part of the coastal zone is designated by the government as the IMU. It usually lies across the sea-land interface and has a long-shore axis running parallel to the geographical coastline, and a cross-shore axis which runs perpendicular to this coastline. The latter is essentially limited landward by the watershed, and seaward by the 200 mile Exclusive Economic Zone, or such other limitations as are deemed necessary to form an effective IMU.

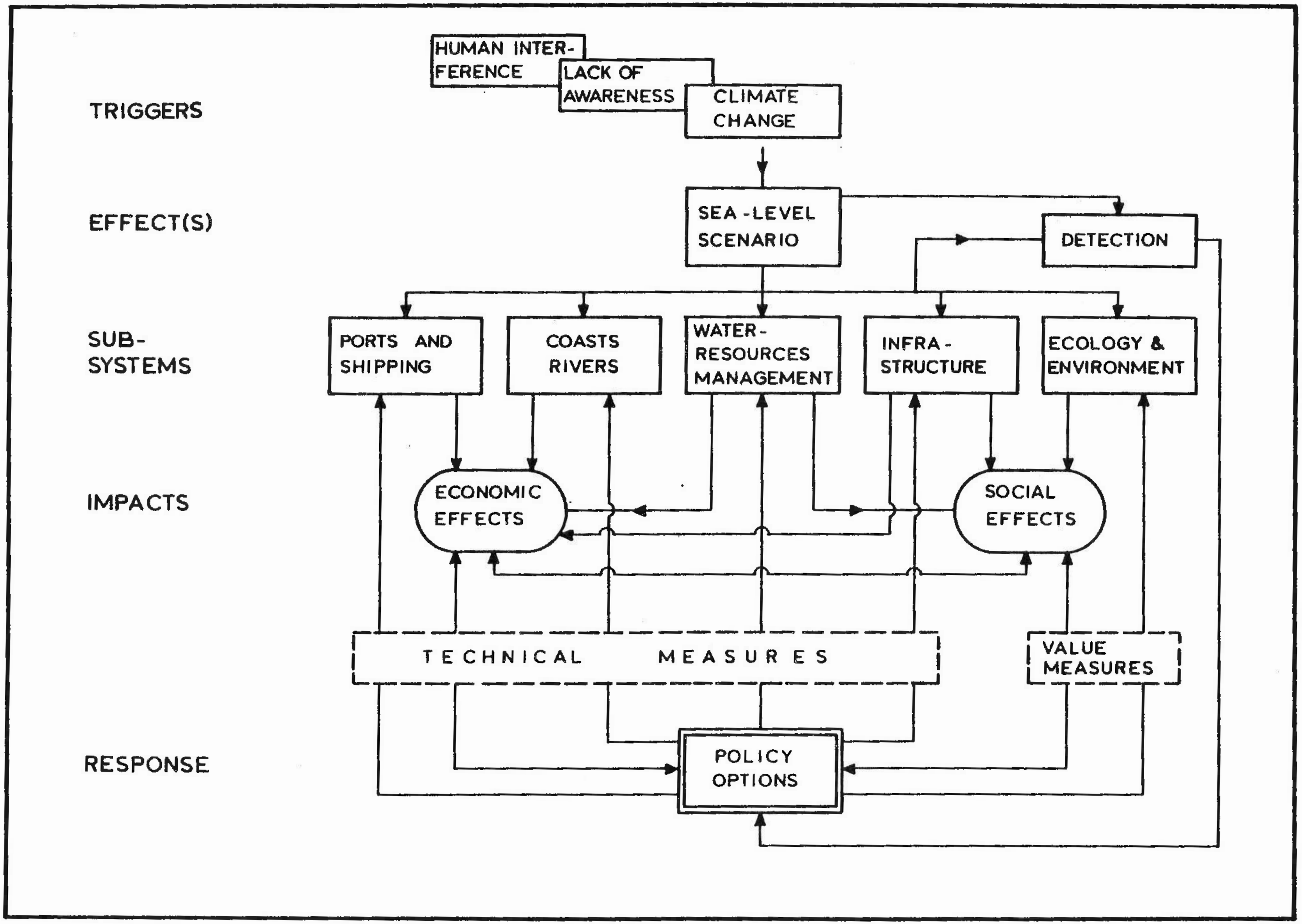
TRIGGERS
EFFECT(S)
SUB-SYSTEMS
IMPACTS
RESPONSE
HUMAN INTER-FERENCE
LACK OF AWARENESS
CLIMATE CHANGE
SEA-LEVEL SCENARIO
DETECTION
PORTS AND SHIPPING
COASTS RIVERS
WATER-RESOURCES MANAGEMENT
INFRA-STRUCTURE
ECOLOGY & ENVIRONMENT
ECONOMIC EFFECTS
SOCIAL EFFECTS
TECHNICAL MEASURES
VALUE MEASURES
POLICY OPTIONS

FIG. 1

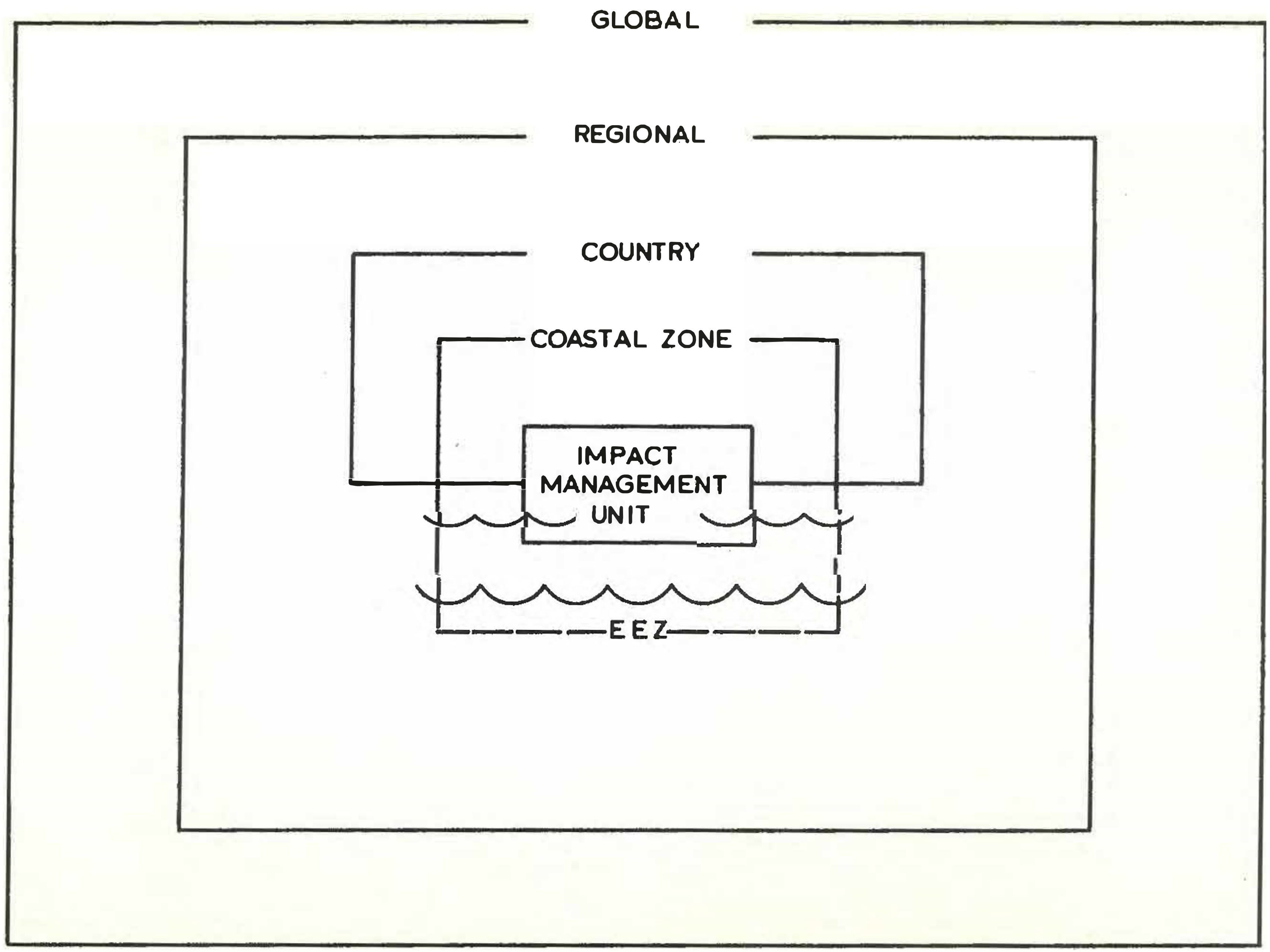

FIG. 2 The Impact Management Unit

2. General approach

Sea-level rise problems are immensely complex, although transgressions of the sea over land, and regressions have punctuated geologic history. For instance, 20,000 years ago the sea-level was 1200 m below where it is now, and 12,000 y.a. 6 m higher (Goemans, 1985). Predictions vary, but it is generally expected that the sea-level will rise between 60 cm and 1,5 m in the next century (Barth and Titus, 1984; Hoffman, 1984; Vellinga, 1988). For the first time however, mankind is able to monitor this phenomenon, measure it, and design a response to its multiple impacts.

The prerequisites for an effective response are site specificity, and clearly delineated areas of investigation, analysis, evaluation, and management. The problems need to be conceptualized in their appropriate locality, quantified, and given dimension within national priorities for implementation.

3. Response

Three types of responses to sea-level rise have been identified: positive defensive action, planned retreat, or abandonment (Vreugdenhil, 1987). These however, clearly refer to engineering and/or land-use aspects, and not to the social and economic interests of a population. Since planned retreat implies positive action, there are actually only two fundamental choices: to fight or not to fight. It is nearly inconceivable that some form of fight is not the response chosen.

3.1 Preventive or reactive

Time horizons for sea-level rise impacts tend to be misleading. In general, projections speak of a certain rise in a given period of time, usually a considerable rise of the sea-level in a century. They ignore the fact that in low-lying coastal areas, such as Bangladesh, Egypt and Indonesia, or low-lying islands such as the Maldives, already troubled by the effects of subsidence for whatever reason (tectonic, oil, gas, or water extraction), and/or erosion through whatever cause (sediment budget dis-balance, storms, cyclones, or hurricanes), a very modest rise of the sea-level of a few centimeters can seriously aggravate and compound an existing situation in a matter of a decade or even less (Overbeek and Schröder, 1988).

It is unquestionable that an impact preventing approach to sea-level rise is preferred. The limits of such a preventive approach are governed by the risk factor set by the government. The factor expresses the probability of coastal defence failure in a given time frame. The preventive response thus has a direct relationship with the acceptable or affordable risk factor.

As the mathematical chances of failure increase, a reactive response structure becomes more imperative. It is clear that, for instance, with a risk factor of 1 : 10,000 (as is the case in The Netherlands) there is much less need for a reactive response structure, than with a risk factor of 1 : 20, often encountered in the less developed countries.

A typical preventive response is to build high, strong dikes. A reactive structure would, on the other hand, consist of a detailed plan to migrate a population if/when the dikes are breached. From the foregoing it may be deduced that in developing nations who cannot afford a risk factor of 1 : 10,000, a reactive response structure is required. Both a preventive and a reactive response demand quantitative insight into where the impact will be felt, what will happen, and what the effects will be.

3.2 Requirements

In the case of a preventive response the implementation of measures is central, whereas with a reactive response planning is the key. Development of either a preventive or a reactive response structure requires:

- Firstly, the creation of rea istic sea-level rise scenarios;
- Secondly,the determination of what certain water levels will do to the shoreline and the coastal area beyond it. This includes inundation (loss of land), and damage (structures, ecology), but also further inland, saltwater intrusion/seepage (contamination of groundwater, crop failure) (Vreugdenhil, 1987);
- Thirdly, the assessment of the social and economic impacts (Kellogg, 1981), and thus values of land, structures, etc.

Preventive measures in line with the desired risk factor can be designed and constructed (i.e. adequate coastal protection). There is of course, a strong relationship between the value of the investment in those preventive measures and the (social and economic) value of what is to be protected. Measures taken to mitigate social (c.q. cultural, etc.) impacts are indicated in Fig. 1 as "value measures".

A reactive planning structure concerns itself with primary factors such as alert systems, public safety and health, including disease control, emergency transportation and communication, drinking water and stocking food supplies, auxiliary energy, emergency shelter, rescue mobilization schemes, rehabilitation outlines, etc.

4. Investigation

4.1 The Coastal Genesis Project

The primary tool for the investigation of the effects or impacacts of a sea-level rise on a specific coast is the use of the experience gained in The Netherlands with Coastal Genesis Project.

This project provides a conceptual model for the response of a coast (The Netherlands) to sea-level rise (Fig. 3). It was derived theoretically on a physical-mathematical basis, and was found to yield consistent and straightforward contributions to hindcast going back as far as 2000 years. Given knowledge of local hydraulic and sedimentologic conditions, site specific responses of any coast vulnerable to sea-level rise can be determined (Stive, 1988).

4.2 The Impact Area Value Model

Determination of the economic value of the coastal zone is to be based on its contribution to the gross national product (GNP). The origin of this model lies in the Ocean Sector Model (Pontecorvo et al, 1980). Conceptually fundamental to the IMU - as was pointed out before - is its link with the sea. Because of this, it becomes a discrete spatial entity, whose (coastal) resources are either utilized in a productive process (supply-side criterion), or exist because the final output is due to some coastal attribute (demand-side criterion).

Essentially, supply-side criteria include extractive (fishing, oil, gas, etc.), and spatial activities (transport, freight, etc.), while demand-side criteria encompass such complementary aspects as warehousing, and geographically linked outputs. It is assumed here that for the model, accidental occurrence of either type of economic activity is negligible.

5. Application

In the joining of the Coastal Genesis and the Impact Area Value models care must be taken that the resulting impact management unit (IMU) does not suffer from a spatial mismatch of geometrics and geopolitics (Rind et al, 1988).

Once the implications of a given sea-level rise for the coastal zone are known, and the value of the impact management unit has been determined, the adequacy of existing, constructed or natural, coastal protection can be assessed, policy options generated, and measures designed, implemented, and enforced if need be.

geological time		years BP	years AD	sea level	observed coastal development
Pleistocene				(m)	
HOLOCENE		10000			
	Preboreal				
		9000			
	Boreal				8700 BP: Southern North Sea is formed 8300 BP: Connection between southern and northern North Sea
		8000		- 25	7800 BP: Coastline appr. 25 km west of present location
	Atlantic	7000	5500 BC	- 15	On average, the coastline retreats and barrier islands are formed in the eastern part of the country
		6000			
		5000	3850 BC	- 4.5	5000 BP: Interconnection of barrier islands in the east; formation of old dunes; mouth of river Rhine becomes active; coastline 8 km east of present position and advancing
	Subboreal	4000		- 3.0	
		3000		- 1.7	3200 BP: Closure of the inlet near Bergen
			1100 BC		Coastal advance comes to an end and retreat begins; the mouth of the river Rhine becomes inactive.
	Subatlantic	2000	AD	- 1.0	
		1000			± 500 AD: Break-through of dunes in the south ±1100 AD: Break-through of dunes in the north-west 1000-1600 AD: Formation of the young dunes
		0	1987	NAP	

Figure 3: Time table with the main events in the development of the Dutch coast (after Stive, 1987).

6. Timing

Coastal infrastructure and coastal protection works require decades to build and they last often for centuries. This emphasizes the need for good stewardship of the coastal zone, since moving such coastal works inland will be prohibitively costly. Timely action is of the essence. Waiting for incontrovertible scientific evidence of a specific rise in the level of the sea, will make effective action, other than flight, come too late.

7. Conclusion

In designing an appropriate response to sea-level rise, it is important to consider that uncertainty prevails as to:

- the extent of the sea-level rise to be expected and the time-frame of its occurrence
- the effect of a higher sea-level on such natural systems as wave climate, wind regime, storm frequencies, etc.
- the magnitude of the impact on the coastal defence system (natural or man-made) and the resulting dislocation and disruption of numerous societal structures in the IMU

Such compounding uncertainties tend to encourage deferral when timely government consideration of the potential problems, planning and implementation of measures, and creating a general public awareness is necessary. A rational and pragmatic preventive response may thus be little more than an ill-prepared reaction with numerous negative side-effects that could have been avoided.

Equally, funding and foreign aid and assistance agencies should become aware that in many cases sea-level rise problems may occur within the generally accepted project time horizon of between 15 and 20 years.

Finally, if the possibility of sea-level rise problems occurring within or beyond the project time-frame is ignored, conceivably this may raise the spectre of litigation, reparations, and political back-lash. Often public funds are involved, and executing agencies may have to account for omission of consideration of the implications of sea-level rise in projects, both at home and in the host country.

Sea-level rise is not a new phenomenon, and it is real. Many of the tools to assess, prevent or mitigate its impacts exist and are being used world-wide. The expertise to model realistic scenarios and generate valid options is also available. The time to act is now, because there is a great deal of work to be done if we are to prepare ourselves for, instead of simply react to sea-level rise.

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