

# The impact of channel deepening and dredging on the sediment concentration of the Ems Estuary

van Maren Bas, T. van Kessel, K. Cronin and L. Sittoni

Coastal and Marine department, Deltares, Boussinesqweg 1, 2629 HV Delft, the Netherlands

E-mail: [bas.vanmaren@deltares.nl](mailto:bas.vanmaren@deltares.nl)

## Introduction

The tidal channels of many estuaries worldwide have been deepened in the past decades to centuries, in order to reclaim land and to allow ever larger ship access to inland waterways. The response of estuarine suspended sediment concentrations to anthropogenic influences is still poorly known, mostly because of lack of data and the complex estuarine sediment transport processes. These deeper channels influence the hydrodynamics (tidal propagation and estuarine circulation), and thereby the sediment concentration. Sedimentation in the ports and access channels requires regular maintenance dredging and disposal. On the short term, maintenance dredging leads to increasing concentration levels in the direct vicinity of the dredging vessel, but long-term effects of dredging on SSC is more difficult to quantify. In this paper, we systematically investigate the individual contributions of deepening and dredging by setting up and apply a numerical sediment transport model in an estuary in which a reasonably large amount of data (recent and historical) exists: the Ems Estuary.

## The Ems Estuary

The Ems estuary has undergone large anthropogenic changes in the past decades to centuries, but human interferences have accelerated in the past 50 years. Three ports and a large shipyard exist in the estuary, requiring regular deepening and permanent maintenance dredging of the access channel. In the lower Ems River (draining into the Ems Estuary), the channel depth increased approximately a factor two, transforming it from a normal tidal river into a hyperconcentrated system. Channel deepening was comparatively smaller (channels already over 10m deep were deepened with one to several meters) in the outer estuary. Since the 1960's the dredging activities in the Ems Estuary have increased significantly – at present about 10 million m<sup>3</sup>/year is annually dredged. Until 1994, a large amount (5 million m<sup>3</sup>/year) of the dredged sediment was not disposed in the estuary, but brought on land.

## Model setup

In order to quantify the individual impacts of dredging and deepening on the suspended sediment dynamics, a 3D numerical model was set up using 8 vertical layers with hydrodynamic forcing by wind, waves, tides and salinity-driven density flows. The hydrodynamic model is calibrated against a range of water level observations stations and flow velocity observations at two locations. A sediment transport model has been set up incorporating the effect of the buffering of fine sediments in the seabed and accounting for deposition in, and dredging and dispersal of sediments from, the three ports that exist in the estuary. The model predicts an up-estuary increase in the surface sediment concentration (and seasonal variation thereof), corresponding to observations. The calibrated model is subsequently applied to investigate various scenarios related to dredging, bathymetry, and hydrodynamic processes.

These scenarios suggest that the effect of dredging on absolute concentration levels is limited. Compared to an estuary without ports, the sediment concentration is larger near the disposal grounds. However, elsewhere in the estuary the concentration levels decrease, because the port also acts as a sink of sediment. The effect of ports and their associated dredging and disposal mostly leads to a redistribution of sediment. More important is the effect of deepening, despite the fairly low increase of typically 10-12 to 12-14m. Deepening of the estuary increased the up-estuary sediment transport, resulting in much larger sediment concentrations at the head of the estuary. The tide-averaged flow velocity profile has a much more pronounced up-estuary component near the bed using the 2005 bathymetry compared to the 1985 bathymetry (Fig. 1). This change can probably be attributed to changes in estuarine circulation, which has been analysed by running the model in barotropic and baroclinic mode. Without salinity effects, there is no up-estuary flow near the bed (Fig. 1) and as a result the estuarine suspended sediment concentrations are much lower.

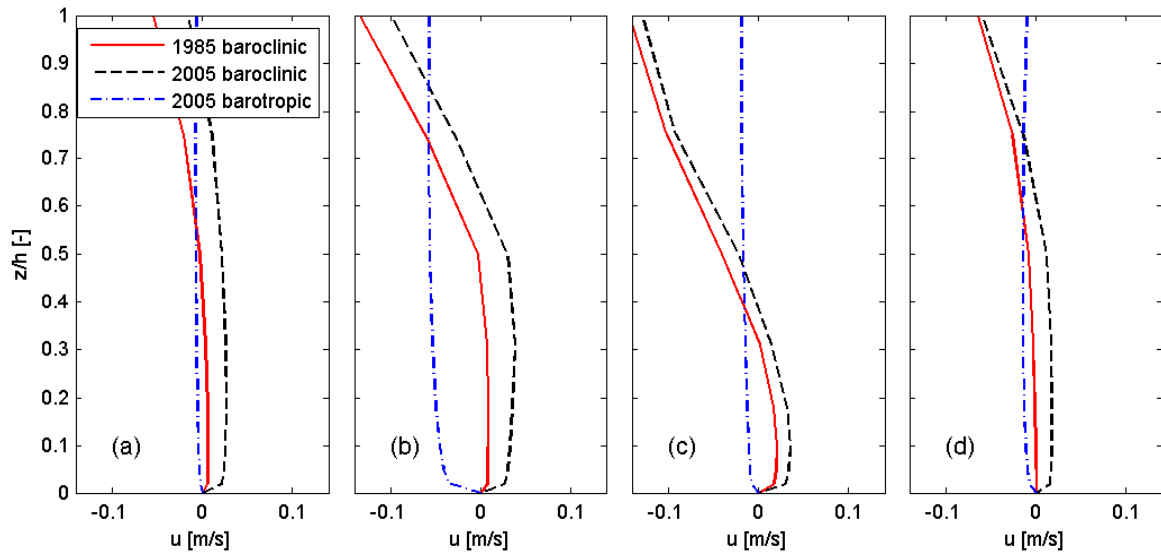


Fig. 1. Residual flow velocity profiles, with positive values directed up-estuary, computed at 4 locations in the estuary, for 1985 and 2005 (baroclinic mode) and 2005 (barotropic mode, i.e. no density effects).

### Conclusions

Our model suggests that baroclinic processes strongly influence the suspended sediment dynamics in the Ems Estuary, and that the magnitude of estuarine circulation increased as a result of channel deepening. As a result, the modelled response to channel deepening is an up-estuary increase in the suspended sediment concentration. The effect of dredging and subsequent sediment dispersal is low when compared to natural conditions, but large compared to periods in which sediment depositing in the ports was extracted from the system.