BIOGEOMORPHOLOGY OF LARGE-SCALE COASTAL LAND RECLAMATIONS

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to be presented at and submitted for the proceedings of

COSU 97 - COASTAL OCEAN SPACE UTILISATION

12 - 14 May 1997
World Trade Centre, Singapore

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1. Introduction

Projections are that Rotterdam, one of the worlds' largest harbours, will be in need of 1250 hectares of additional harbour area within the next 15 years. To meet this demand a substantial land reclamation ("Maasvlakte-2") is considered, which could provide 1000 hectares of new harbour areas and 750 hectares for nature and recreation. In addition, just north of the Rotterdam harbour area a land reclamation is considered to relieve the urban development of The Hague ("Nieuw Holland"). Delft Hydraulics was commissioned to investigate the morphological impacts of four land reclamation alternatives and associated sand mining scenarios. The area of impact investigated extended approximately 25 kilometres north and south of the planned land reclamation and some 50 kilometres seaward (Figure 1).

2. Modelling approach

The aim of the Delft Hydraulics study was to predict the influence of land reclamation proposals on the morphodynamic behaviour of the surrounding marine and coastal environment. Delft Hydraulics' numerical model system Delft-3D was used to make intercomparisons between the morphodynamic impacts of the four land reclamation alternatives (Figure 2) and associated sand mining options.

The Delft-3D model system was embedded in a larger framework of methodological steps to ensure that the requirements of both scientific reliability and efficiency were met. This also involved a comprehensive analysis of the antecedent and present morphological evolution of the entire area under consideration in a conceptual model.

<u>Computational resolution and constraints</u>

In terms of computational and mathematical-physical effort this morphodynamic implementation belongs to the most advanced applications to date. A curvi-linear model grid was used to allow high resolution in areas with steep gradients (e.g. to represent the surf zone). Thus avoiding the need for set of nested current models.

The main constraints adopted were:

- The Maasvlakte-2 reclamation was assumed to be realised instantaneously, i.e. no effects relating to the constructional phases of the land reclamation were taken into account.
- The time horizon of the computations was five years.
- Modelling was restricted to the two horizontal dimensions.

Subdivision of the model area

To accurately calibrate and validate the numerical model against observations and the conceptual model the area was sub-divided into five smaller areas with approximate similar morphologic characteristics. For each detailed area a set of significant aspects was defined against which the results of the numerical model were evaluated. These include:

- Stability of new coastal sections.
- Development of scourholes.
- Maintenance costs section Scheveningen - Hoek van Holland.
- Maintenance costs sections at Goeree.
- Morphological development Haringvliet.
- Costs of maintenance dredging access channel.

Hydrodynamic and Morphodynamic Modelling

Morphodynamic behaviour in the marine and coastal environment is externally forced by currents generated by wind, waves and tide. An important step in arriving at reliable predictions of bottom topography is the formulation of representative boundary conditions for the hydrodynamic models. Agreement between the modelled sediment transport and that encountered in reality under average conditions was defined as the primary criterion for evaluation of the representative nature of the boundary conditions.

Boundary conditions for the tidal model were obtained from an existing model that covers the complete Dutch west-coast (Zeedelta model, Rijkswaterstaat). The set of boundary conditions applied in the study comprised water level, velocity and discharge conditions.

The wave climate was obtained from long-term offshore wave measurements (13 years) . It was found that by the application of five wave boundary conditions a satisfactory agreement was obtained with estimated sediment transports along the Dutch coast. The wind conditions applied in the study corresponded to the wave boundary conditions.

To facilitate accurate modelling of surfzone dynamics, a curvi-linear grid was constructed for the tidal model with a relatively high resolution in the nearshore zone. Nesting techniques provided high nearshore resolution of wave model results (Figure 3). Accurate modelling of wave-current interactions was achieved by performing five wave height calculations over a tidal cycle.

The Bijker sediment transport formulations were used to calculate the bottom and equilibrium-suspended sediment transports. To calculate lag effects in suspended sediment concentrations due to abrupt changes of wave and current the full advection-diffusion equation was solved.

The above models are coupled in Delft-3D to simulate the morphodynamic behaviour of the area under investigation. A pre-defined hierarchical tree-structure executes the various sub-models in sequence, facilitates data transfer between the sub-models and automatically updates of the bottom bathymetry.

Validation

An important aspect in any morphodynamic study concerns the possibility of validating the ability of the applied models to simulate observed morphodynamic behaviour, preferably in the area considered. Fortunately, the Haringvliet estuary is a well-monitored area. The results of the preliminary efforts (this validation is a yet ongoing project) to hindcast the observed bottom topographical changes are given in Figure 5. A comparison is made between the observed sedimentation pattern over the peiod 1990-1995 and that morphodynamically computed over the period 1990-1991. It sofar appears that in areas with strong topographical relief the simulated changes are quite satisfactory, while in areas with little topographical relief the simulated changes can be even qualitatively off. This would imply generally, that nearfield predictions are more reliable than farfield predictions.

3. Results

In order to arrive at an objective evaluation of all simulated alternatives a number of key-aspects were defined. These aspects, including the impact on the maintenance costs of various pre-defined sections of coast and of the land reclamation itself, the development of "natural" areas, and the costs of the maintenance dredging of the access channel (Euro-Maas channel) to Rotterdam Harbour are valued for all four alternatives, as can be seen in Table 1. It should be noted that in the overall evaluation also related side-issues such as the influence of the design on the manoeuvrability of ships approaching Rotterdam Harbour were taken into account to some degree.

The influence of the four Maasvlakte-2 reclamation alternatives appeared to be confined mainly to the surrounding land reclamation region. The impact on the morphological behaviour of the area north of the Euro-Maas channel was limited. The Maasvlakte-2 alternatives extending further seaward gave rise to additional erosion of the coast between Ter Heijde and Scheveningen. Local erosion holes developed primarily direct south-west of the land reclamation (Figure 4), which indicates that "hard" sea-defence structures will be necessary in those areas. The shallow area directly south of the Maasvlakte-2 (Haringvliet) is found to experience additional accretion if the land reclamation extends further seaward. The influence on the maintenance dredging of the Euro-Maas Channel was limited, a further extension of the land reclamation resulted only in a limited increase in the deposition of sediment in the channel.

The sand mining alternatives which were investigated did not have a significant influence on the large-scale morphodynamic behaviour of the area, although local adjustments of the slopes of the mined areas occurred. Sediment eroded from the top and deposited at the foot of the slopes in the mined areas (see Figure 4).

This advanced application of the Delft-3D system played an important role in providing reliable predictions of the morphodynamic behaviour in the study area. It appears , however, necessary to interpret and aggregate the results based on a broader concept of and expertise with the morphodynamics of the antecedent and present area.

Acknowledgement

The Municipality of Rotterdam and the Ministry of Transport, Public Works and Water Management are thanked for their permission to publish the results of this study. The help and guidance of Dr D J Walstra in preparing this paper is appreciated.

Key Aspects		Land Reclamation Alternatives			
		South	Parallel	North	Island
Stability of new coastal sections	North Site	-	0	0	0
	West Site	0	-	0/+	0
	South Site	+	+	-	0
	East Site	n.a.	n.a.	n.a.	+
Development of scourholes		-	0/-	0/+	0/-
Maintenance section Scheveningen - Hoek van Holland		0	-	-	0/-
Maintenance sections at Goeree		+	0/+	0	0/-
Morphological development Haringvliet *		0	0	0/+	0/-
Maintenance dredging access channel		+	-	0	+

* Positive in case of sedimentation
Negative in case of erosion

Table 1. Morphological evaluation (key: + is positive; 0 = neutral: - is negative)

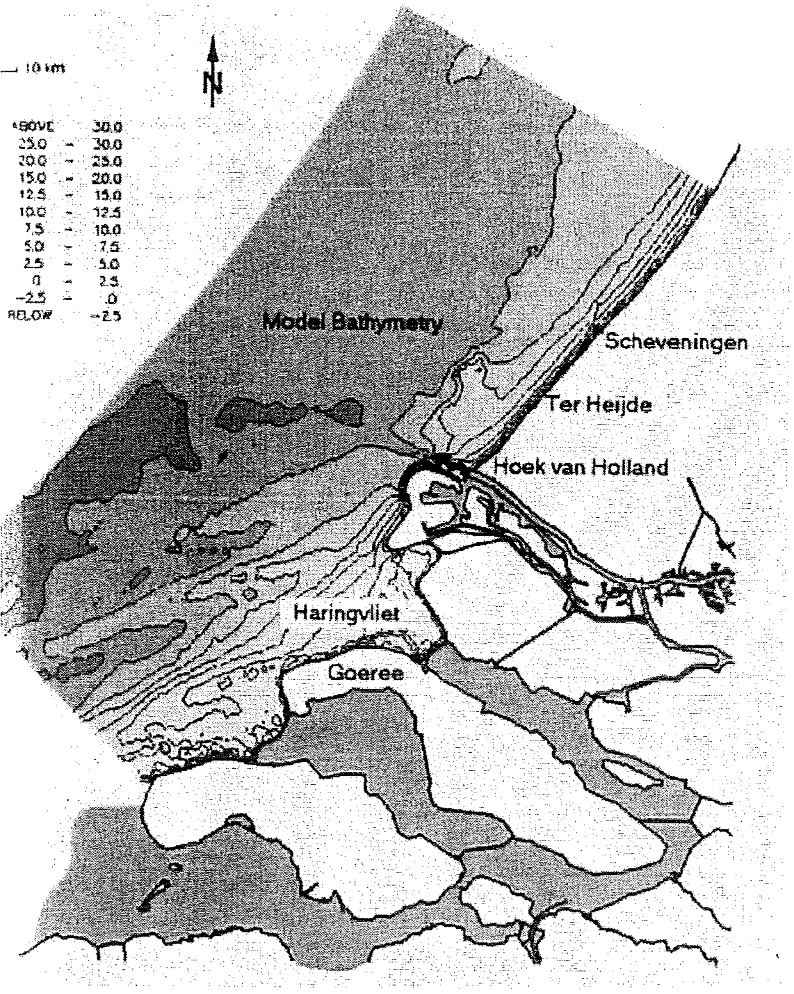

Figure 1.
Plan view of model area

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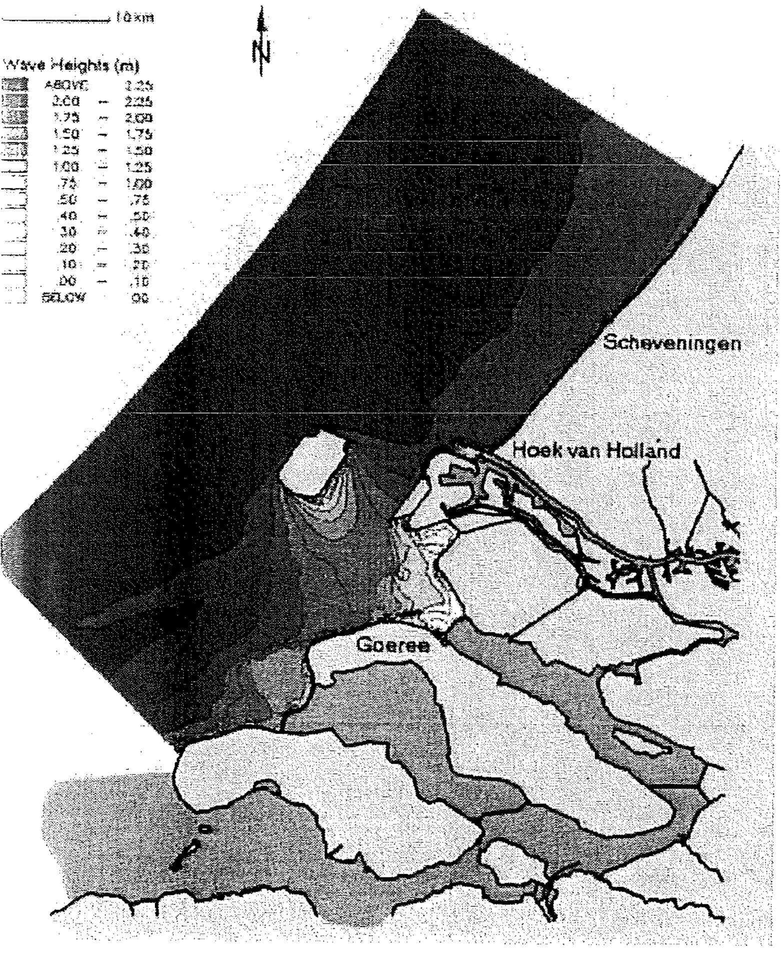

Figure 3.
Calculated wave field for
"Island" alternative

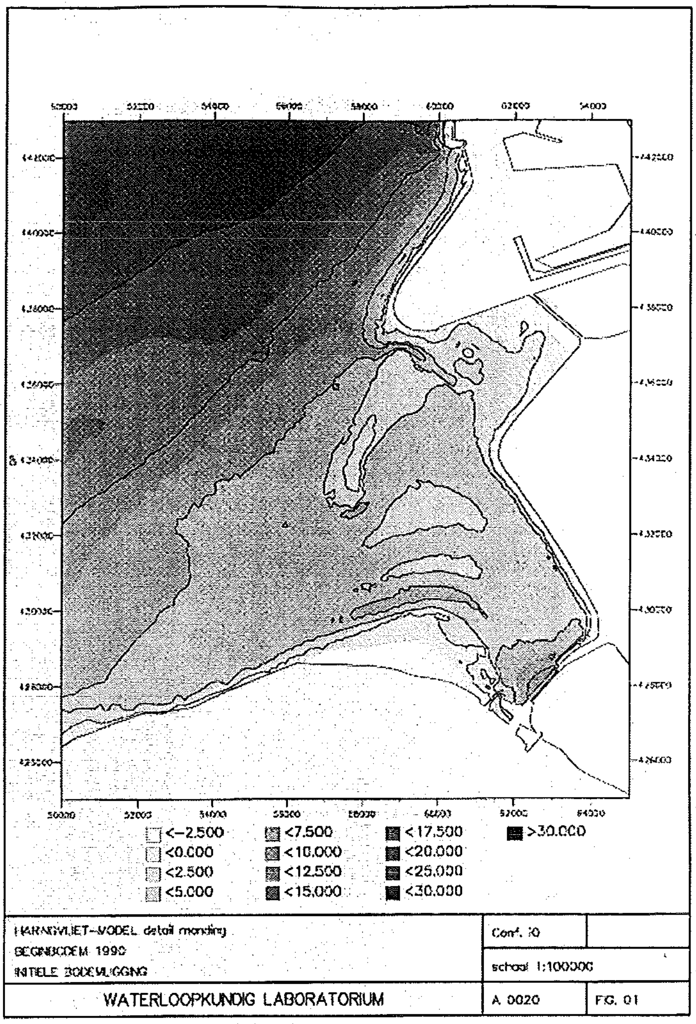

Fig 5a Haringvliet bottom topography 1990

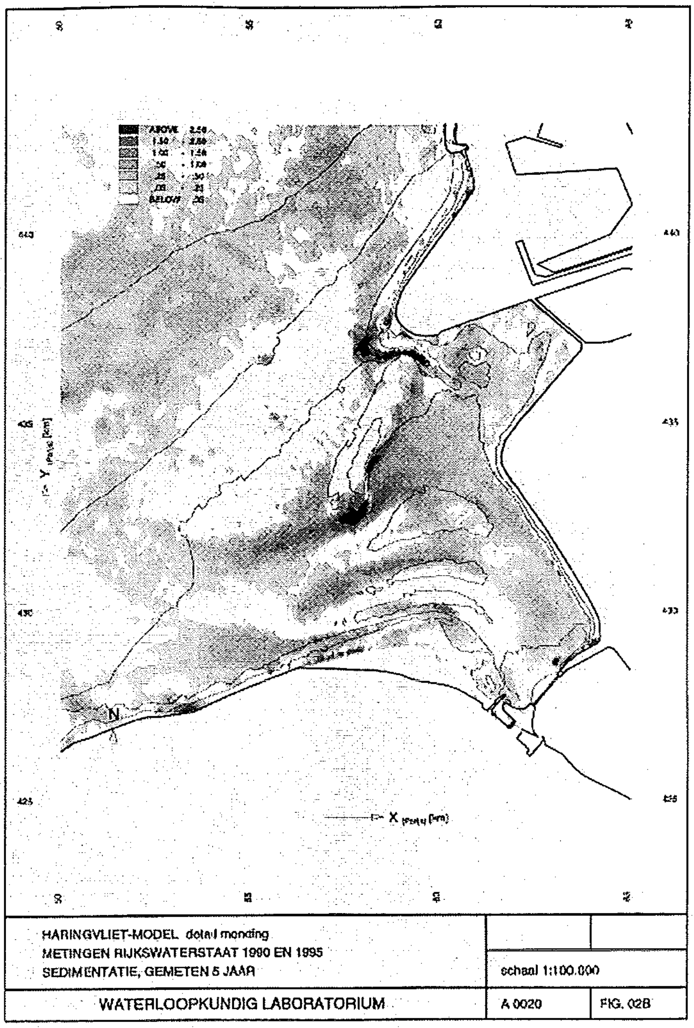

Fig 5b Haringvliet measured sedimentation 1990-1995

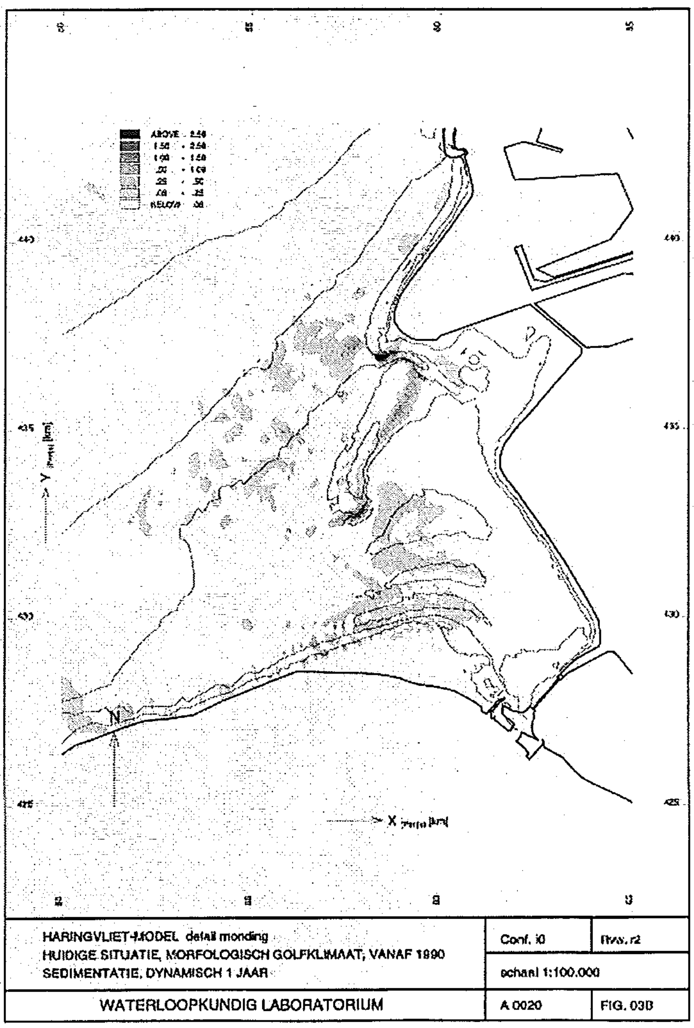

Fig 5c Haringvliet computed sedimentation 1990-1991