TRANSNET SOC LTD

FEASIBILITY STUDY (FEL3) FOR THE DEEPENING OF BERTHS 203-205

PORT OF DURBAN

CENTRAL SANDBANK MORPHOLOGICAL STUDY

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1.0 INTRODUCTION

1.1 Background

A morphological study has been performed to assess potential changes to the central sandbank in Durban Bay due to scour and sedimentation. Morphology (from the Greek words *morfe* = form and *logos* = study) is the science of surface features and forms including the forces and processes that create them.

This study has been prompted by the Extension of Sandbank Risk Assessment, ZAA 1370-RPT-040.

Changes to the hydrodynamic functioning of the port due to development may lead to increased scour and/or sedimentation in areas of concern. The central sandbank has been identified as an ecologically sensitive habitat in Durban Bay. As part of the Pier 2 deepening, it has been proposed to extend the central sandbank.

The purpose of this report is to compare the status quo with the proposed layout in terms of flow patterns and potential for scour and sedimentation (morphology) over the short and long term.

A numerical model has been used to simulate severe storm events as well as long term (50 year) changes to the port. Directly comparing the resulting morphological trends allows conclusions to be drawn as to the viability and impact of such changes on the shape of the sandbank.

1.2 Model setup

Hydrodynamic flow modelling and simulation has been performed using Delft3D-FLOW. Delft3D-FLOW is a multi-dimensional hydrodynamic simulation program which calculates non-steady flow and transport phenomena that result from tidal and meteorological forcing on a rectilinear or curvilinear boundary fitted grid.

The FLOW model is coupled to a Delft3D-WAVE model to enable the inclusion of effects resulting from wind and wind generated waves. It is shown that without these processes, very little if any scour occurs and that wind is the main driver behind sediment transport within the port.

A curvilinear 2D (1 layer in the vertical, i.e. depth-averaged) computational grid has been employed. Generation of a high quality grid has been an iterative process to ensure good orthogonality, smoothness and aspect ratios in the desired range. Orthogonality refers to the perpendicular intersection of grid lines while smoothness is measured by the ratio of neighbouring grid cell dimensions being below a value of around 1.1 in the area of interest.

Any significant change in the computational grid requires re-calibration which is an intensive procedure of tuning model parameters to match simulation results to field measurements.

The setup, calibration and validation of this model are described in detail in ZAA 1370-RPT-043 Hydrodynamic Model Setup and Calibration.

Table 1.2.1 below outlines the extent of simulations performed for this study. Refer to Figures 1.2.1 to 1.2.3 for an overview of the model grid and bathymetry for the model used.

DELFT3D SIMULATION SCHEDULE										
	GRID	IDENTIFIER								DESCRIPTION
1	DBN12	-	CUR	-	S1			CURRENT LAYOUT, STORM FROM SSW
2	DBN12	-	CUR	-	S1	-	3D	CURRENT LAYOUT, STORM FROM SSW, 3D SIMULATION *
3	DBN12	-	CUR	-	S2			CURRENT LAYOUT, STORM FROM NNE
4	DBN12	-	CUR	-	50Y			CURRENT LAYOUT, LONG-TERM SIMULATION
5	DBN12	-	3H	-	S1			OPTION 3H LAYOUT, STORM FROM SSW
6	DBN12	-	3H	-	S1	-	SLR	OPTION 3H LAYOUT, STORM FROM SSW INCLUDING SEA-LEVEL RISE
7	DBN12	-	3H	-	S2			OPTION 3H LAYOUT, STORM FROM NNE
8	DBN12	-	3H	-	S2	-	SLR	OPTION 3H LAYOUT, STORM FROM NNE INCLUDING SEA-LEVEL RISE
9	DBN12	-	3H	-	50Y			OPTION 3H LAYOUT, LONG-TERM SIMULATION
10	DBN12	-	3H	-	50Y	-	NW	OPTION 3H LAYOUT, LONG-TERM SIMULATION, NO WIND / WAVE

* A full 3D simulation on a 5 layered (in the vertical) grid has been performed as a test. This model however requires full re-calibration which is in progress, with computational times up to 48 hours per simulation.

Table 1.2.1: Delft-3D simulation schedule

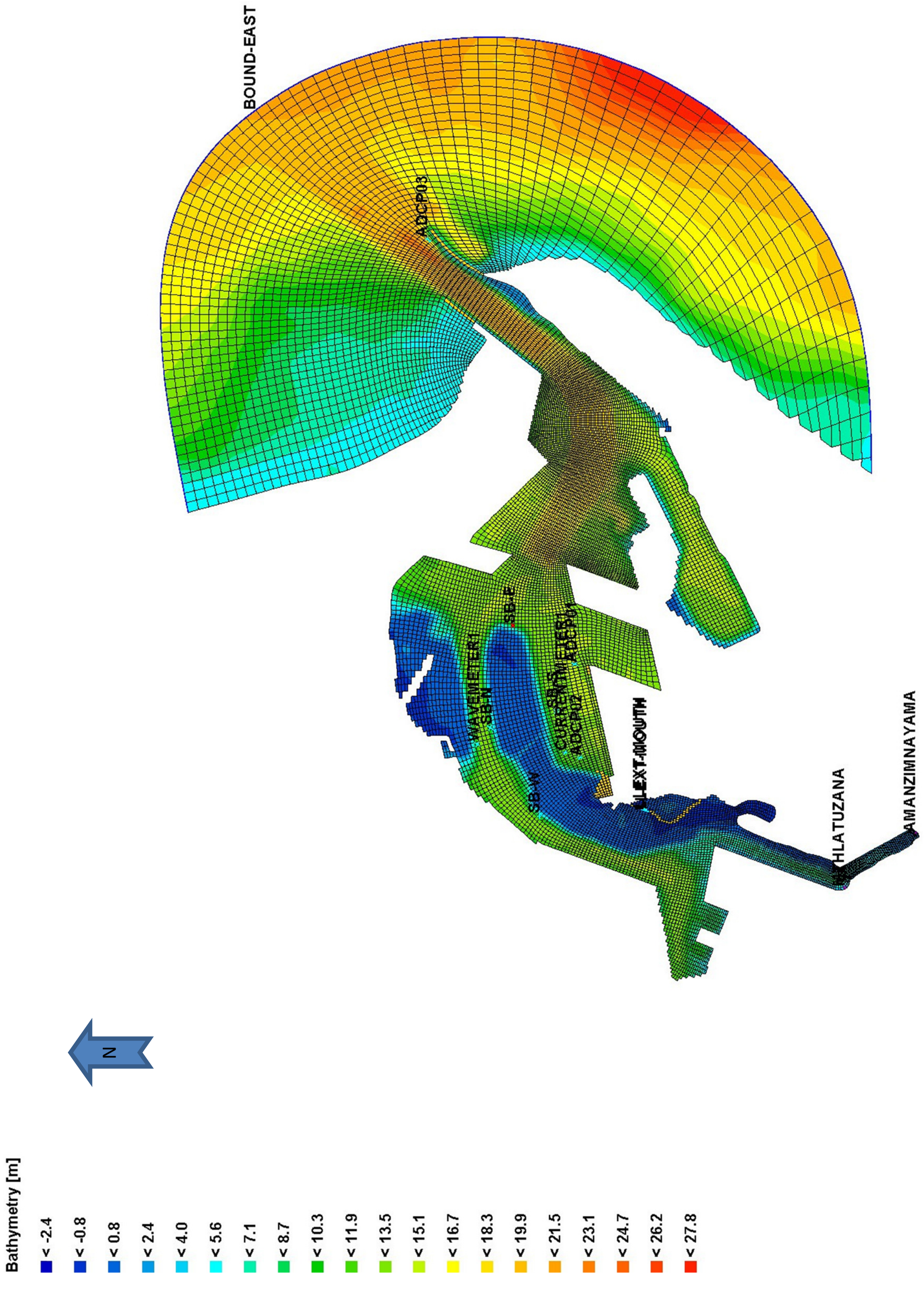

Figure 1.2.1: Durban Bay hydrodynamic model grid (Grid DBN12)

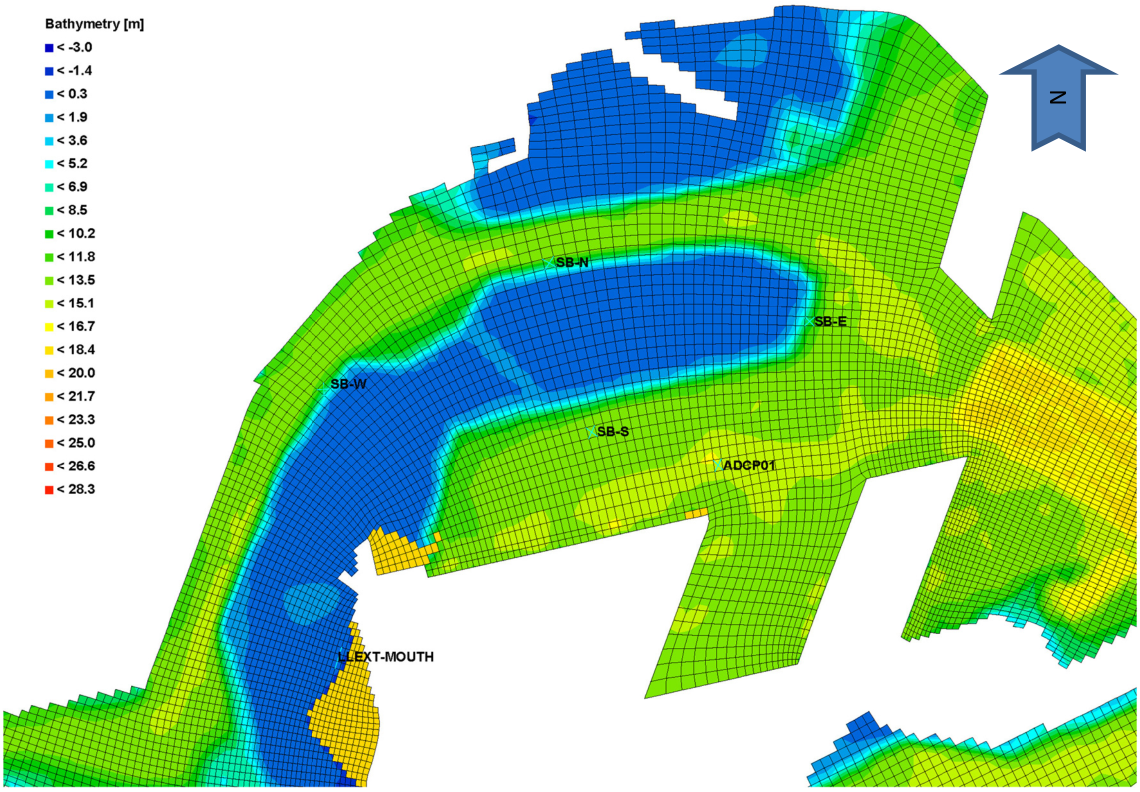

Figure 1.2.2: Durban Bay hydrodynamic model – Detail at current Sandbank

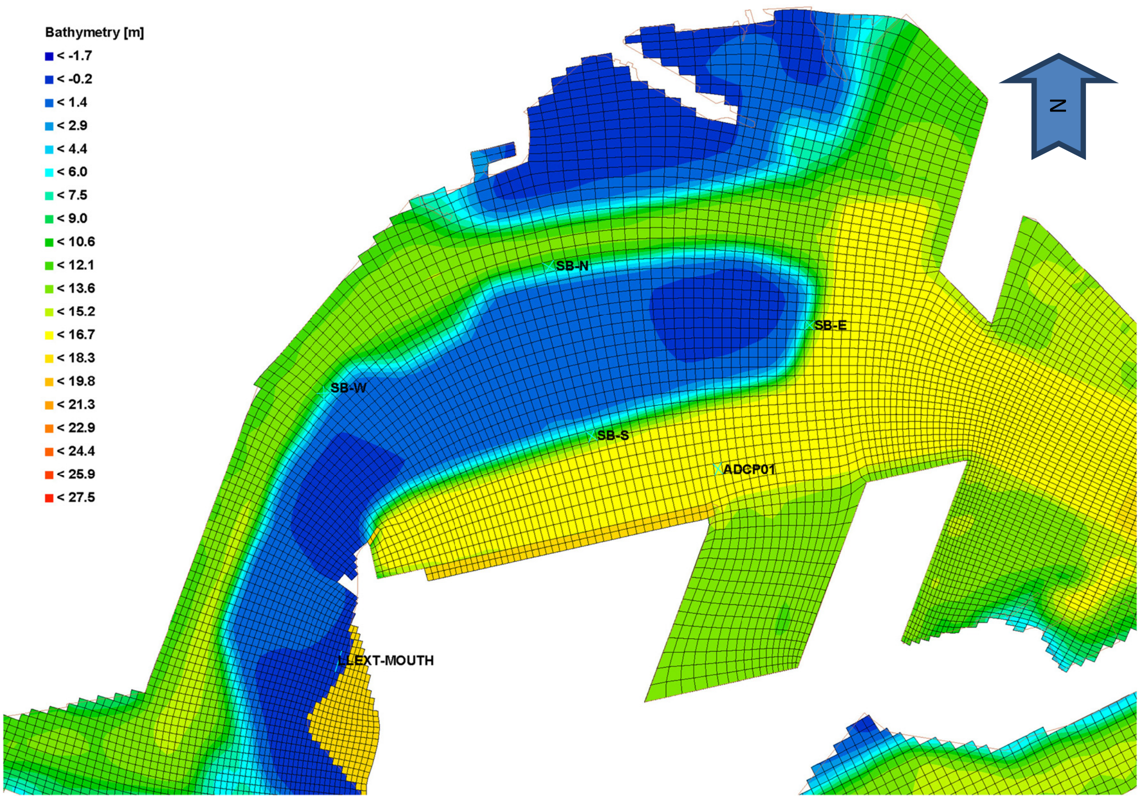

Figure 1.2.3: Durban Bay hydrodynamic model – Detail at proposed Sandbank (Option 3H)

1.2.1 Boundary conditions

A single open boundary has been defined outside the harbour mouth, denoted as “BOUND-EAST” in Figure 1.2.1. Water level forcing has been applied at this boundary as a time series of water levels. Tides as per January 2010 have been used as shown below for the storm and long term simulations respectively.

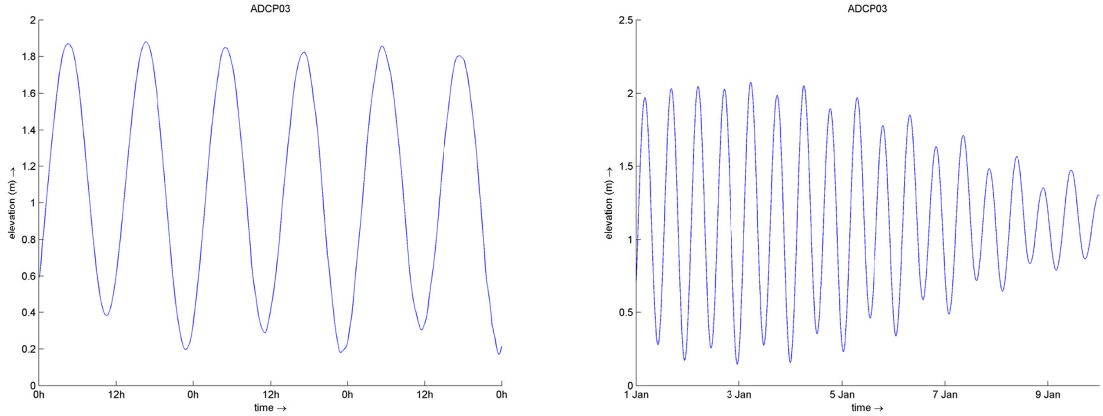

Figure 1.2.4: Water level time series, a) Storm- ; b) Long-term-simulation

1.2.2 Physical processes

1.2.2.1 Wind

For the existing and extended sandbank layouts, extreme storm events characterised by 1 in 50 year wind velocities (increased by 5% to allow for climate change), from North-easterly and South-westerly directions, have been generated. Wind speed has been ramped up from zero to a 48 hour average of 24.7 m/s over the first day of the simulation, where after it has been maintained for the next two days until the end of the simulation.

For the long-term simulations, typical recorded wind velocities and directions have been used corresponding to spring conditions.

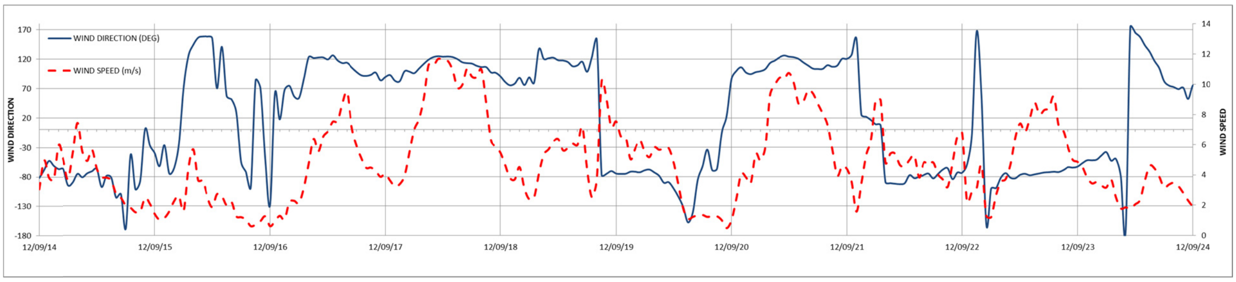

Figure 1.2.5: Wind conditions for Long-term simulations

1.2.2.2 Waves

Constant wave conditions have been applied at the boundary for each of the storm conditions.

It has previously been determined that ocean swell penetrating Durban Bay has a negligible effect at Berths 203-205 and hence the central sandbank. For the purposes of these simulations, a 3m significant wave height with a 10s period is applied at the offshore boundary, coming from a direction of 146°. The same wave conditions have been used for the long-term simulations, but with a significant wave height of 1m only.

1.2.2.3 Sediment

An arbitrary sediment bed thickness of 5m has been applied via a map file over the relevant areas of the port, for each scenario. Bed thicknesses of zero has been defined in various areas covered by scour protection, rock etc.

The following sediment properties have been used for all morphological simulations:

- Reference density for hindered settling 1600kg/m³
- Specific density 2650kg/m³
- Dry bed density 1600kg/m³
- Median sediment diameter (D50) 200um

1.2.2.4 Morphology

Delft3D provides for a spin-up interval to be applied before morphological changes develop at the start of simulations. This prevents inaccurate patterns of erosion or accretion taking place while the simulation stabilises from initial boundary conditions to fully dynamic boundary conditions. The default value of 720 minutes (12 hours) has been retained for this interval.

A characteristic complication of morphology is the fact that such changes most often take place over time scales orders of magnitude larger than typical flow changes. Delft3D allows the user to apply a scale factor to morphological changes in order to conveniently (and quickly) simulate changes that might occur over very long periods.

The long term simulations consist of a 10 day simulation with an applied Morphological time scale factor of 1921 to effectively simulate the morphology over a 50 year period. Taking into account the 12 hour spin-up period, the effective morphological simulation is 9.5 days or 228 hours. To scale 228 hours up to 438 000 hours (50 years), a factor of 1921 has thus been used.

For the storm simulations during which significant changes are expected in any case, a Morphological time scale factor of 1.0 has been applied.

The non-cohesive sediment transport formulation of Van Rijn (1993) has been selected. This formulation distinguishes between sediment transport below a reference height as bed-load and that above the reference height as suspended load transport. Sediment is entrained in the water column by imposing a reference concentration at the reference height. Van Rijn (1993) also allows for the inclusion of wave effects. Through the online coupling of FLOW and WAVE modules, the elevation of the bed is dynamically updated at each computational time-step, ensuring that hydrodynamic flow calculations are always carried out using the correct bathymetry.

1.2.2.5 Climate change and associated Sea-Level Rise

For each of the post construction storm scenarios, additional simulations have been performed with an increased sea level. Water level increase has been applied to provide for sea-level rise of 0.58m and storm surge of 0.759m. Derivation of these values are described in detail in ZAA 1370-RPT-028, Design Report – Effects of Climate Change on Engineering Design, Ref(2).

2.0 RESULTS

2.1 Storm simulations

2.1.1 Storm from the SSW

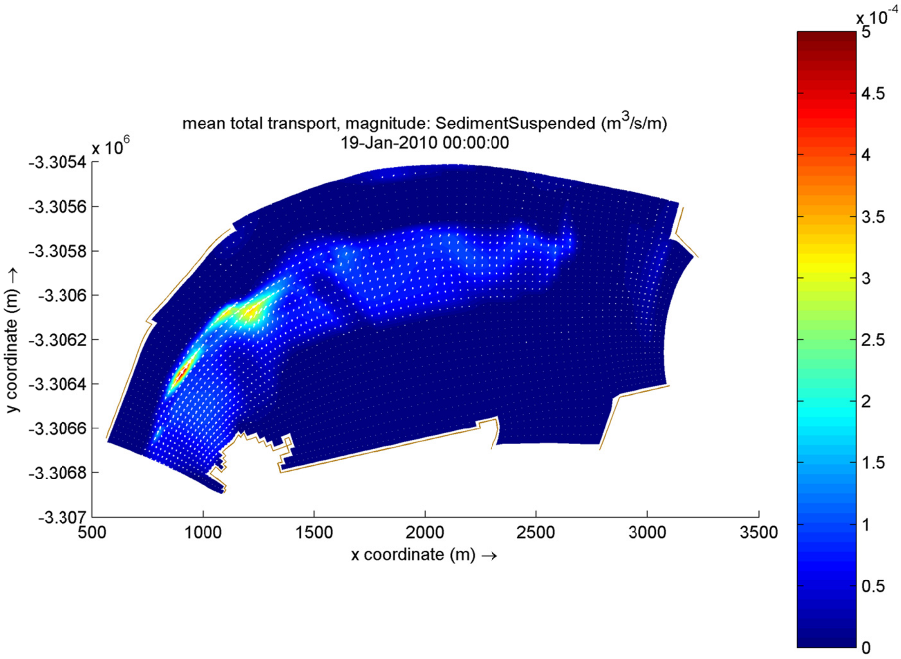

Figure 2.1.1: Current layout SSW Storm – Mean Total Sediment Transport

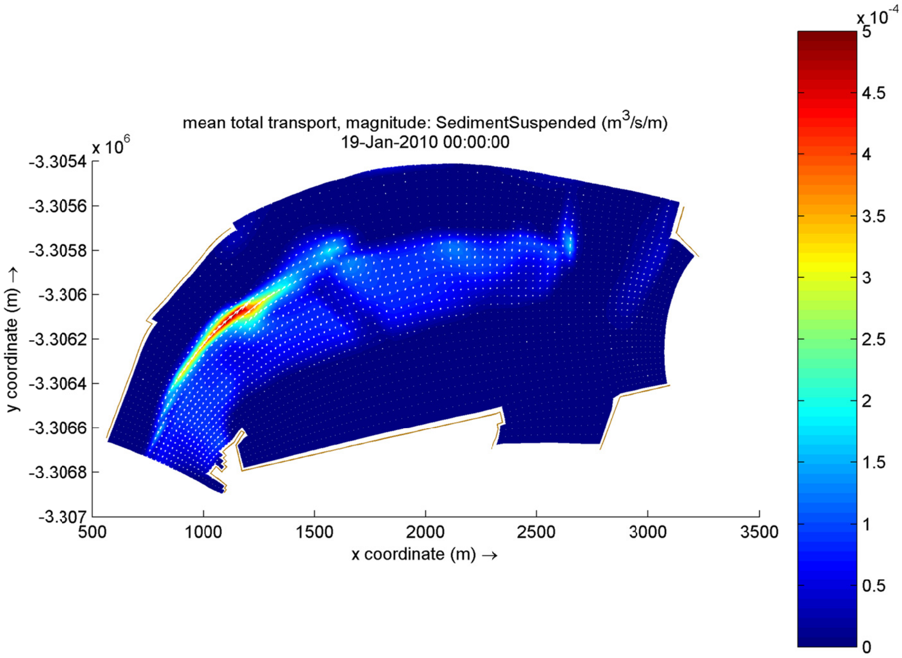

Figure 2.1.2: Option 3H layout SSW Storm – Mean Total Sediment Transport

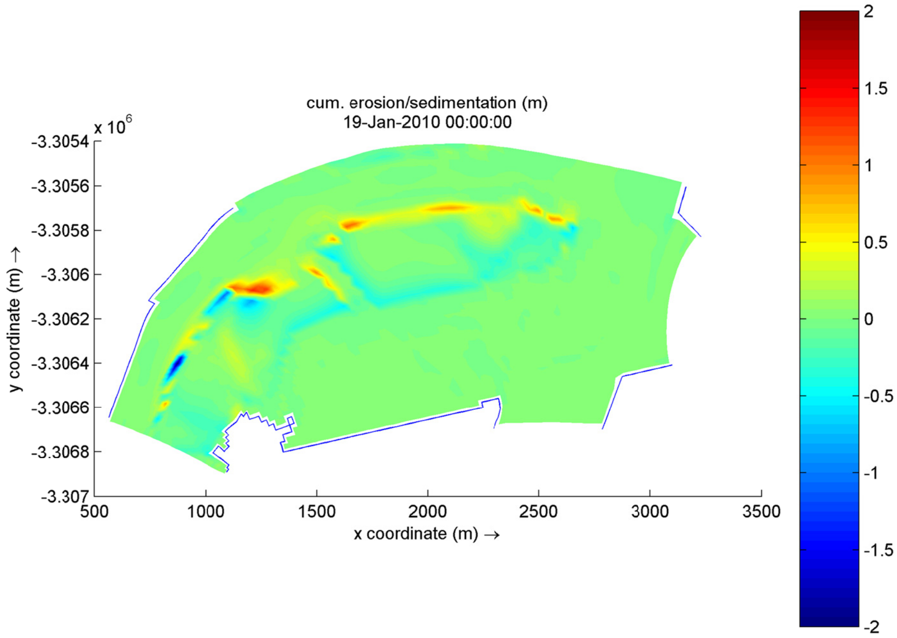

Figure 2.1.3: Current layout SSW Storm – Cumulative Erosion (blue) and Sedimentation (red)

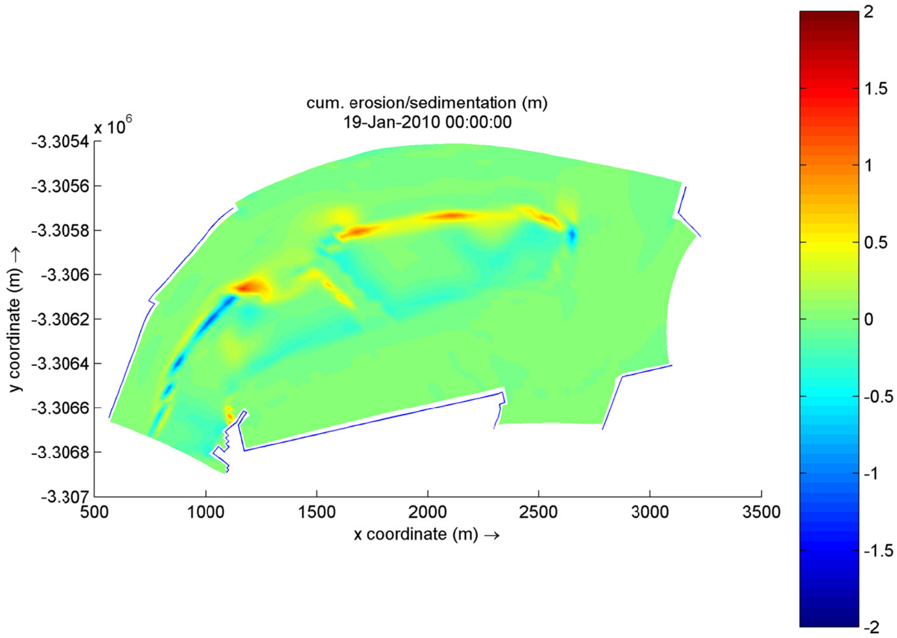

Figure 2.1.4: Option 3H layout SSW Storm – Cumulative Erosion (blue) and Sedimentation (red)

2.1.2 Storm from the NNE

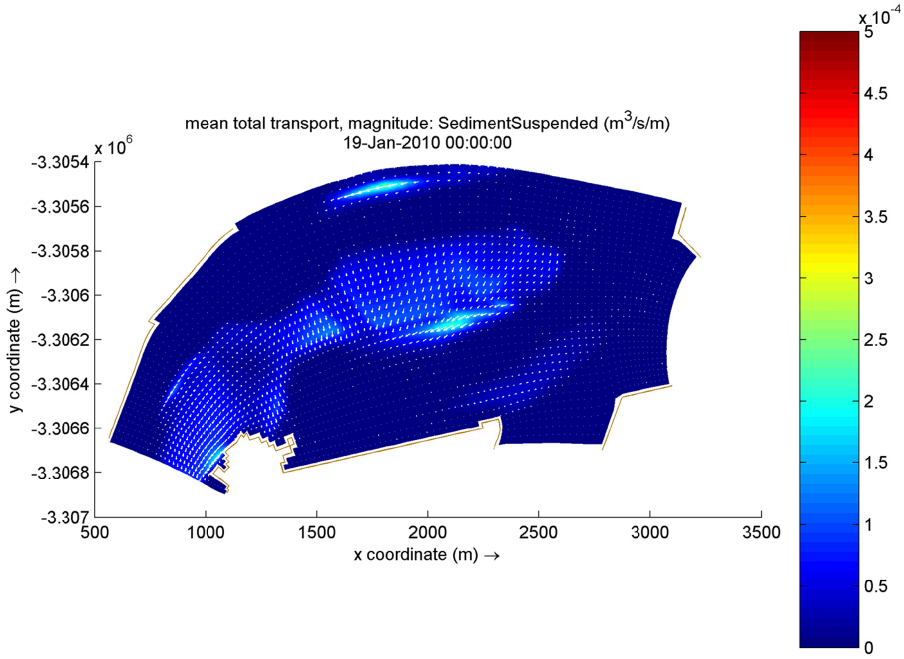

Figure 2.1.5: Current layout NNE Storm – Mean Total Sediment Transport

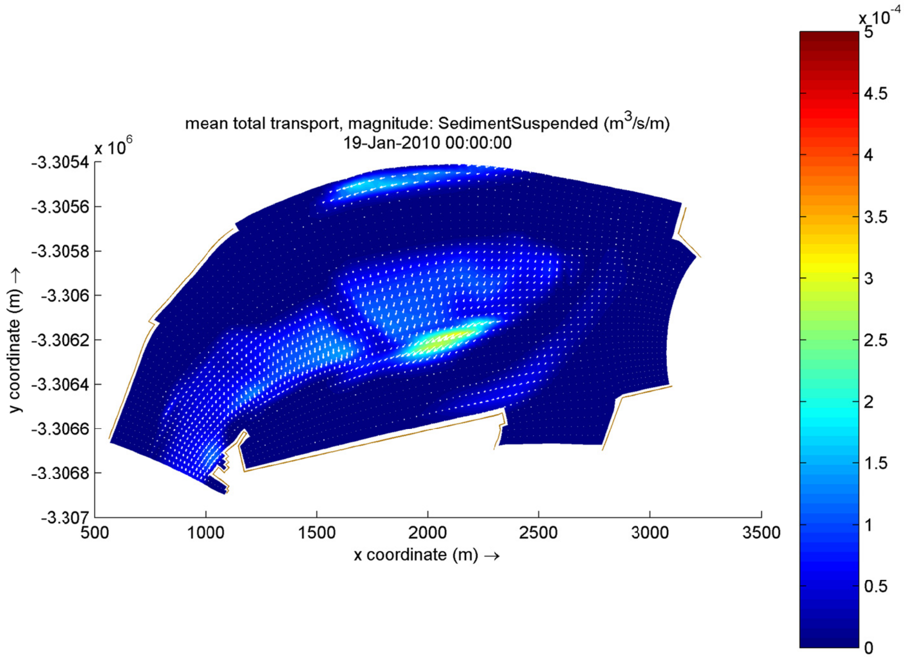

Figure 2.1.6: Option 3H layout NNE Storm – Mean Total Sediment Transport

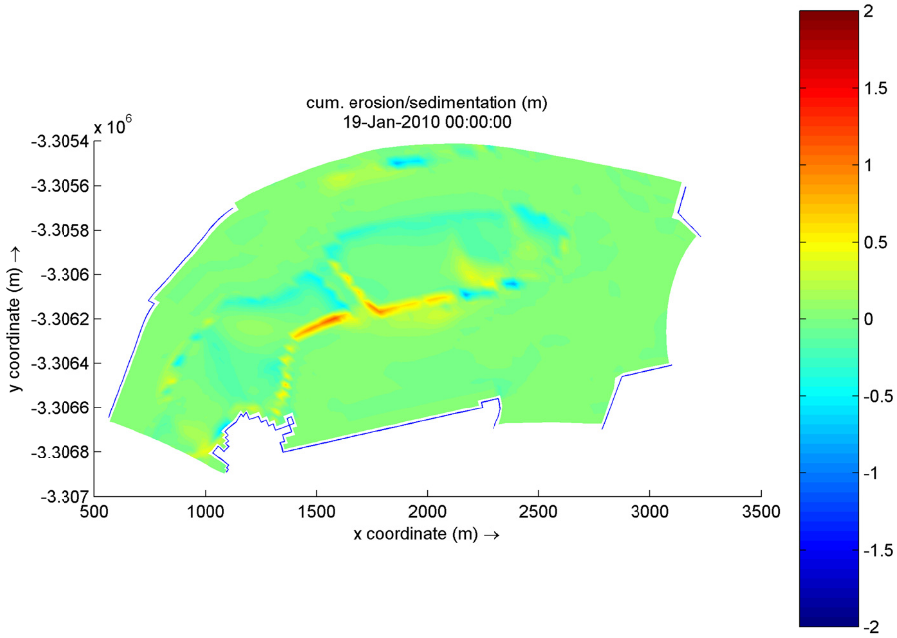

Figure 2.1.7: Current layout NNE Storm – Cumulative Erosion (blue) and Sedimentation (red)

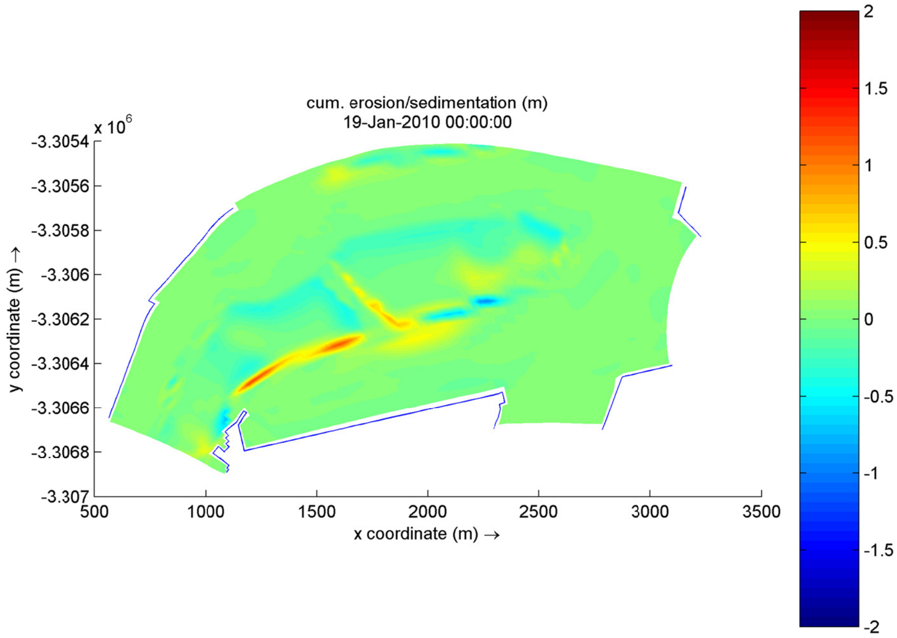

Figure 2.1.8: Option 3H layout NNE Storm – Cumulative Erosion (blue) and Sedimentation (red)

2.2 Storm Simulations including Sea-Level Rise

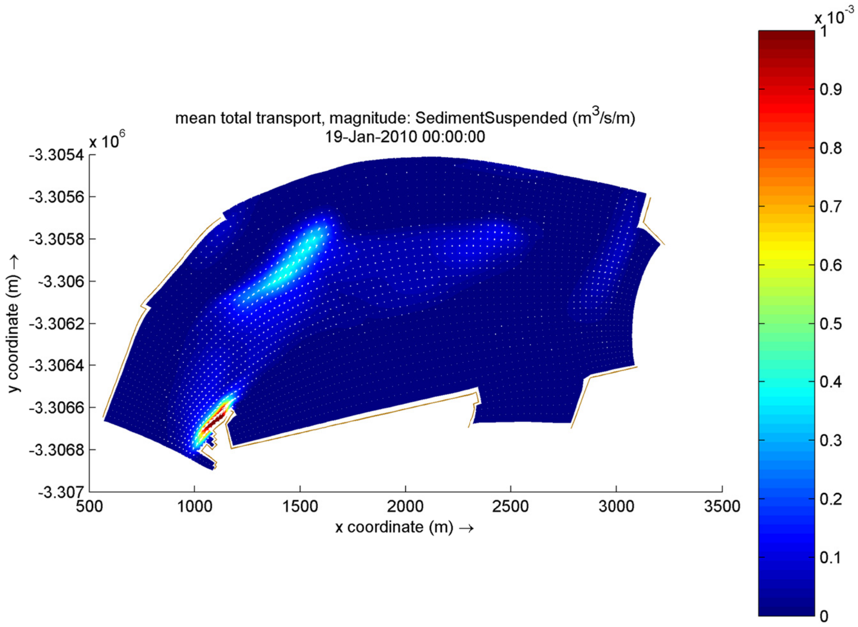

Figure 2.2.1: Option 3H layout SSW Storm including Sea-Level Rise – Mean Total Sediment Transport

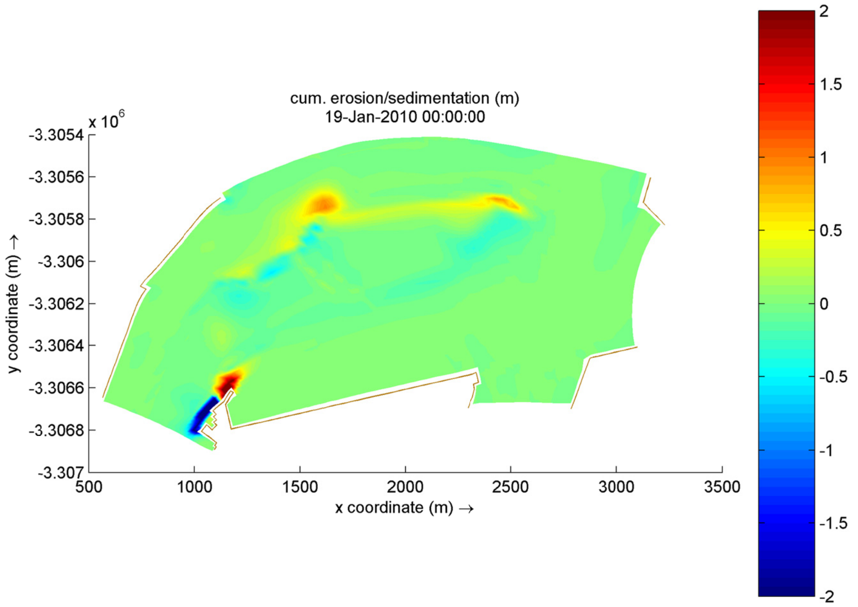

Figure 2.2.2: Option 3H layout SSW Storm including Sea-Level Rise – Cumulative Erosion (blue) and Sedimentation (red)

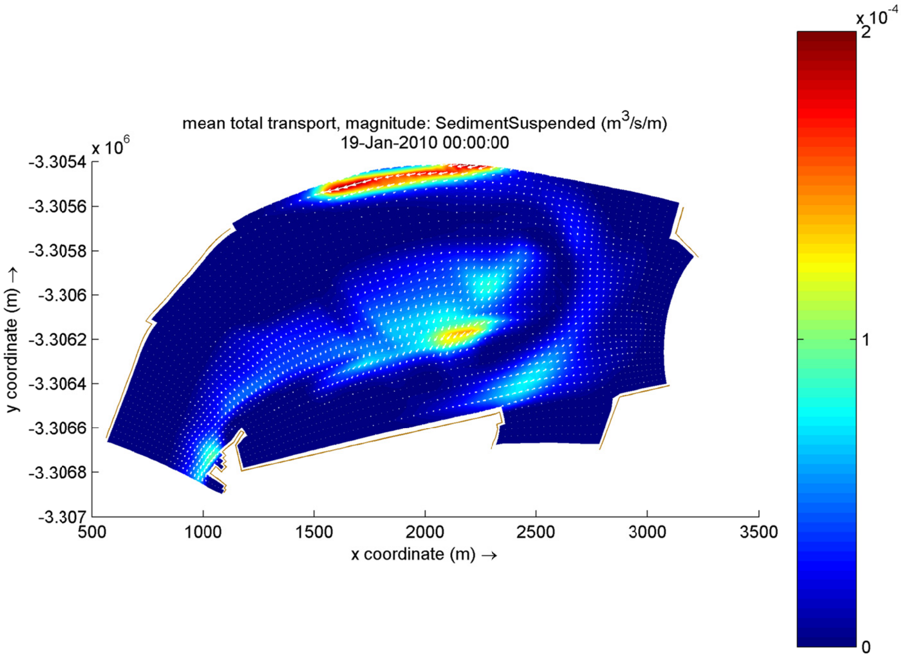

Figure 2.2.3: Option 3H layout NNE Storm including Sea-Level Rise – Mean Total Sediment Transport

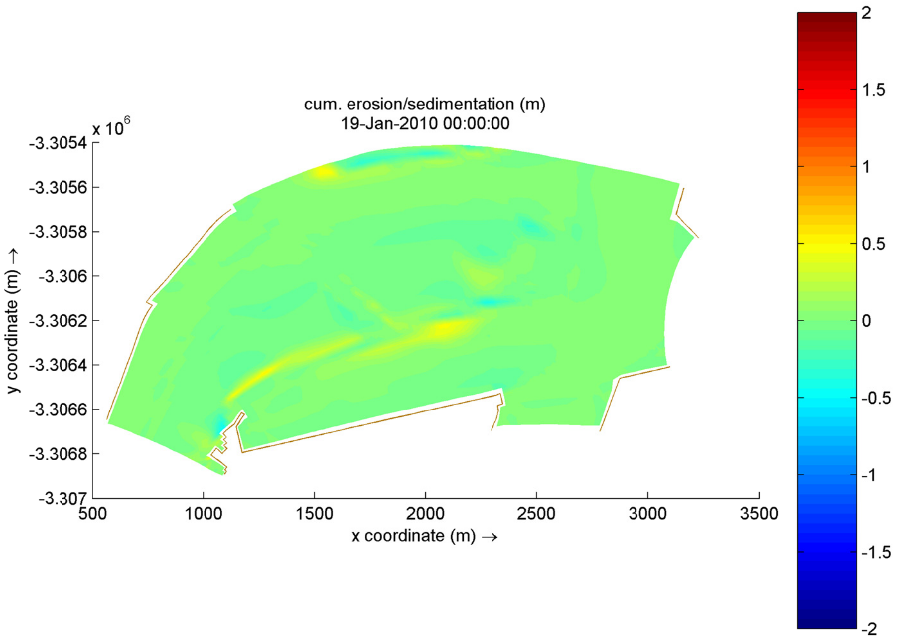

Figure 2.2.4: Option 3H layout NNE Storm including Sea-Level Rise – Cumulative Erosion (blue) and Sedimentation (red)

2.3 Long-term Simulations

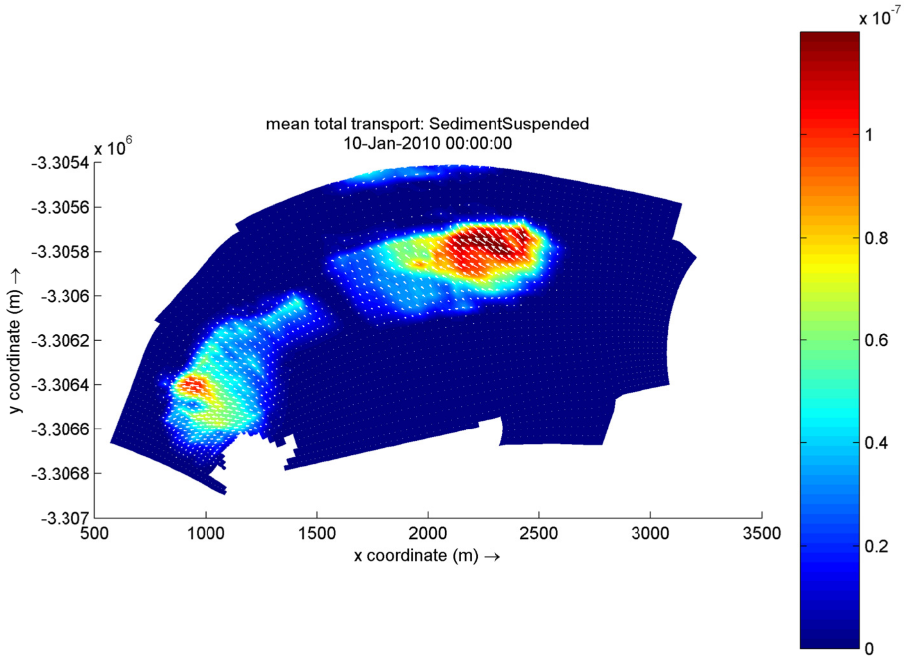

Figure 2.3.1: Current layout Long-term – Mean Total Sediment Transport

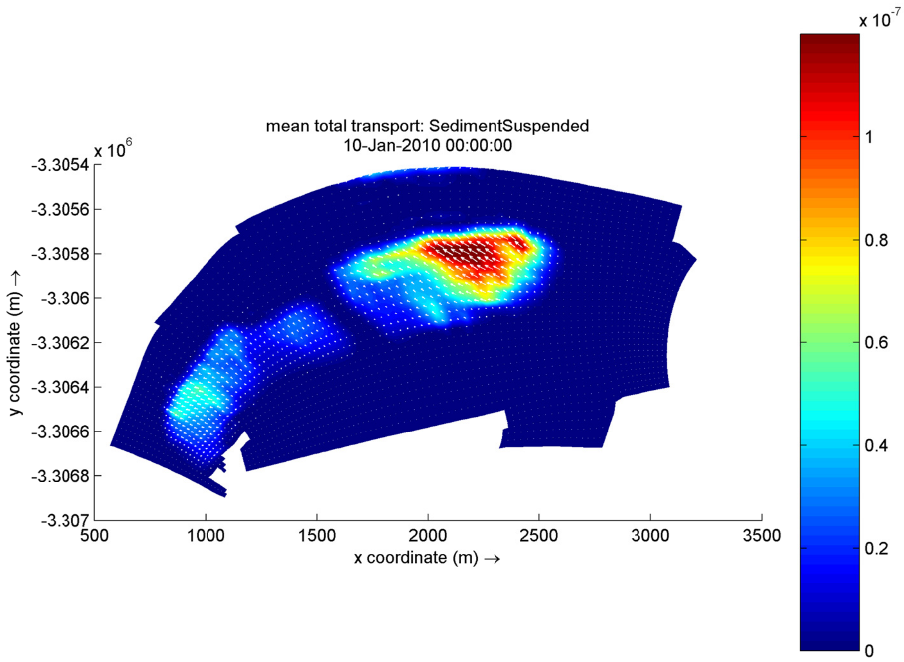

Figure 2.3.2: Option 3H layout Long-term – Mean Total Sediment Transport

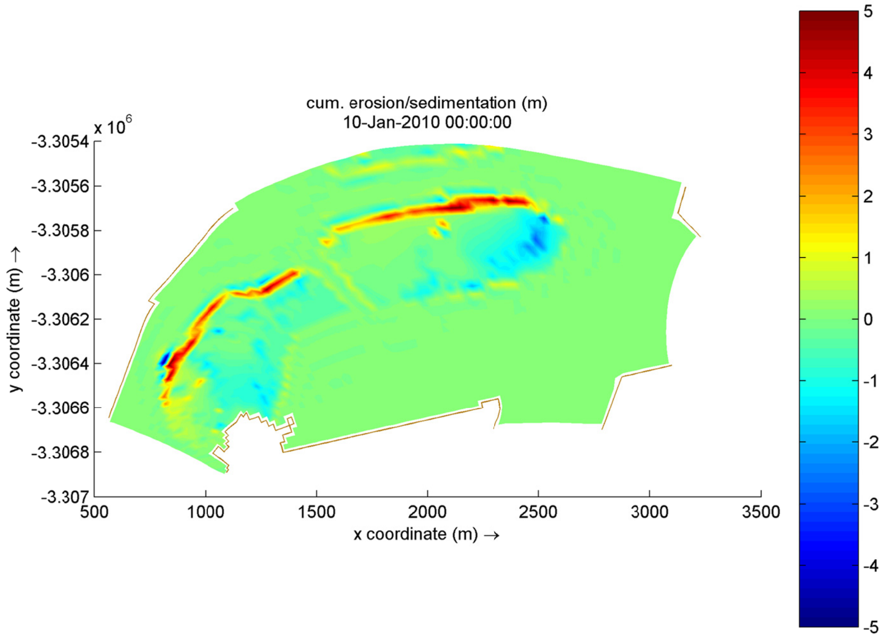

Figure 2.3.3: Current layout Long-term – Cumulative Erosion (blue) and Sedimentation (red)

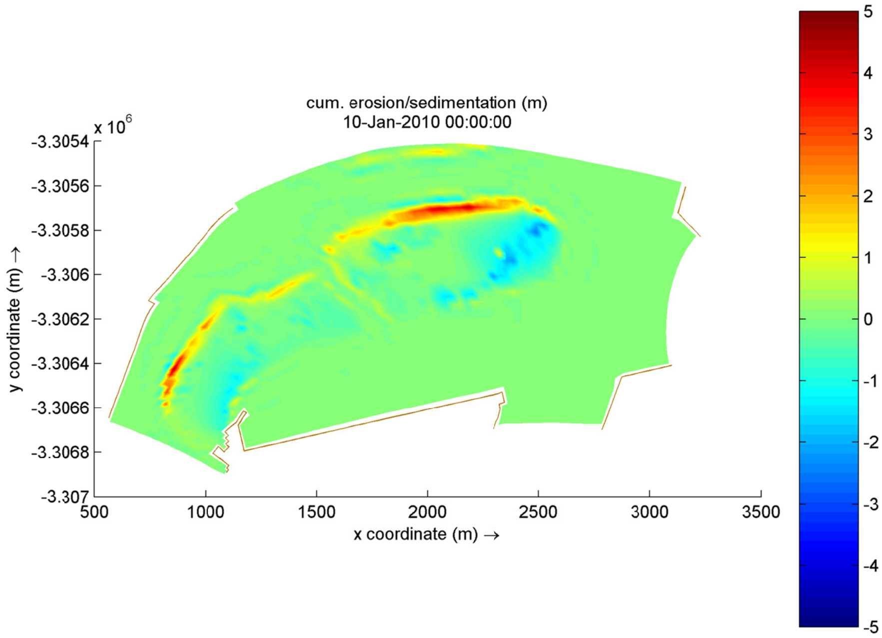

Figure 2.3.4: Option 3H layout Long-term – Cumulative Erosion (blue) and Sedimentation (red)

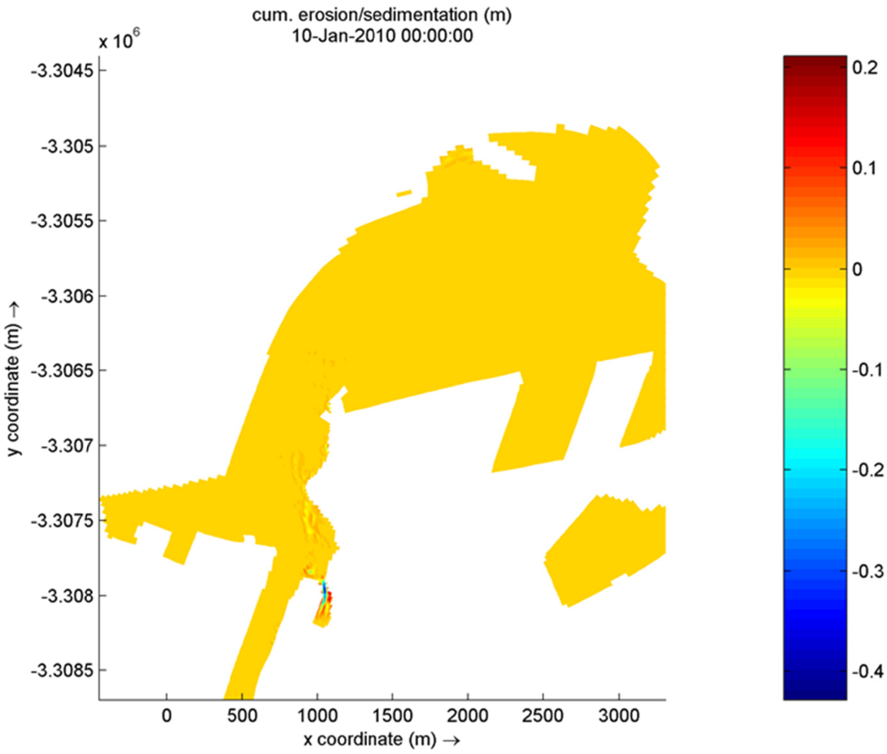

Figure 2.3.5: Option 3H layout Long-term, no wind / wave – Cumulative Erosion (blue) and Sedimentation (red)

2.4 Discussion and conclusions

Reviewing the results, it has been noted that there are only very minor differences between morphological trends for the current and proposed arrangements.

During the SSW storm event, increased sedimentation has been observed for the post-deepening scenario along the North-Western arm of the return quay at the end of Berth 205. This is a deeper, sheltered area created after placement of the caissons, which allows current velocities to fall. Sedimentation in this area is not deemed problematic since it does not encroach on the deepened navigational area off Berths 203 to 205.

For the SSW storm simulation including an allowance of 1.339m for sea-level rise and storm surge combined, erosion is evident near the end of berth 205 in the region of the abandoned caisson. This is a small area that might benefit from some form of scour protection in around one hundred years' time, and the current design for that area includes a retaining wall system with associated scour protection.

During the NNE storm event, sedimentation along the Southern slopes of the sandbank has been found to be of similar magnitude compared to the current scenario although spread over a larger area. This may be attributed to the increased area of shallow water subjected to scour by waves. Rates of erosion for both scenarios are of similar magnitudes however.

It is clear that significant maintenance dredging will be required after any storm event of this magnitude, irrespective of the direction of attack or sandbank geometry.

For each of the storm events it may also be observed that there has been very little tendency for sedimentation in the Congella channel, and scour is observed at the Southern end of this channel during the NNE event. There is no evidence of increased scour between Berth 205 end and the Little lagoon area; on the contrary it appears that erosion is reduced in this area when observing results from the long-term simulations.

A storm simulation omitting the effect of wind generated waves has been shown to yield almost zero erosion over the entire port area. (Figure 2.3.5)

Under normal conditions it appears that less erosion occurs over the enlarged sandbank, and there is a general tendency for sedimentation along the Congella channel for both long-term scenarios. It is possible that the larger sandbank might have a breakwater effect, reducing average wave heights and hence the tendency for erosion.

It has been concluded during this study that the proposed development at Berths 203 to 205 and the associated extension of the central sandbank, will have a negligible effect on the hydrodynamics of Durban Bay. Erosional and depositional trends are largely dictated by wind and wind generated waves in shallow water. Maintenance dredging as currently performed will be unaffected and if possible, dredged material removed from the toe area of the sandbank should be placed evenly on top of the sandbank, since that is most probably where this material originated from.

3.0 REFERENCES

1 CSIR (2012) Deepening, Lengthening and Widening of Berths 203 to 205, Pier 2, Container Terminal, Port of Durban: Potential Long Term Impacts to Sandbank Habitats, Water and Sediment Quality. CSIR Report Number: CSIR/NRE/ECOS/ER/2012/0038/B

2 ZAA 1370-RPT-028 Design Report – Effects of Climate Change on Engineering Design

3 ZAA 1370-RPT-040 - Extension of Sandbank Engineering Risk Assessment

4 ZAA 1370-RPT-043 - Hydrodynamic Model Setup and Calibration

5 Deltares (2011) Delft3D-FLOW User Manual Version 3.15. Deltares, Delft, The Netherlands.

6 Deltares (2011) Delft3D-WAVE User Manual Version 3.04. Deltares, Delft, The Netherlands.