Climate change effects on restoration of estuarine dynamics within the Delta region

Deltares

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Modelling effects of sea level rise and increased connectivity

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Summary

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Contents

1 Introduction

Various changes will occur in the Southwest delta resulting from the combined effects of climate change and infrastructural adaptations. This will induce changes in habitat availability and species composition. The effect of climate change, such as sea level rise, river peak discharges and the increase of the sea water temperature, will influence the functioning of the marine ecosystem of the Southwest Delta.

In the last century, the average sea level in the North Sea increased with 20 cm. Various initiatives will be developed within the Delta region to prepare this region for ongoing sea level rise and changes in river discharges. Many of these adaptations will focus on restoration of estuarine dynamics (tidal ranges, salinity, morphology, nutrients) by restoring connections with the North Sea and rivers. Moreover, also individual basins might be re-connected with each other. The goal of these adaptations is to make the Delta more resilient to sea level rise and river discharges and increase both its natural and production values.

The increase of water temperatures will enable species from more Southern regions to establish themselves in the Delta region. Depending on their invasive capacity they might influence functioning of the ecosystem. Moreover, the restored connections between the individual basins will facilitate the distribution over the Delta. An important factor for a successful introduction of a particular species is the presence of suitable habitat and conditions for settlement.

Many scenarios have been defined in relation to the restoration of estuarine dynamics for the various basins (e.g. Volkerak-Zoommeer, Grevelingenmeer, Haringvliet). However, large scale changes that wil;l be induced in combination with sea level rise might be difficult to foresee. Therefore, a 1D modelling effort was conducted. In this study the effects of climate change and future infrastructural adaptation on the hydrodynamics and water quality of the South West Netherlands are modelled using a 1D approach with the modelling software SOBEK.

Results of this study are implemented in habitat models to predict effects on species distribution.

1.1 Background

This study is a part of the Dutch research program Kennis voor Klimaat (Knowledge for climate). This program focuses on the development of knowledge to better assess investments for spatial planning and infrastructure over the coming twenty years in terms of their resistance to climate change (Knowledge for Climate website, 2011). The present study is part of the Knowledge for Climate project "Climate change effects on restoration of estuarine dynamics within the Delta region", which is part of the Hotspot "South-West Netherlands Delta". The aim of this project is to develop a tool to predict the effects of climate change on natural values within the Delta area. The Pacific oyster (Crassostrea gigas) has been chosen as a model species. Changes in environmental conditions have been calculated with a hydrodynamic and waterquality model (this study) and used as input to the habitat model of Pacific oysters (Schellekens et al., 2012). NIOZ-Yerseke has conducted field studies on the conditions that that influence the settlement of Pacific oysters (IJzerloo and Bouma, 2012).

The existing calibrated and validated 1D model of the Delta (Delta-model, WL|Delft Hydraulics, 2007) was used as a starting point for the baseline scenario. Two additional scenarios representing possible developments in the delta region, are modelled:

1. Sea level rise of 0.8 m NAP
2. Increased water flow between the North Sea and Grevelingen, and an opening between Grevelingen and Volkerak –Zoommeer.

2 Methodology

2.1 Model set-up

The Delta-model is a 1D model of the South West Delta in the Netherlands developed by Deltares during the years 2006-2007. The model is an application of the SOBEK hydrodynamics and water quality model. The modelled area covers all the Northern and Southern Basins of the Delta, including the Westerschelde (see
Figure 2.1).

The hydrodynamic forcing of the model is composed of all discharges from the rivers upstream, and the tidal variation from the North Sea (downstream). All infrastructural elements (sluices and dikes) can be modelled dynamically.

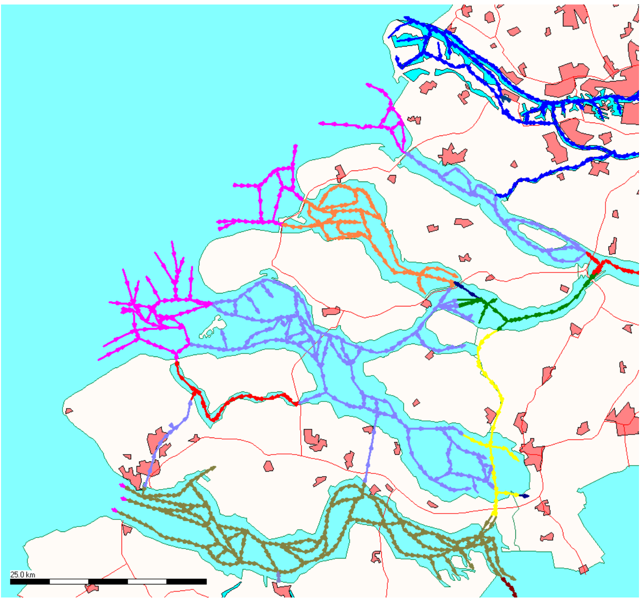
For water quality simulation all point sources, which are mainly polder discharges, were taken into account. Water level, flow velocity, chloride and a significant number of eutrophication related water quality processes were calculated. The ecology was modelled up to the level of algal production with the algal model BLOOM.

The Delta-model was run for a reference year as a baseline. The input data for the reference year were obtained from monthly averages of the years 2000 to 2005. They include the following forcing:

- Hydrodynamics
- Meteorology
- Water quality

The model was calibrated and validated. An extensive description of the Deltamodel is available in WL| Delft Hydraulics, 2007.

Figure 2.1: 1D model schematization. Different colours represent different basins.



2.2 Scenario description

Three scenarios were run in this study:

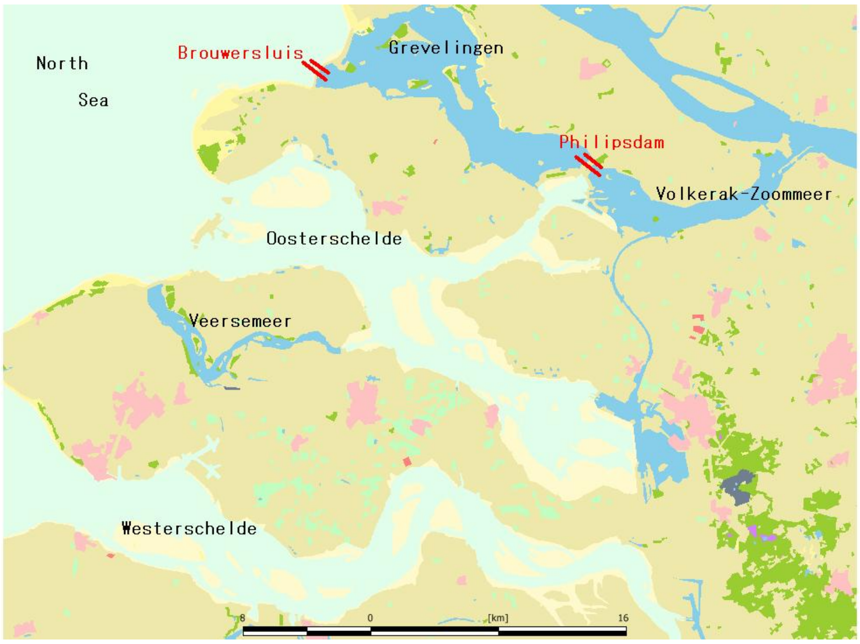
1. Baseline: current situation (reference year 2000-2005). For further insight see WL| Delft Hydraulics, 2007.

2. Scenario 1: 0.8 m sea level rise. The level at the sea boundaries is set 0.8 m higher than in the current situation. All the other input variables are the same as in the baseline.

3. Scenario 2: adjustment tidal range Grevelingen and Volkerak-Zoommeer. In this scenario infrastructural elements of the Delta were modified:
   – the Brouwersluis between the North Sea and Grevelingen: here the flow exchange between the two basins was increased in order to get a tidal range of about 0.5 m (between -0.35 m NAP, and +0.15 m NAP).
   – the Philipsdam between Grevelingen and Volkerak-Zoommeer. In this case an opening was created between the two basins (in the baseline scenario the two basins do not communicate). The water exchange was set to reach a tidal range of about 0.3 m (between -0.25 m NAP, and +0.05 m NAP). All the other input remained the same as in the baseline scenario.

The simulation period of each scenario is one year.

Figure 2.2: overview of the area of the Delta that was analyzed in the model. The names of the basins are in black in the image. Indicated in red are the two structures that were modified in the model in order to obtain the tidal range as described in scenario 2.



2.3 Outputs

For each scenario the following outputs were produced.

1 Maximum and average flow velocities (m/s)
2 Average of duration of the dry period (days)
3 Average and maximum shear stress
4 Average salinity (ppt)
5 Average chlorophyll-a (µg/l)

The results of the 1D model were transformed to 2D maps by interpolating the single points on 20x20 meters grid in GIS. The interpolation method used was the Inverse distance weighting (IDW). This was done for all parameters except duration of the dry period. This is done in order to produce input maps for spatial modelling tools, such as HABITAT, that will be used to predict changes in relevant estuarine habitats for the Delta in response to changes in environmental factors such as currents, water depth, substrate type and location, inundation frequency or duration, and water quality.

3 Results and discussion

Results are presented in the following paragraphs in the form of 2D maps of model results.

For salinity there is no significant difference between the baseline and the sealevel rise scenario (Figure 3.1 and Figure 3.2 respectively), while in scenario 2, the implemented opening causes the saltwater of the Grevelingen to mix with the freshwater of the Volkerak. In the latter, salinity increases from few ppts to more than 24 ppts in the area closer to the opening and to about 12-15 ppts in the part of the lake closer to the freshwater of the Hollandse Diep. In the Grevelingen salinity decreases around 3-4 ppt on the Volkerak site.

The more dynamic water regime of the Grevelingen-Volkerak in scenario 2 causes a substantial decrease in chlorophyll (from 30-35 µg/l to 25-15 µg/l) in the Volkerak (see Figure 3.4, Figure 3.5, Figure 3.6), and a small increase (10 to 15 µg/l) in a relatively large area of the Grevelingen.

The flow velocities (both average and max) seem not to be influenced by the sea level rise, while they slightly increase around the opening in scenario 2 (see Figure 3.8 to 3.13). The same conclusions apply to the results of average and maximum shear stress (see Figure 3.14 to 3.20). Although flow velocities overall are reliable there is an artefact in flow velocities near Bruinisse (North part of the Oosterschelde). Here average and maximum flow velocities in the 2D maps are high, while in reality flow velocities in this part of the Oosterschelde are extremely low. This artefact is caused by the transformation of the 1D-model results to the 2D maps.

The 2D maps can be used to perform habitat scenarios. This will yield a first insight on the effects of climate change for relevant estuarine habitats and species. As a model species, the Pacific oyster was selected. In addition to this modelling study an inventory was made of species that may become invasive due to climate change. This might facilitate application of the habitat model developed for the Pacific oyster to other species.

3.1 Salinity

Figure 3.1: Salinity (ppt) for the baseline scenario (average over 1year).

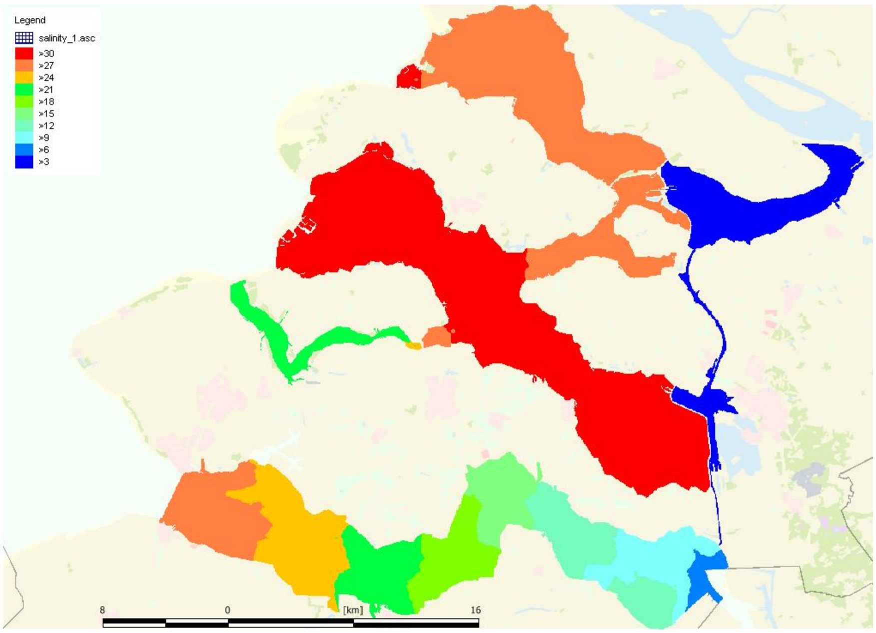


Figure 3.2: Salinity (ppt) for the baseline scenario 1 (average over 1year).

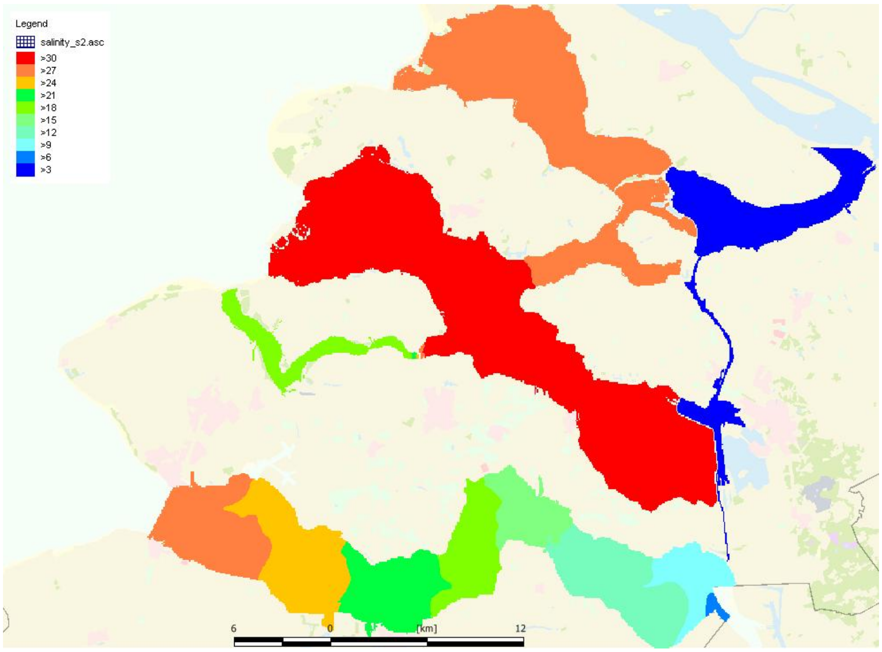
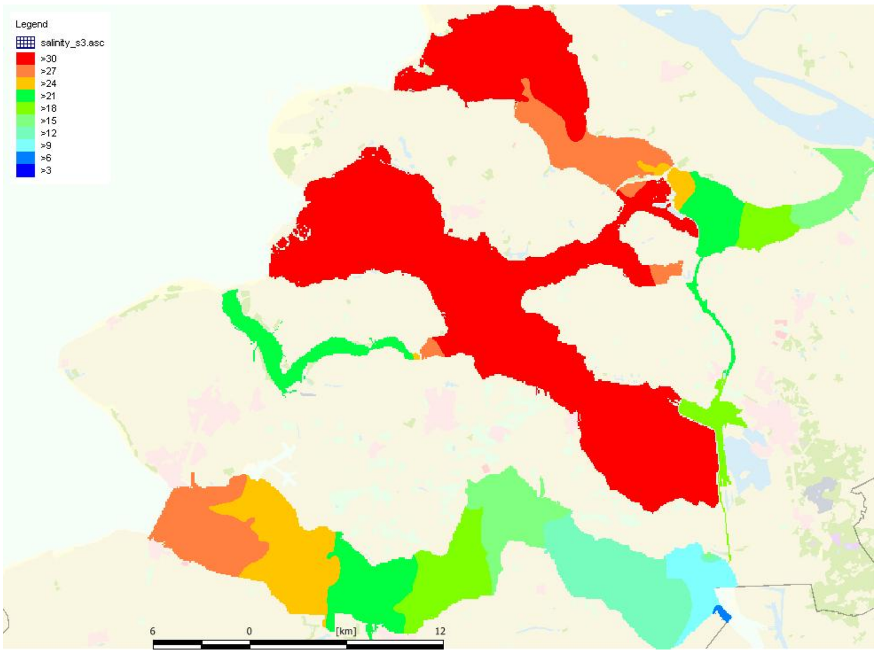


Figure 3.3: Salinity (ppt) for scenario 2 (average over 1year).



3.2 Chlorophyll-a

Figure 3.4: Chlorophyll-a concentration (µg/l) for the baseline scenario (average over one year).

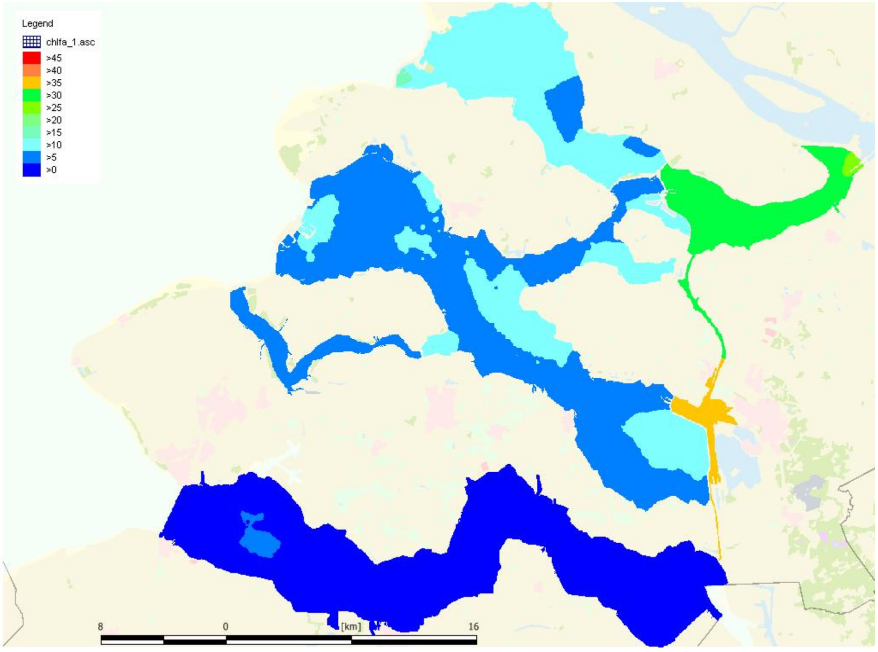


Figure 3.5: Chlorophyll-a concentration (µg/l) for scenario 1 (average over one year).

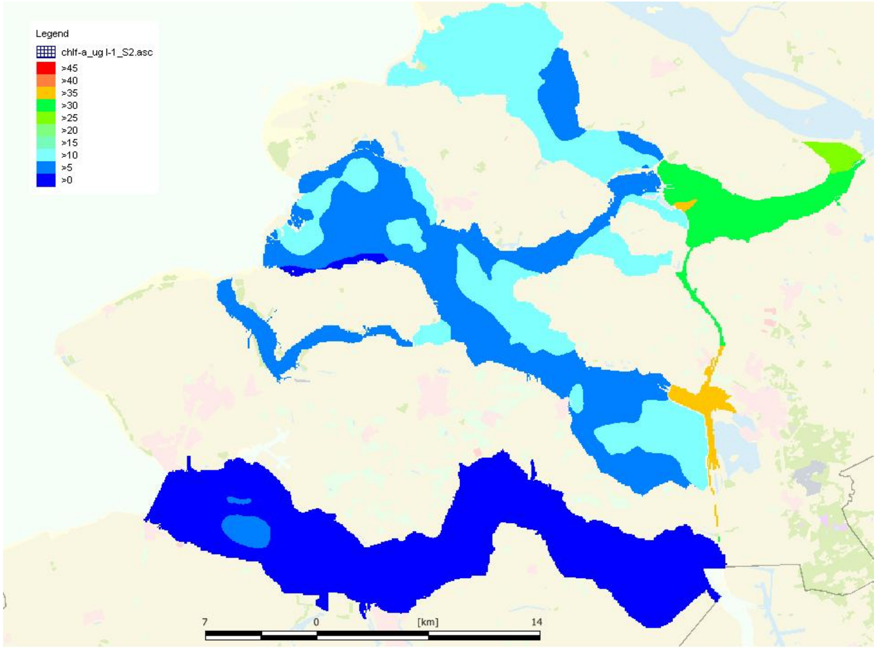
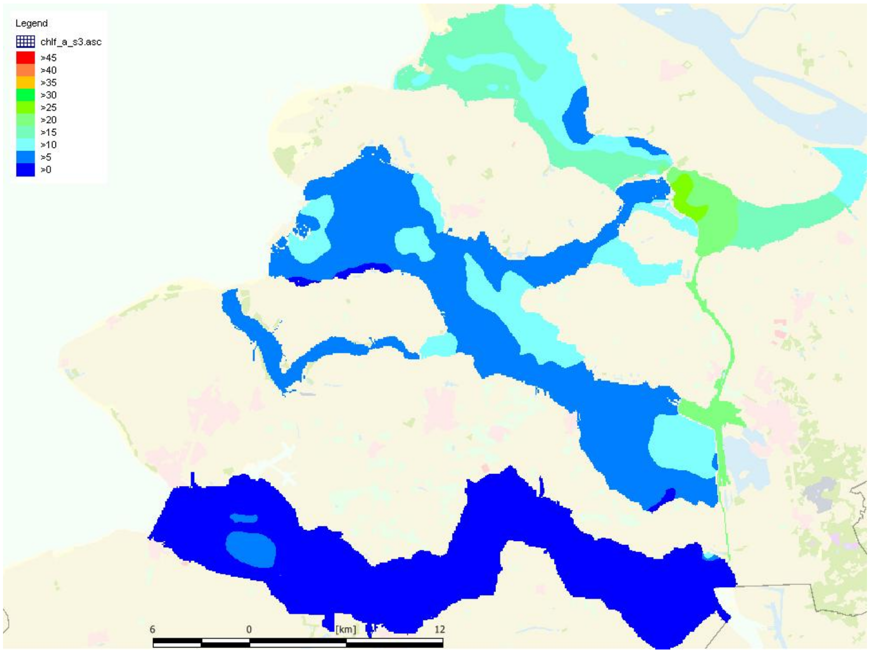


Figure 3.6: Chlorophyll-a concentration (µg/l) for scenario 2 (average over one year).



3.3 Flow velocities

Figure 3.7: flow velocity(m/s) for the baseline scenario (average over 1 year).

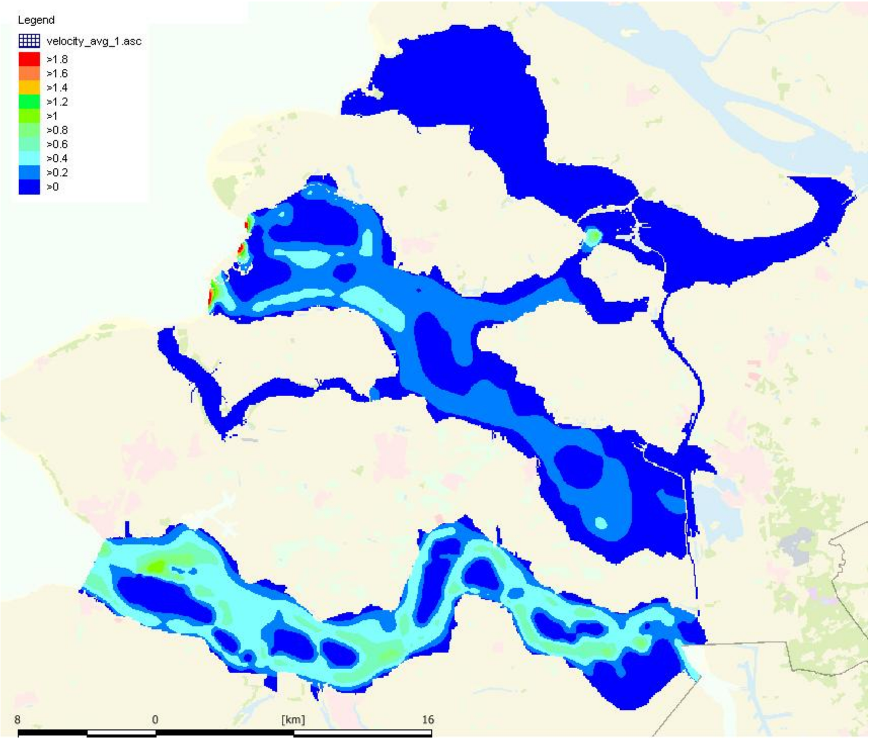


Figure 3.8: flow velocity(m/s) for scenario 1 (average over 1 year).

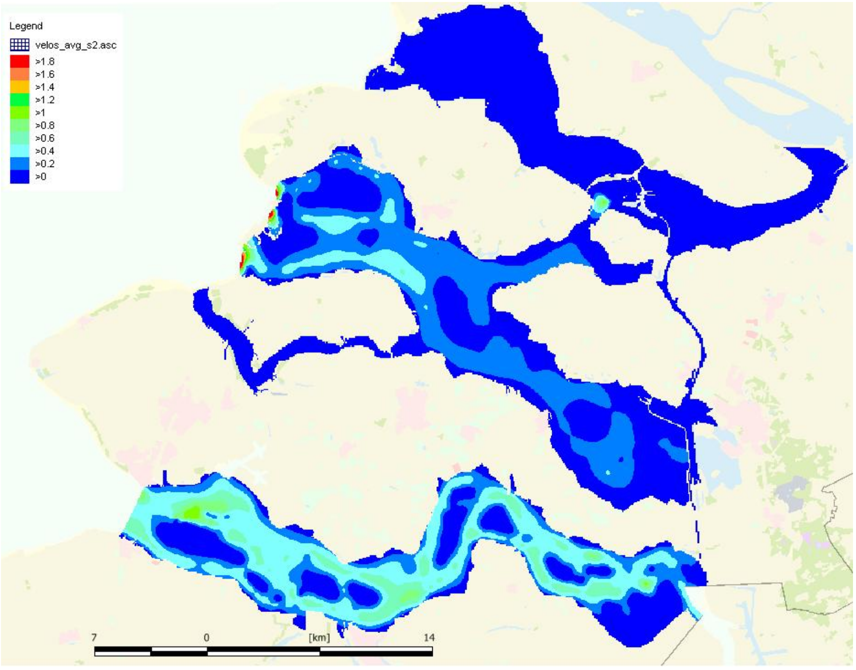


Figure 3.9: flow velocity (m/s) for scenario 2 (average over 1 year).

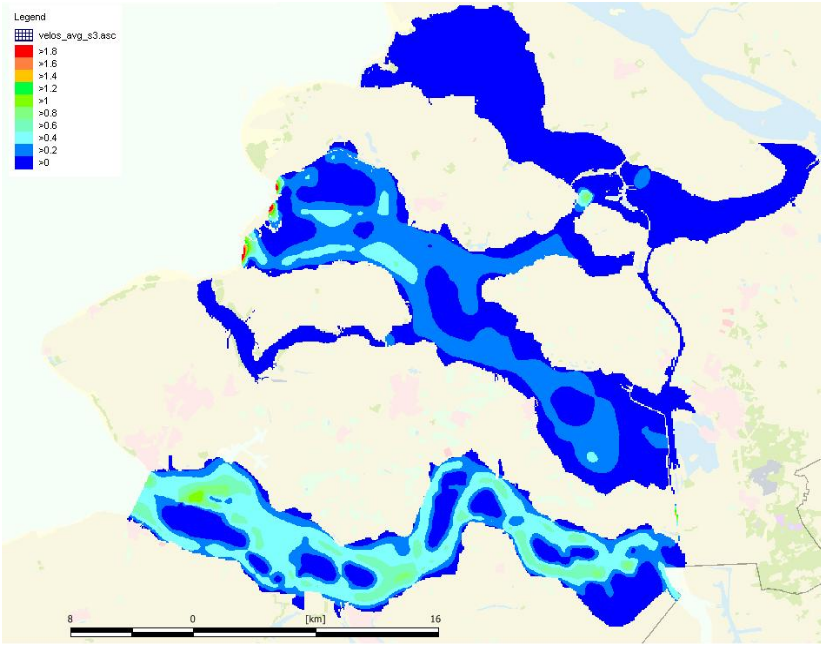


Figure 3.10: flow velocity(m/s) for the baseline scenario (maximum over 1 year).

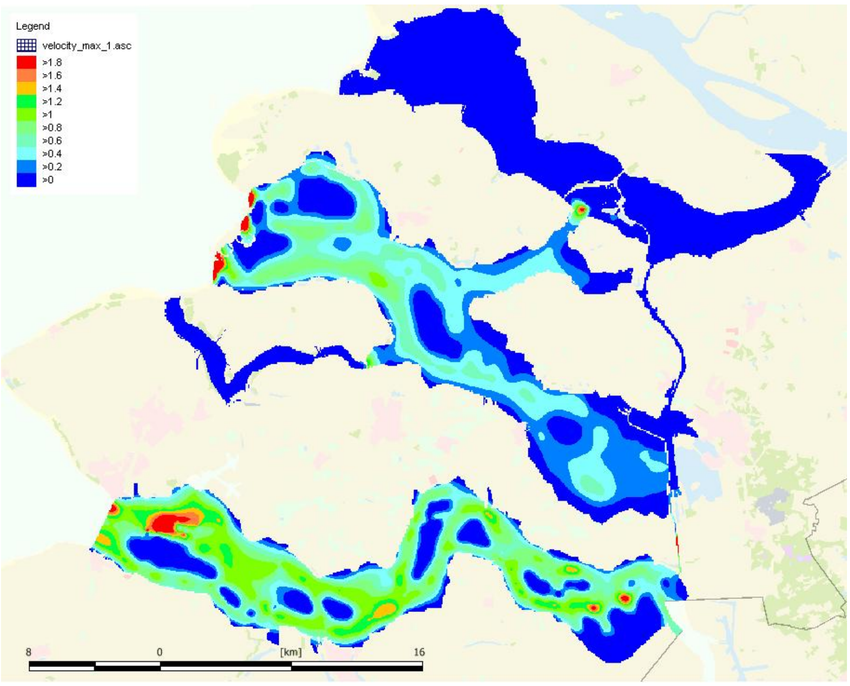


Figure 3.11: flow velocity(m/s) for scenario 1 (maximum over 1 year).

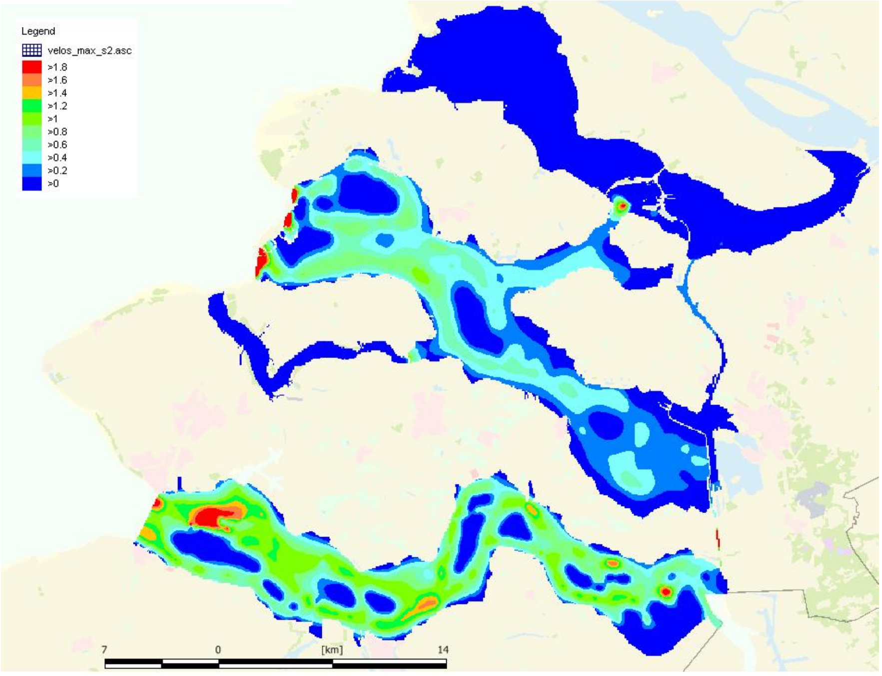
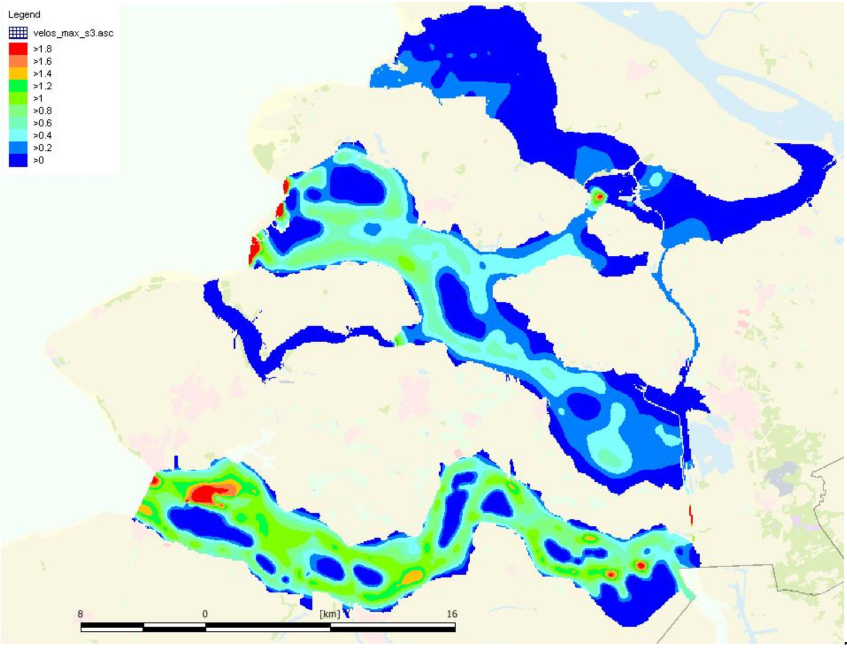


Figure 3.12: flow velocity (m/s) for scenario 2 (maximum over 1 year)



3.4 Shear stress

Figure 3.13: shear stress (N/m²) for the baseline scenario (average over 1 year).

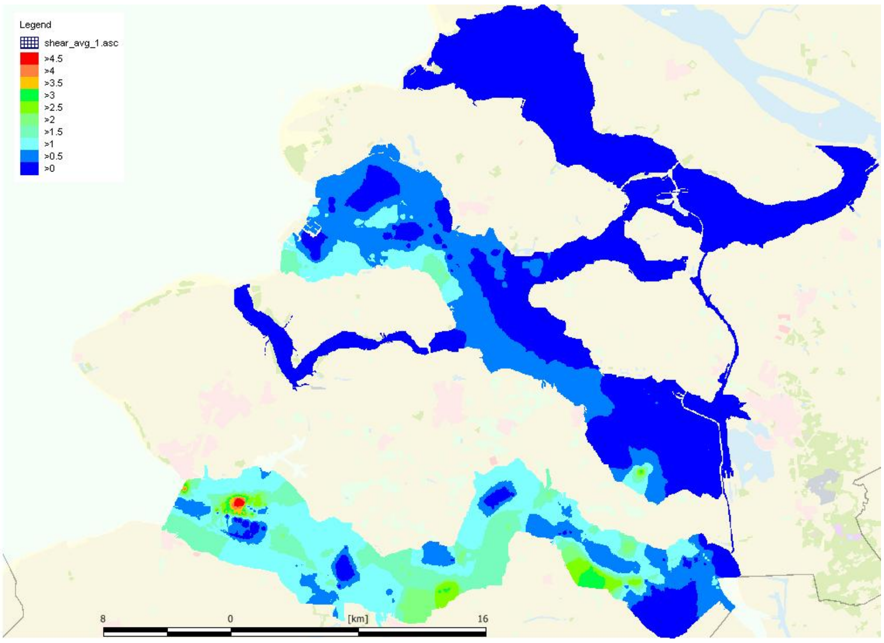


Figure 3.14: shear stress (N/m²) for scenario 1 (average over 1 year).

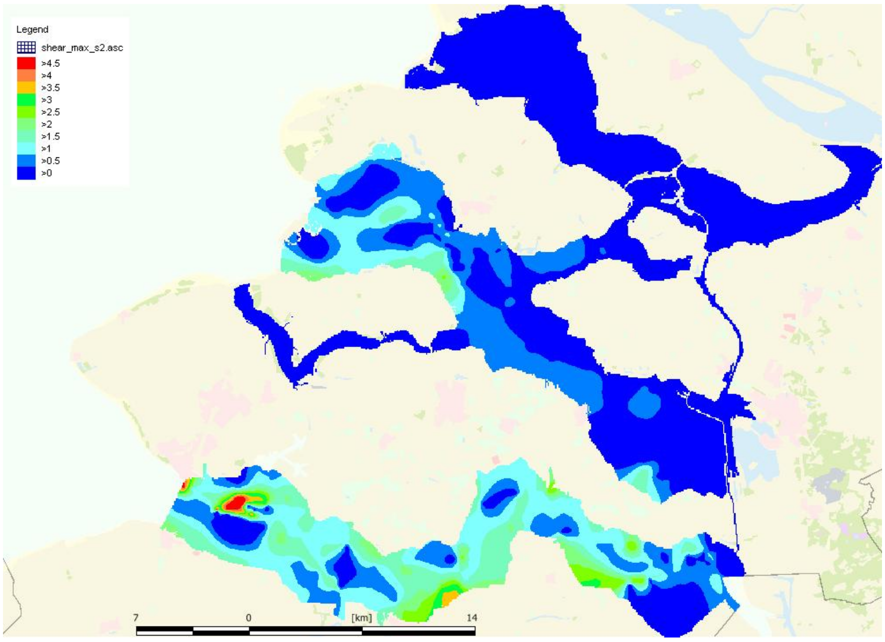


Figure 3.15: shear stress (N/m²) for scenario 2 (average over 1 year).

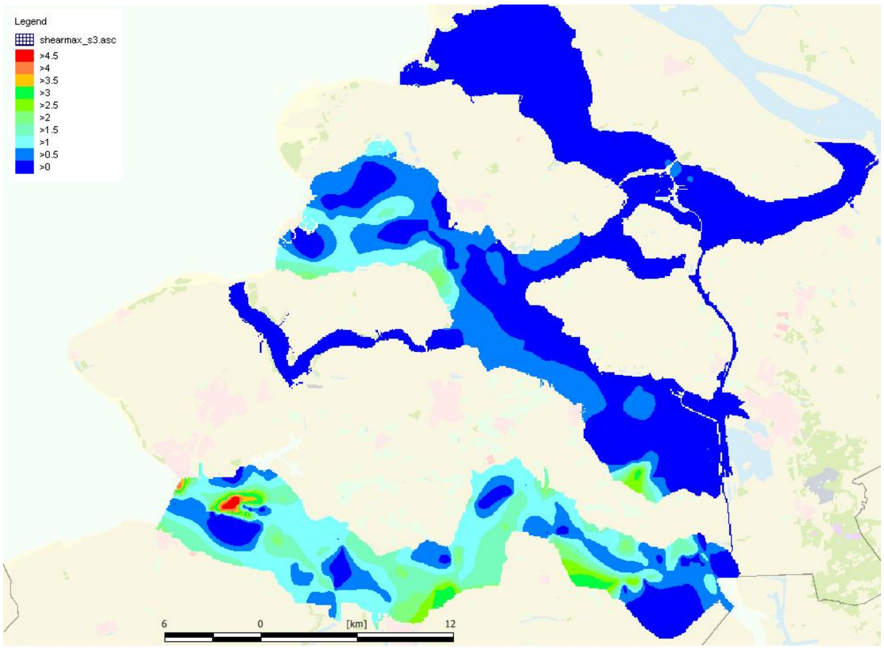


Figure 3.16: shear stress (N/m²) for the baseline scenario (maximum over 1 year).

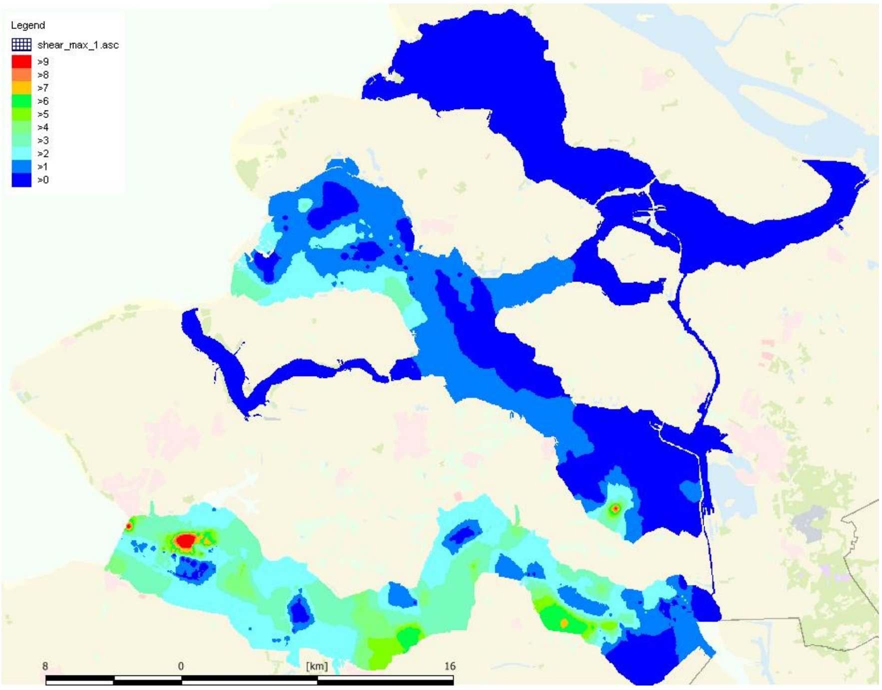


Figure 3.17: shear stress (N/m^2) for scenario 1 (maximum over 1 year).

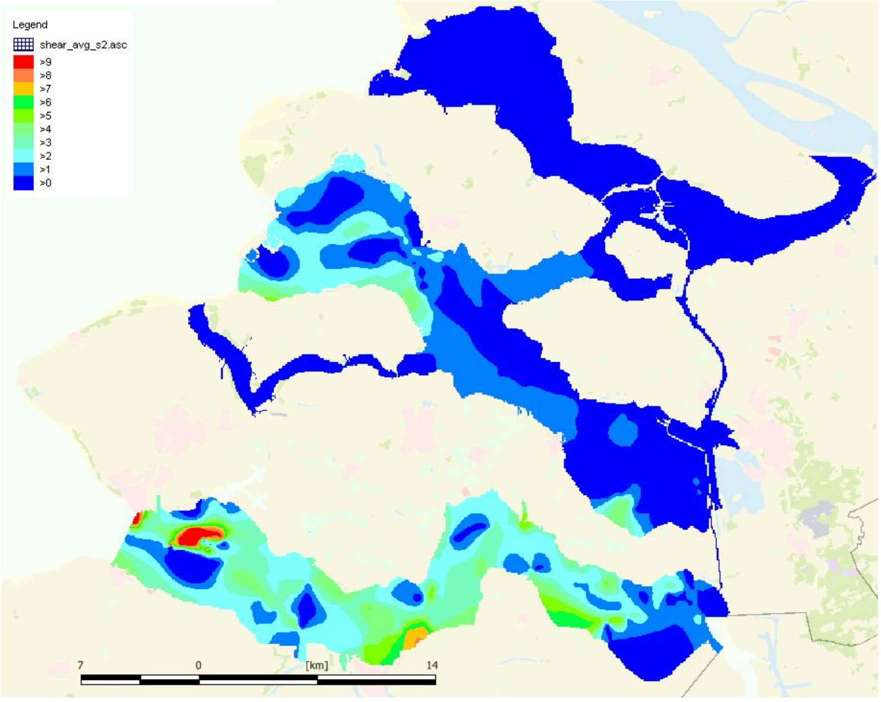
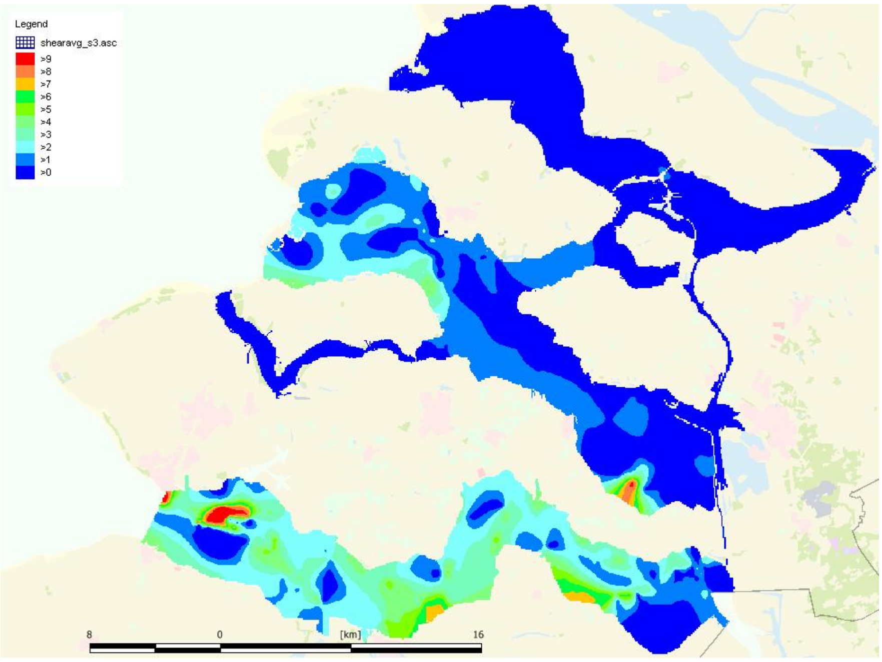


Figure 3.18: shear stress (N/m^2) for scenario 2 (maximum over 1 year).



4 References

Wl | Delft Hydraulics, 2007. Deltamodel - hulpmiddel ter ondersteuning van het beheer en beleid van de zuidwestelijke Delta.