Part II

Mississippi Barrier Island Restoration

Optimization of closure methods

US Army Corps of Engineers

April 2013
Final

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file : AC8767-101-106
registration number : LW-AF20122340
version : 4.0
classification : Client confidential

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1 INTRODUCTION

1.1 Background

The main goal for the restoration of the barrier islands in the United States Army Corps of Engineers, Mobile District's (USACE) Mississippi Coastal Improvements Program (MsCIP) is to restore the crucial sediment budget, including littoral zone geologic processes around Ship, Horn and Petit Bois islands. The restoration effort seeks to return sediment into the system within the barrier islands to pre-Camille conditions as much as possible given the realities of navigation channel dredging, climate change (sea level rise, increased frequency of storms etc.) and other anthropogenic activities. Restoring the Mississippi barrier islands to a condition similar to the natural system that functioned before human intervention (defined as Pre-Camille conditions) offers the best opportunity to ensure the long-term viability of these islands.

The restoration of Ship Island will be constructed in four phases under separate contracts. Currently the bid documents for the first construction phase, which is defined as the initial closure of Camille Cut, are being prepared. The construction activities for Phase 1 are expected to start in August-September 2013 and will last one year.

In 2011-2012 the CH2M HILL HILL/Royal HaskoningDHV/Deltares consortium executed extensive hydrodynamic and morphological analyses in order to provide detailed information on sediment budget on the Mississippi Coastal Cell (MCC) and to assess the effect of the restored Ship Island on the surroundings [1]. In order to provide more detailed information on the hydrodynamics and morphological processes during Phase 1 construction of the Camille Cut closure, additional analysis was requested by the USACE. This additional information will help USACE and the project contractors to identify potential obstacles and reduce the overall risk profile of the project which could lead to lower project costs.

1.2 Objective of the study

The main objective of this study was to identify and quantify the construction risks associated with the construction of the sand fill closure of Camille cut. The study intends to inform both USACE and the project contractors on potential sand losses, the behavior of the sand fill under normal and storm conditions, and about the extent of turbidity in the surrounding waters (filling plume) in an open fill condition.

The main risks involved in designing and constructing the closure are:

- How much sand will be needed for the closure and what amount will be lost during construction as a result of natural processes? Will the sand be lost outside the designed profile?
- During critical construction phase, in extreme cases, fill erosion might exceed fill production capacity and additional measures might be required to limit sand losses and avoid progress delays.

Four tasks were defined for this study:

Task 12.1: Optimization of the profile design for the restored Ship Island fill
Task 12.2: Estimation of sand losses during construction of the Ship Island fill
Task 12.3: Identification of protection measures to minimize turbidity during construction
Task 12.4: Design Review Workshop

In these tasks, the following key questions are answered:

- What are the expected losses from the final construction template?
- Is the production capacity sufficient to close the final gap?
- What is the expected Phase 1 profile width after 1 year?
- What is the impact of using finer sediment for the fill?
- Are the turbidity limits likely to be exceeded?

1.3 Approach

In order to collect information on working experiences within the area and discuss possible construction methods, a workshop with prospective contractors was held on June 14, 2012. The results of that workshop were extensively discussed during the Design Review Workshop on June 15, 2012; these discussions are summarized in Appendix 1 to this report. During the latter workshop, three closure scenarios were defined for assessment in the present study:

- Scenario 1 - Closing from east to west;
- Scenario 2 - Close gully in the west and proceed further from the east;
- Scenario 3 - To be defined upon completion hydrodynamic investigations.

The assessment was based on simulations with process based numerical models for a set of typical climatic conditions and parameters representing the process of construction. Main parameters for this were the (average) characteristics of the fill material, the production cycle and the fill production capacity. These latter parameters were based on a practical approach considering normal construction practices.

To evaluate the designed cross-section alternatives (Task 12.1), the advanced process-based cross-shore model Unibest-TC was used. The estimation of sand losses (Task 12.2) and identification of protection measures to minimize turbidity during construction (Task 12.3) were carried out using the Delft3D model. Based on the model results from the different tasks, sand losses have been estimated, and possible measures to minimize these losses are discussed.

1.4 Team

The CH2MHILL-Royal HaskoningDHV-Deltares management team included David Stejskal (CH2M HILL), Marius Sokolewicz, Winfried Pietersen and Linda Mathies (Royal HaskoningDHV) and Hans de Vroeg and Dirk-Jan Walstra (Deltares). The remaining team members Johan Henrotte and Tijmen Smolders (all RoyalHaskoningDHV), Arjen Luijendijk and Roland Vlijm (all Deltares), focused on the modeling and analysis. The Quality Control was carried out by Robin Morelissen, Dirk-Jan Walstra (both Deltares) and Dick Kevelam (Royal HaskoningDHV).

1.5 Disclaimer

Model simulations have their limitations, and the accuracy of model predictions is subject to these limitations - partly due to the inherent unpredictable (chaotic) behavior of weather systems. Models show trends in morphological processes, and their results should always be interpreted by experienced morphological experts. Even then, due to the nature of the considered processes, predictions are only an approximation of reality and should only be used as an indication of the expected developments in the natural system.

2 METHOD OF CLOSING

This chapter describes the current situation, the design and phases as defined by USACE and the possible scenarios for the initial (Phase 1) closure. An overview of the data provided by USACE for this study can be found in Appendix 2.

2.1 Description of the current situation

An approximately 15,000 feet wide breach, known as Camille Cut, separates East Ship Island from the West Ship Island. The breach is relatively shallow with a bottom level ranging between -5 and -12 feet relative to MSL, with the deepest part, the ebb channel, close to West Ship Island. See Figure 2-1 for the bottom level profile at the axes of the designed fill through the gap.

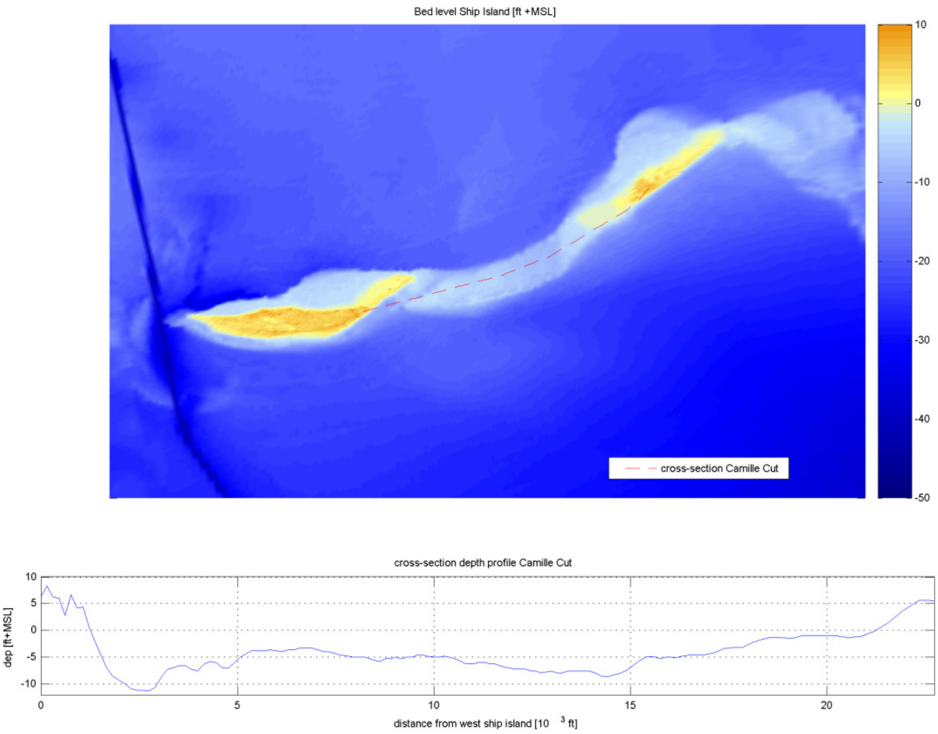


Figure 2-1 Bed level top view and longitudinal section along the Camille Cut [ft relative to MSL]

Local bathymetry varies throughout the year and hurricanes may have a significant impact on the actual bed level. The bathymetry used in this study was the same as in previous phase [1]. The natural phenomena, e.g. the recent Hurricane Isaac, may have caused significant local changes in the bathymetry which are not reflected in the modeling. However, these changes are not expected to have a large impact on the results of the study.

2.2 Ship Island Restoration in Four Phases

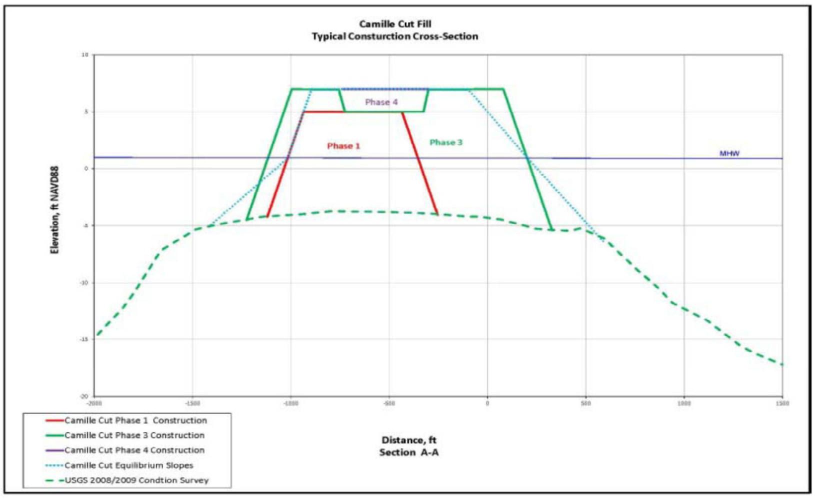


Figure 2-2 Construction phases of Camille Cut closure [USACE]

Figure 2-2 and Table 2-1 provide an overview of the construction phases for a typical cross section.

Phase 1 comprises initial closing of the gap with a 500 ft wide berm up to +5 ft NAVD88. A total amount of approximately 6.1 MCY of sediment will be placed during this first phase. During the following three phases, this initial closure berm will be widened to the full designed width of approximately 1,100 ft and raised to the final level of +7 ft NAVD88 (Phase 3 and 4). Also a large sand fill placement on the south side of East Ship Island will be carried out (Phase 2).

Table 2-1 Overview of construction stages Ship Island restoration

Phase 1:	Initial closure of Camille Cut. Top of berm with an elevation of +5ft NAVD88, crest width of 500ft. Total amount of 6.1 MCY
Phase 2:	Reconstruction of East Ship Island. Top of berm with an elevation of +6 ft NAVDD88, crest width of 1,100 ft. Total amount of 4.8 MCY
Phase 3:	Widen and raise Camille Cut Fill. Top of berm up to elevation of +7ft NAVDD88. Crest of berm of 1,000 ft. total amount of 7.2 MCY
Phase 4:	Cap Camille Cut Fill. This part will consist of a total amount of 1 MCY finer grained sand.

Relatively coarse sand[1] (320 µm) from the Petit Bois Borrow Area (location indicated on Figure 2-3) will be used for most of the core of the berm, while, finer sand from the Ship Island borrow area (Figure 2-3) will be placed on top. Relatively coarse sand (320 µm) from the Pascagoula Harbor Dredged Material placement site known as DA-10 will be used for East Ship Island placement.

[1] The average D50 of the Petit Bois Borrow Area is 320 µm. The average D50 based on the borrow area that will be used for phase 1 is 330 µm. In the modeling, 300 µm has been used as a conservative approximation.

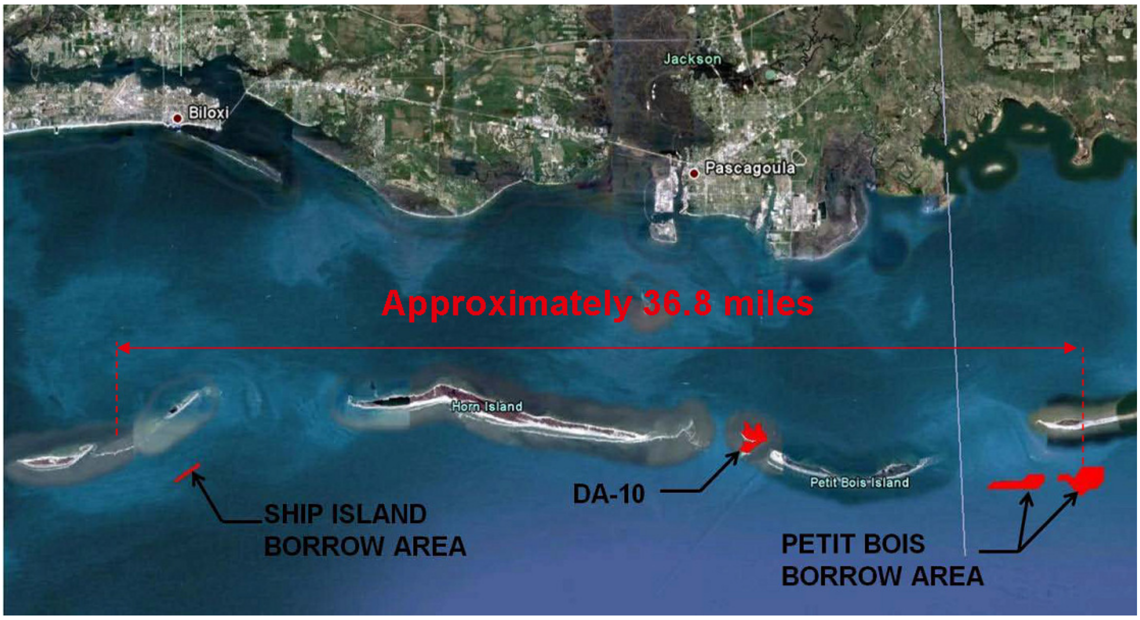


Figure 2-3 Overview of project area and locations borrow areas

This study focused only on the first phase of the Ship Island restoration: the initial closure. Detailed description of Phase 1 profile is given in Chapter 2.2.1. The final design template (Phase 4) is described in Chapter 2.2.2. Phase 2 and 3 were not considered in this study.

2.2.1 Phase 1 design template

The construction template for Phase 1 of the closures consists of a 500 ft wide crest at +5-ft NAVD88 level with side slopes of 1:12 from top to MSL, and a 1:20 slope from MSL to bottom level.

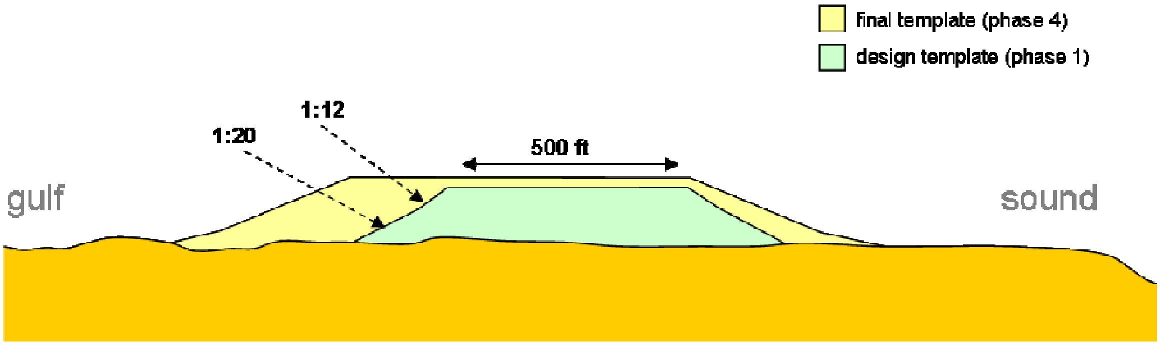


Figure 2-4 Cross-shore profiles for different construction stages [USACE]

Sediment used for the construction of Phase 1 will be dredged from the Petit Bois East Borrow Area. The sediment characteristics from this borrow area are described in Chapter 3.1.

It is noted that the USACE is also considering an alternative Phase 1 template, built with finer grain (D50=200 µm) material, dredged from the Ship Island Borrow Area (also indicated in Figure 2-4).

2.2.2 Final (Phase 4) design template

The final construction template for the sand fill closure (Phase 4) is proposed to be a 1,000 ft wide crest at +7-ft NAVD88 level with side slopes of 1:12 from top to MSL, and a 1:20 slope from MSL to bottom level. A typical cross-section is depicted in Figure 2-4. For Phase 1 of construction, sand losses are defined as the amount of sediments deposited outside this final template. From a contractual point of view, the definition of sand loss for a particular construction phase needs to be clearly defined as does a method of measurement. Sand losses might be interpreted differently by the designers and contractors in particular because of the staged construction under separate contracts.

The 1:12 construction slope from top to MSL, and the 1:20 slope from MSL to bottom level of the fill are based on (USACE) experience with filling projects in the area and is based upon sand with a D50 in the 300 µm range. The slopes are unprotected and will therefore respond to local wind and wave conditions and in particular to storms and hurricanes. In general a combination of a raised water level and larger waves tends to erode the higher part of the fill and deposit the eroded sand at the lower parts. This natural adjustment of fill profile will also occur during the construction period depending on season and frequency of storm during the construction period. A single storm might redistribute the fill considerably. Section 5.1 of this report further elaborates on this effect.

2.3 Closing scenarios

In general terms, flow velocities in the remaining gap are expected to increase due to a reduction of the cross-sectional area until a certain maximum is reached. The final closure gap is a critical construction stage.

The three (alternative) closing scenarios considered in this study were based on the main direction of closing starting from either the East or West, or starting from both sides with a final closure in the middle. These scenarios represent a variety of construction methods which may be preferred by either USACE or the project contractor for cost or other reasons and these scenarios are intended only to provide a basis for this assessment study.

Closure from East to West
In the draft bid documents [3], the USACE chose to close the Camille Cut in the direction from East Ship Island to West Ship Island (Figure 2-5), following the direction of the littoral transport. The logical reasoning used by the USACE is that, prior to Hurricane Katrina, Camille Cut actually nearly closed itself by these natural processes; thus the best closing strategy will be to follow the same direction. This closure method implies that the rather deep (ebb) gully near the eastern tip of the West Ship Island will be closed last (Figure 2-1).

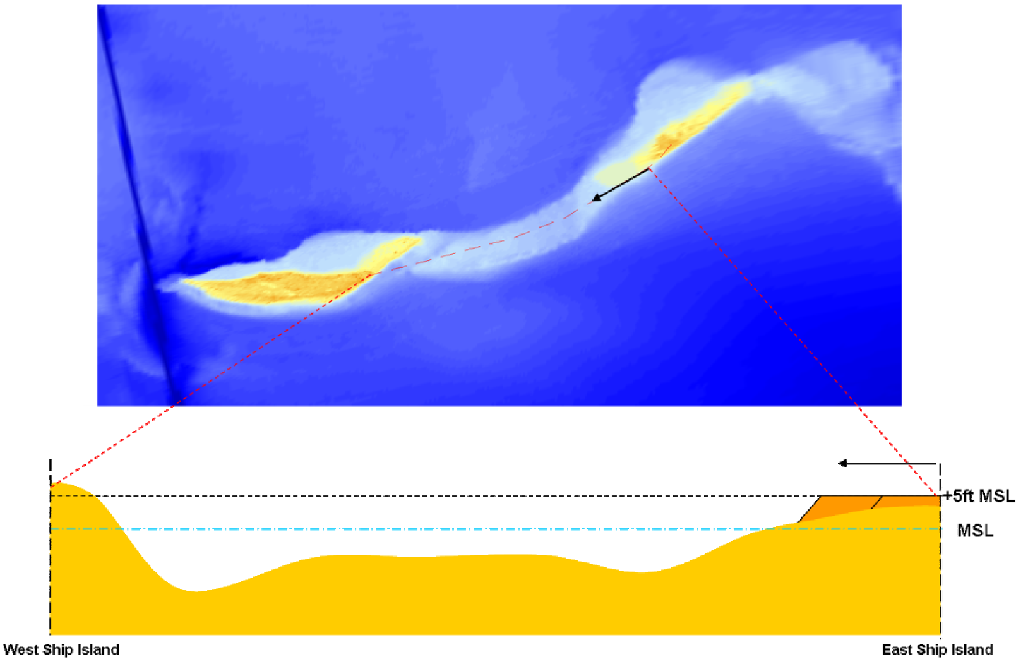


Figure 2-5 Closure of Camille Cut from East to West

Closure from West to East

Another way to close the Camille Cut is to work from West Ship Island to East Ship Island, and close the relatively deep (ebb) gully on the west side first. The end part, near East Ship Island, is relatively shallow.

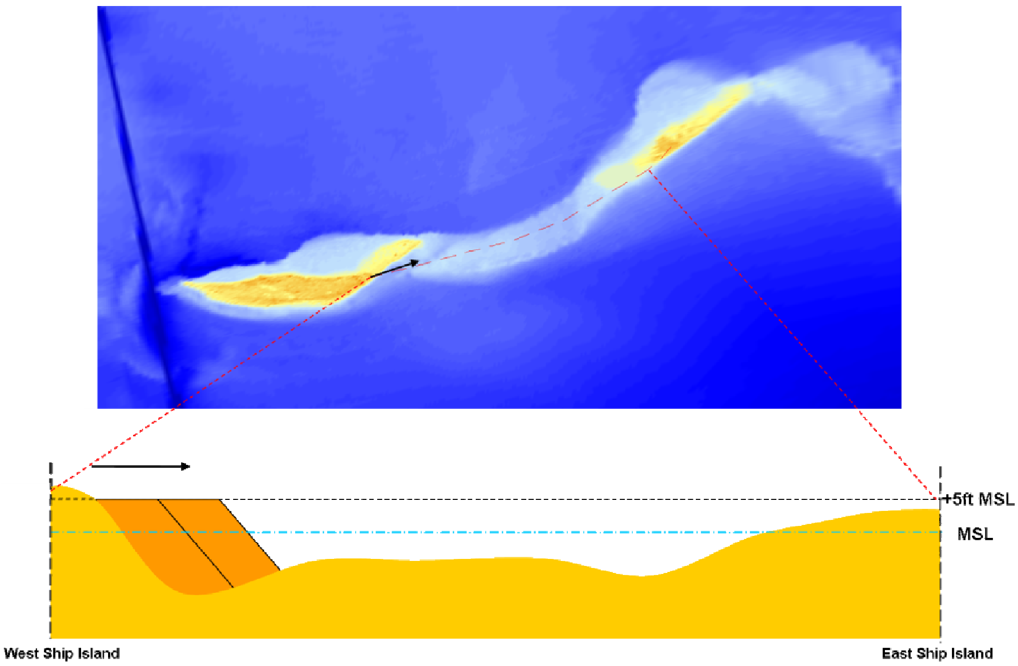


Figure 2-6 Closure of Camille Cut from West to East

Closure from both West and East side

The third scenario which was determined after initial hydrodynamic simulations, was to close the Camille Cut from both sides. The advantage is that the final stage of closure will be in relatively shallow water and will therefore require less fill during this critical phase.

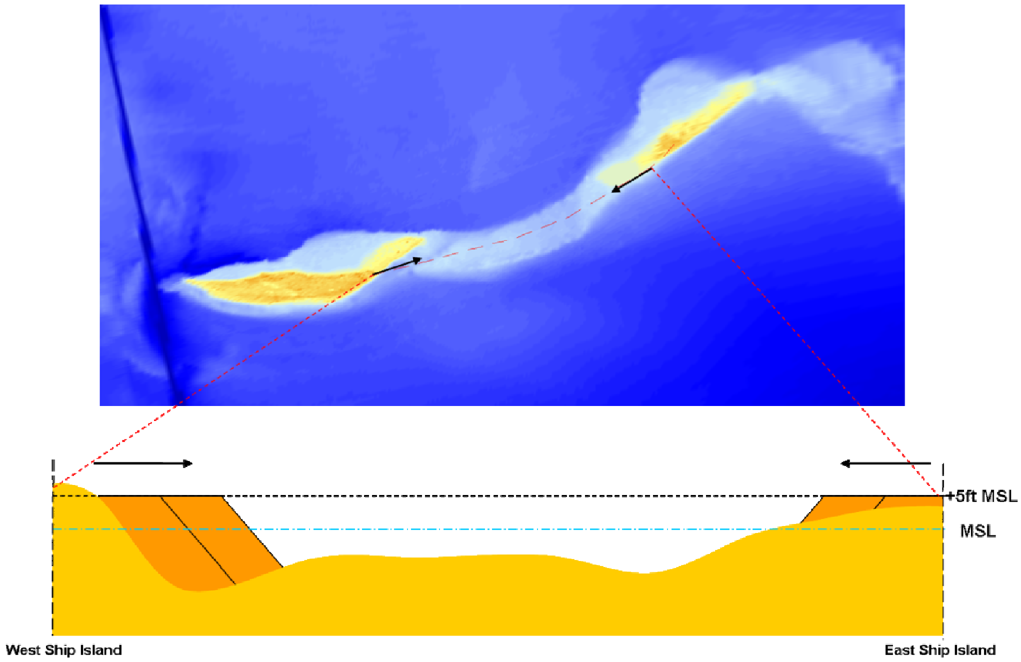


Figure 2-7 Closure of Camille Cut from both West and East side

3 DATA ANALYSIS

This chapter describes analysis of information provided by the USACE (Appendix 2): sediment characteristics, dredging equipment, production rates, and turbidity limits.

3.1 Characteristics of available sediment for construction of Phase 1

Phase 1 will use sediment from the Petit Bois East Borrow Area, located approximately 39 miles from Camille Cut (see Figure 2-3). The characteristics of this borrow material are summarized hereafter assuming that the material will be dredged by a hopper suction dredge.

3.1.1 Petit Bois East Borrow area

The characterization of fill sand is based upon the data of vibra-core samples taken from 37 locations within the borrow area. The total number of available samples was129. Main field and laboratory data were summarized by USACE and made available for this study[2]. Additional information (bore logs and grain size distribution) for most of the samples (not all) was made available as part of the draft bid documents [3]. These bore logs were used to supplement the additional data on grain size distribution.

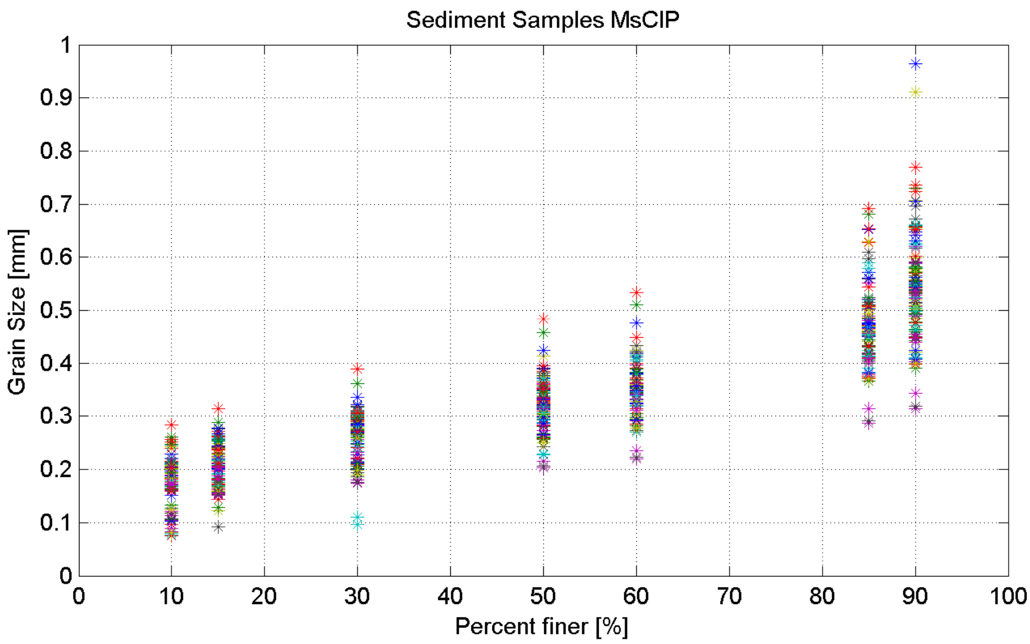


Figure 3-1 Grain size distribution of sediment samples Petit Bois East Borrow

Based on USACE's interpretation, the overall conclusion is as follows:

[2] Data provided in an Excel document *"Petit Bois East Borrow Geotechnical Summary.xlsx"*

- Estimated available sand volume in the borrow area[3] is: 10.7 million CY (8.2 million m^3)
- The average D90 (weighted by volume) is: 0.55 mm
- The average D50 (weighted by volume) is: 0.33 mm
- The average %fines (weighted by volume) is: 7%

In accordance with USA ASTM, fines are defined as the fraction of sediment with a grain size smaller then 0.074 mm (passing sieve #200).

These average values provide a fair interpretation of the characteristics of the total available volume, but do not represent in full the characteristics of an individual or a sequence of individual hopper loads. There will be individual loads with a lesser than average grain size diameter and a higher than average percentage fines depending on the actual layer dredged at a certain point of time. The percentage of fines is a critical factor in determining sand losses and turbidity effects in the surrounding waters during the filling process. To obtain an impression of this variability in the borrow area, and thus in the dredging and filling process, the data was analyzed specifically on this aspect.

Figure 3-2 presents the relation between the percentage of fines and the *Coefficient of Uniformity* (CU) for all available samples. CU is an indication of the grading of the sand and is defined as D60/D10. A low CU indicates a steep grain size distribution and a high CU indicates a more wide distribution of grain sizes and in general a higher percentage of fines (if D50 is about similar).

[3] This volume is based on elevation of borings and associated Thiessen polygon areas. USACE noted (September 2012) that based on additional surveys and average area end method calculations, the volume is 11.7 MCY. This difference has no impact on the analysis in the present study.

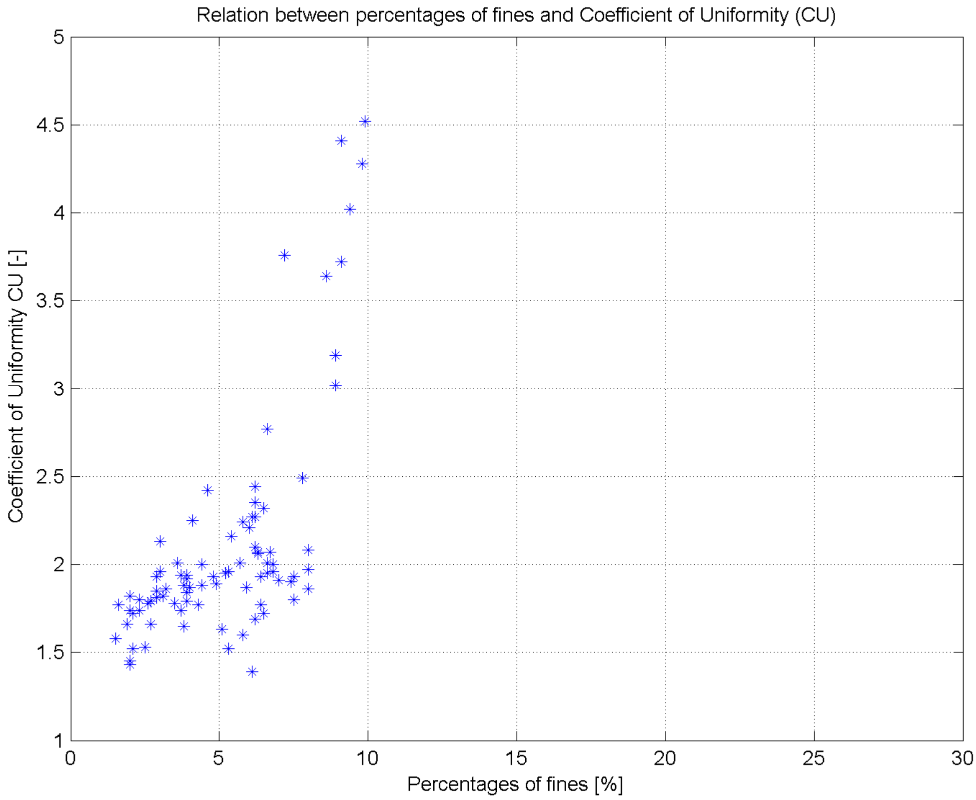


Figure 3-2 Relation between percentages of fines and Coefficient of Uniformity (CU)[4]

Most of the sand has a CU in between 1.5 and 2 and a percentage of fines ranging between 2% and 8%. There are however samples from a layer with somewhat different characteristics, with a higher grading and with percentage of fines within the range of 8-10%. Although not characteristic for the borrow area as a whole, this represents a significant volume. The characteristics of the borrow area for modeling purposes are estimated therefore as follows in Class I and Class II

Class I
- Estimated Volume: 8.6 million CY
- Average D50: 0.33 mm
- Average %fines: 7%

Class II
- Estimated Volume: 2.1 million CY
- Average D50: 0.29 mm
- Average %fines: 9%

The modeling was based on the latter characteristic (class II) with 9% fines thus adopting a worst case scenario in terms of sand losses and turbidity effects. The way these characteristics were schematized in the model is described in Chapter 4.2.2 and Appendix 3.

[4] The analysis was performed using all sample data for which D60 and D10 were available in the set provided by USACE.

It is noted that in the course of modeling work, USACE provided more detailed information from lab-testing of 15 samples from the borrow pit. These samples, selected upon the highest fines content, show a much higher content of very fine fraction than originally assumed in the study. This information can be considered as very conservative. It was used in the present study as a worst-case scenario, as the content of fines in the hopper can be influenced either by avoiding areas with very high content (the amount of sediment available in the pit is larger than required for the Phase 1 operation[5]), or by overflowing (see next chapter).

3.1.2 Effect of hopper overflow on grain size distribution

During the (hydraulic) loading process, a part of the fines will be washed out overboard and there will be some difference between the grain size distribution in the borrow area and in the hopper. Overflowing of fines can purposely be used to improve the grain size distribution of the fill material (less fines and therefore a slightly larger D50). This is most effective for wide grain size distributions, typically for CU above 2 and depending on the overflow time. The process will more or less even out local variations in the borrow area towards the average or even below average. In view of the average grain size distribution, it is assumed that overflowing time will be limited as the hopper will reach its loading mark relatively quickly. Although a few percent of fines will be lost during the process, for this study it was assumed that the characteristics of the fill material on an average will be similar to that of the borrow area. This is a reasonable assumption to find the upper limit of fines in the fill site and to judge the effects of turbidity on the surrounding waters during the fill process.

3.2 Production rates

The production rate is defined as the amount of material which will be placed during a certain time period [cy/s] and an important input parameter for the assessment The main parameters which determine the production rates are the load capacity of the hopper [cy], the duration or time at which this load will be unloaded, and the interval between individual hopper loads (Figure 3-3). These parameters are to a great extent dependent on the used equipment.

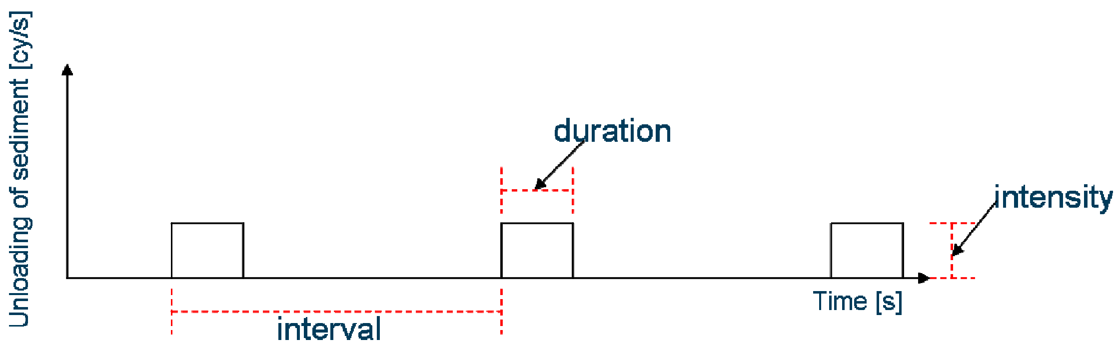


Figure 3-3 Definition sketch of production process to derive production rate

The interval between different loads depends on the sailing time (average sailing speed of the vessel and sailing distance) and the loading time. The duration of the production depends on the total load of the ship

[5] The remaining sand in the borrow area will be utilized in Phase 3 of the restoration project.

and the pumping capacity to unload the ship. The intensity depends on the capacity of the pumping station (time needed to unload the vessel).

Based on information provided by the USACE, the following principles were used for the assessment as a representative base case:

- Construction will be executed with one dredging spread (one hopper);
- A 6000 m^3 hopper, discharging through a 900 mm discharge pipeline
- A net unloading time of 40 minutes
- Time of one cycle of 8 hours (loading time (40 min)+ sailing time(190 min) +discharge time (60 min)+sailing time (190min));
- Hopper sand bulk density: 1700 kg/m^3
- Hopper Load to mark: 10.200 tons

This results in a production of 24,000 CY a day, which means an average closure rate of 70 ft of the Phase 1 profile per day.

Since the USACE also requested to take into account the use of a large commercially available hopper dredge, the following characteristics were used:

- A maximum sand load capacity of approximately 9300 cy (total capacity is approximately 13.500 cy) ;
- An unloading time of 2 hours.

The characteristics of this large hopper dredge were used in the sensitivity analysis in the turbidity modeling (see Chapter 5):

3.3 Turbidity standards

During sand placement, fine material is proposed to be spread out into the area causing turbidity. Turbidity limits which are allowed during construction are defined for the State of Mississippi as 50 Nepthelometric Turbidity Units (NTUs) above the background turbidity at 750 ft from the discharge point. The modeling results are based on TSS, not NTU. In order to develop a correlation between TSS-NTU, the USACE prepared a sediment TSS-NTU regression relation is shown below (Figure 3-4) based on field measurements. Following these results, the critical turbidity level of 50 NTU above the background level corresponds to a TSS concentration of 0.087 g/l.

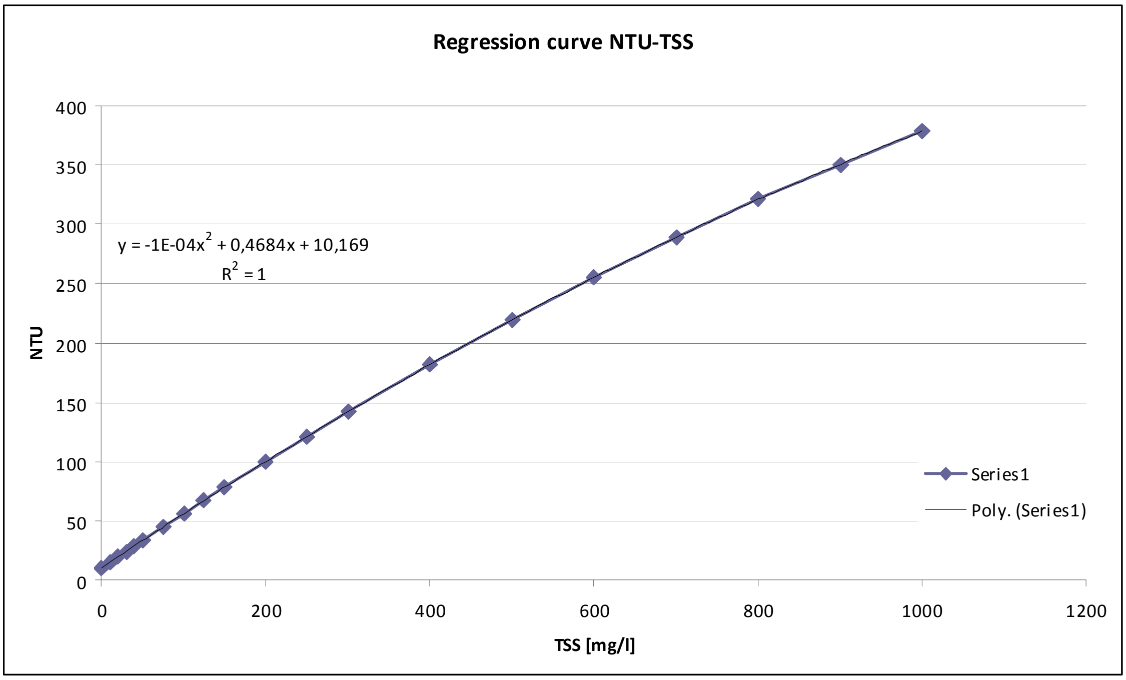


Figure 3-4 Conversion NTU to TSS [USACE]

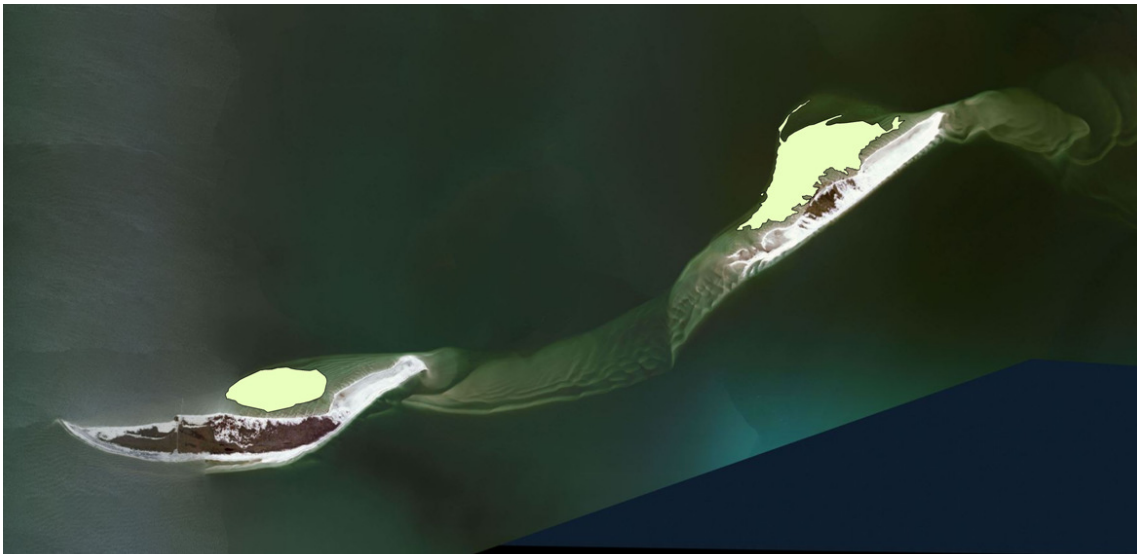


Figure 3-5 Indication of sea grass areas near Ship Island [USACE]

Critical areas with sea grass are situated north of East Ship Island and north of West Ship Island (Figure 3-5). These are protected areas and therefore the amount of turbidity in these regions should be limited.

4 APPROACH TO MODELING STUDY

To answer the key questions and provide information on the processes which could be expected during closure, two different types of process-based models were used during this study. This chapter gives a brief description of the two models, the approach which is applied, and the main choices which were made in the modeling approach.

4.1 Modeling of cross-shore profile development

In order to determine to what extent the evolved cross-shore Phase 1 profile exceeds the final (Phase 4) profile, morphological cross-shore computations were executed by using the Unibest-TC model. Unibest-TC is a process-based numerical model which computes the cross-shore profile development due to water level variations, wind, waves and currents. The intent of the analysis was to determine if the Phase 1 equilibrium profile will extend beyond the final (Phase 4) design profile. If the Phase 1 profile extends beyond the final design profile, the material will be considered lost from the construction template and will have to be replaced during phases 3 & 4.

Schematization of cross-shore profile

A typical cross-shore profile along the fill was selected. The schematized fill has a slope of 1:20 below MSL and a steeper slope of 1:12 near the crest. The crest width is 500 ft (152.4 meters). The slope at the Gulf side is the same as the slope at the Sound side (Figure 4-1).

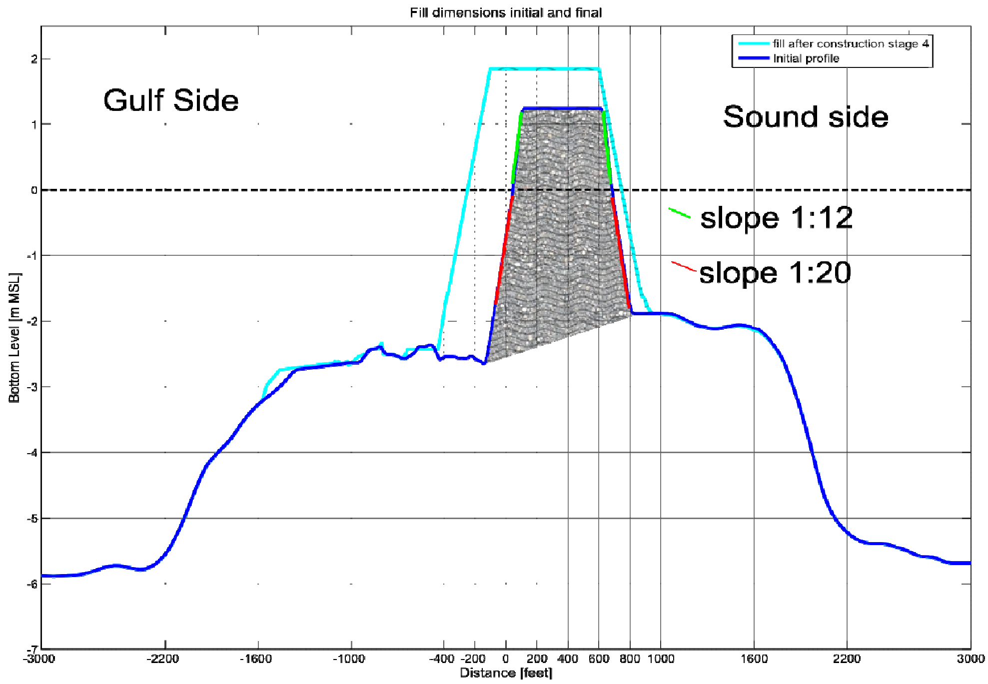


Figure 4-1: Cross section of the fill at Camille Cut. Profile as used in the Unibest-TC model.

Wave conditions

For the Gulf side the annual wave climate which was derived during the previous modeling study [1] was used. The conditions are shown in detail in Appendix 3.

The response of a cross-shore profile is sensitive both to the magnitude of wave conditions and to the order in which individual wave conditions occur. Therefore a sensitivity analysis was carried out by varying the wave sequence in which they occur in the scatter table representing the wave climate. In order to determine wide range of possible wave sequences, the wave conditions from Appendix 3 were ordered in four different sequences:

- wave conditions are sorted randomly (wave sequence 1 and wave sequence 2);
- wave conditions are sorted from highest to lowest significant wave heights (wave sequence 3) and
- wave conditions are sorted from lowest to highest significant wave heights (wave sequence 4).

For the Sound side, the waves were hind-casted on the basis of wind data from the meteorological stations Gulfport and Gulfport Outer Range. On the basis of the wind speed and fetch length in the Sound, the waves near Ship Island were computed with the Bretschneider formula. This resulted in a time series for the near-shore wave conditions at the Sound side of West Ship Island as presented in Appendix 3.

Since only waves directed from the North-northwest or Northeast can attack the fill at the Sound side the Sound side sequence is much shorter then the ones for the Gulf side. Furthermore, all waves with a significant wave height smaller than 0.20 meters were excluded.

Tide

A schematized tide was included in the modeling. A daily variation of the water depth was created using a sinusoidal function which varies between -0.25 and + 0.25 m MSL (diurnal tide).

Sediment grain sizes

The sediment properties were varied. For this study two different grain sizes were used:

- fine sediment: D50 of 210 µm, D90 of 280µm and DSS of 170µm
- coarse sediment: D50 of 300 µm[6], D90 of.440 µm and DSS 0f 230 µm.

4.2 Modeling approach of 2D effects

To determine the sediment losses during different stages of closure, 2D computations were executed with the use of the Mississippi Coastal Cell (MCC) - Delft3D model [1]. The MCC-model covers 250 km of coastline of the states of Louisiana, Mississippi and Alabama and stretches to 50 km offshore. Grid sizes near Ship Island are in the order of 10x40 meters, suitable for accurately computing the dispersion of suspended sediments and deposition of fines under tidal-, wind- and wave driven currents at distances in the order of 100m-10km.

Prior to the sediment transport and turbidity modeling, which require time-consuming computations, initial hydrodynamic computations were performed. Based on the results of this initial hydrodynamic analysis, the final three closing scenarios and two critical construction stages were selected for the sediment transport and turbidity modeling.

[6] An average D_{50} of 330 µm is available in the Phase 1 borrow area (see section 2.2). However, this is an average value, and therefore finer grain sizes are also be expected in the borrow area. For modeling purposes a D_{50} of 300 µm was used as a conservative approximation.

Next, different (stationary) stages of the fill construction were modeled with the MCC model. The hydrodynamic processes, the sediment transports, sediment losses and turbidity at these fixed stages were studied.

4.2.1 Initial hydrodynamic analysis using the MCC-model

To investigate the effect of different closing strategies and different stages of closure, initial hydrodynamic computations were performed with the use of the MCC model.

The flow patterns through Camille Cut were examined for different stages of closure[7] (0%, 50%, 70% 80% 90% and 95%) for three different closing scenarios:

- *Closure from East to West (*Figure 2-5*)*: this is the default scenario which is selected in the draft tender documents by the USACE [3]. Closure in the westward direction will follow the natural net long-shore transport direction. Final closure will take place at the western part, the relatively deep part of Camille Cut;
- *Closure from West to East (*Figure 2-6*)*: This closure in the eastward direction will first close the gully on the west side of Camille Cut, the final closure will be executed in the (relatively) shallow eastern part;
- *Closure from West and East (*Figure 2-7*)*: The final closure will be executed in the middle of the Camille Cut, in a relative shallow area.

Schematization of closure
During these initial hydrodynamic computations, the closure structure was highly schematized. Use was made of a so called "thin dam" feature, which is one of the possible ways in Delft3D to easily schematize constructions. A thin dam can be described as an infinitely high wall, which only blocks the flows perpendicular to it (i.e. thin dam has no width). For the final sediment transport and turbidity computations, the fill is schematized in detail.

Waves not included
The hydrodynamic analysis was performed by modeling a spring-tide period. At this stage of the modeling, only the effect of the tide was taken into account. Sensitivity simulations have shown that the effect of waves on the hydrodynamics is not significant. To limit the computational time during this screening exercise, the contribution of waves on the hydrodynamics was therefore not included. During the detailed morphological and turbidity modeling, waves were fully taken into account.

Effect of wind
Two wind conditions were included; one condition with wind from the Gulf side, and one condition with wind from the Sound side.

4.2.2 Morphological and Turbidity modeling

After completing the hydrodynamic computations, a limited set of conditions and scenarios was selected (Table 4-1). Both the East to West closure scenario and the closure from both sides (closure in the middle) were examined during this part of the study. Sediment transport in this system is predominately East to West; therefore, the team (USACE and CH2M HILL /RHDHV/Deltares) decided that the East to West

[7] The percentage of closure is defined over a cross section through the Camille Cut which intersects the existing islands at MSL, and is expressed in the width of the open section compared to the total width of the Cut. The percentage of closure in this approach is not related to the cross-sectional area.

closure scenario was the most practical since it would utilize the natural transport patterns during closure. Also, the magnitudes of the velocities of the East to West vs. West to East closure scenarios were similar. For these reasons, the “closure from West to East” scenario was not carried forward for further evaluation (see also 5.2). Instead of the “closure from West to East” scenario the team decided to examine the two selected scenarios (East to West and closure from both sides) with a finer sediment grain size. These scenarios were computed with the morphological model, which accounts for waves, wind and tide.

Table 4-1 Overview closure scenarios simulations

Scenario	Scenario	Sediment Grain Size	Stage of closure
S01	Closure from East to West	300 µm	70%
			90%
S02	Closure from West and East	300 µm	70 %
			90%
S03a	Closure from East to West	210 µm	70%
			90%
S03b	Closure from West and East	210 µm	70%
			90%

In addition to the above-described scenarios, a sensitivity analysis was performed where the model and environmental parameters, which the model outcomes are most sensitive, were varied. In the table below an overview is given of the parameters which were varied in the simulations.

Table 4-2 Overview sensitivity analysis simulations

Run	Description
1	Base case simulation, 70% closure East to West
2	Wind/waves from Sound
3	Storm condition
4	Re-suspension of fine sediments
5	90% closing scenario
6	Different sediment distribution i.e. 13% fines
7	a large commercially available hopper dredge, with a larger capacity (increase in discharged volumes and different pump capacity)
8	Reduced fall velocity (75 % of w_s)

Bed level schematization

In contrast with the aforementioned initial hydrodynamic computations, the closure scenarios were schematized more accurately for the morphological and turbidity computations. The fill was schematized in the actual bathymetry. In total four bathymetries, consisting of two scenarios and two stages of closure, were constructed (Figure 4-2). The reference bathymetry used in this study was based on the bathymetry which was used in the 2012-modeling study [1].

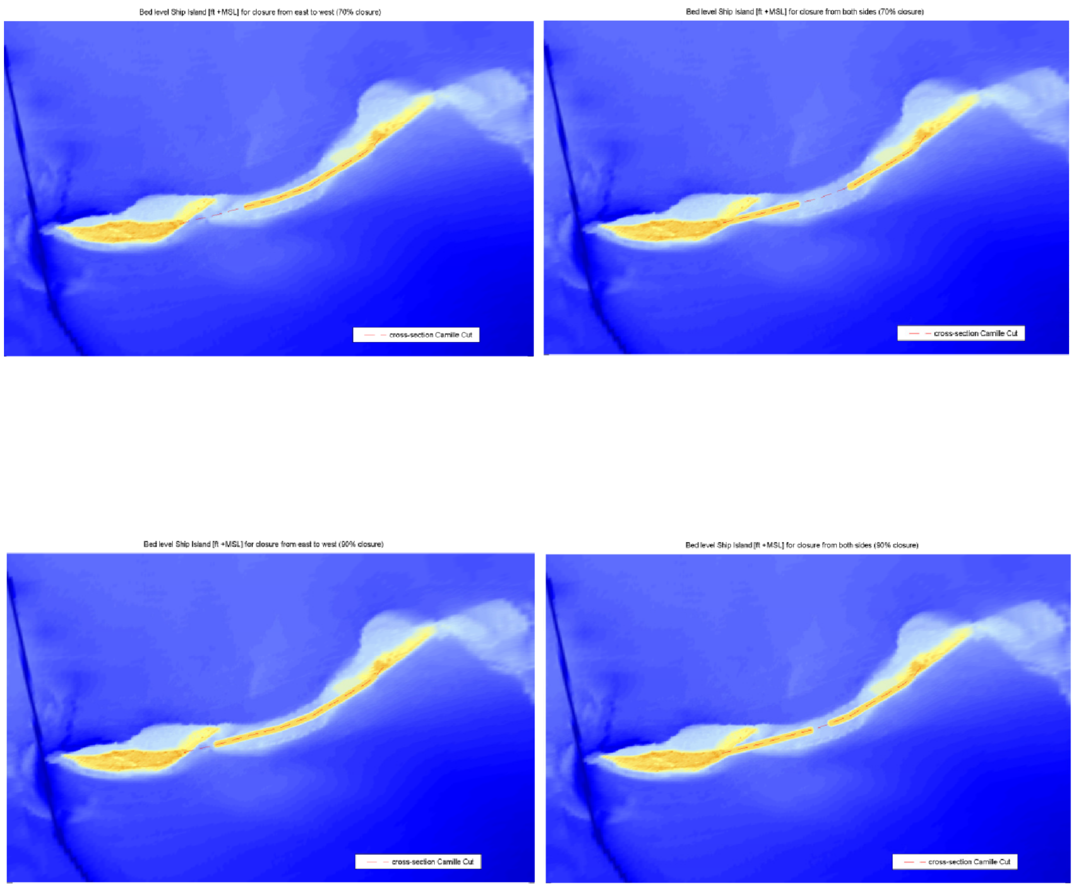


Figure 4-2 Bathymetry closing scenario S01 (left) and S02 (right) for 70% (upper panel) and 90% (lower panel) closure

Hydrodynamic background conditions

A period of two weeks, covering a spring-neap tidal cycle with a maximum range of 0.8m (see Figure 4-3), was simulated.

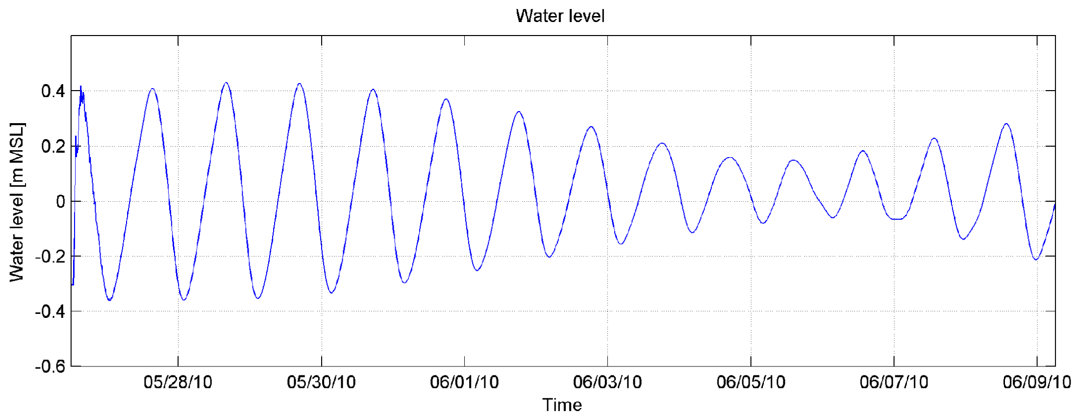


Figure 4-3 Water levels during simulated spring-neap tidal cycle in the vicinity of the Ship Island Fill

Selection of representative wind- and wave conditions

In the 2012 modeling study [1] the annual wave climate was schematized by 165 conditions. From these 165, two representative average conditions were selected:

- one condition (cond041) from the Sound side - a wind/wave condition from the northeastern direction: an average wave condition (Hs=0.6, Tp=3s U=7.6 m/s);
- one condition (cond049) from the Gulf side - a wind/wave condition from the southeastern direction. (Hs=1m, Tp=6.7s U=6.8m/s)

The boundary conditions for the MCC model were based on the runs which were executed in the 2012 study [1]. For the sensitivity analysis a more severe southern storm (cond129: Hs=2.5m, Tp=8.2s, U=11.9m/s) was also simulated.

Implementation of dredging activities

To study the effect of dredging activities, the discharge option in Delft3D-FLOW was used. Considering the relatively shallow depths, high current velocities, and the grid sizes (10x40 m) in the vicinity of the Ship Island fill, the nearfield behavior of dredging activities was schematized as a depth-averaged discharge. More details are provided in Appendix 4.

For the suspended sediment modeling assessment the three finest sediment classes were considered as coarser sediment rapidly settle and are not expected to contribute to the farfield turbidity levels. For modeling of suspended sediments especially, the sediment fall velocity is important. In Table 4-3 the applied sediment classes and associated fall velocities (w_s) are presented using Van Rijn, 1993 [4].

Table 4-3 Sediment fall velocities

Sediment Classes	D50 (µm)	cohesive/ non cohesive	Ws (mm/s)
Fines 1	50	cohesive	1.972
Fines 2	30	cohesive	0.710
Fines 3	10	cohesive	0.079

The total dredging cycle was 480 minutes, of which 40 minutes is for dumping sediment in the Ship Island Fill (see Chapter 3.2). For the Closure from West and East scenario, two dumping locations are defined (one on each side) with half of the concentrations compared to the East to West scenario, simulating a scenario with two smaller TSHD[8] with half of the hopper volume, compared to the East to West scenario. With the sediment distribution for fine sediments as described in Appendix 4, this resulted in the discharge rates below.

Table 4-4 Sediment distribution Ship Island Fill discharges

Sediment Classes	D50 (µm)	Percentage	Discharge concentration closure from East to West (kg/m^3)	Discharge concentration Closure from West and East (kg/m^3)
Fines 1	50	5%	136.40	68.20
Fines 2	30	3%	81.84	40.92
Fines 3	10	1%	27.28	13.64

[8] TSHD: Trailing Suction Hopper Dredger

5 ANALYSIS OF RESULTS

This chapter describes the results of the analyses of the profile development, erosion in the closure gap, and turbidity distribution.

5.1 Cross-shore profile evolution

Construction of the Phase 1 fill is expected to last approximately 1 year. During this construction period, the cross-shore profile will evolve due to wind, waves and currents. To determine to what extent the evolved cross-shore Phase 1 profile exceeds the footprint of the final (Phase 4) template (i.e. how much sediment will settle outside of this footprint), morphological cross-shore computations were executed by using the Unibest-TC model. The investigations aimed at answering the following questions:

1. How will the Phase 1 profile evolve during the construction period?
2. How much sediment will exceed the final template during the construction period?

Cross-shore profile evolution gulf side
The dimensions of the constructed fill will change due to wave-induced cross-shore sediment transport. For the Gulf side the same wave conditions were used as in the 2012 modeling study [1]. The sequence of the individual conditions in this annual wave climate determines, to an extent, the response of the profile. Therefore four different sequences of the annual wave climate were simulated during this study (see Appendix 3 and Section 4.1 for more details):

- wave conditions are sorted randomly (wave sequence 1 and wave sequence 2);
- wave conditions are sorted from highest to lowest significant wave heights (wave sequence 3) and
- wave conditions are sorted from lowest to highest significant wave heights (wave sequence 4).

The results of the model for wave sequence 1 (random sequence) are shown in Figure 5-1 and can be used as an example to explain how the results of the Unibest-TC model can be interpreted. From Figure 5-1 three trends were derived, 1) the erosion front of the crest, 2) the accretion zone at the tow of the fill, and 3) the adjustment of the bed slope.

In order to study the development of the erosion front the cumulative loss of volume of the crest in time was investigated in detail for wave sequence 1. The results are shown in the upper graph of Figure 5-1. Initially the erosion front increases. After only 50 days the total loss of volume in the crest zone was approximately 30 cubic yards per feet. After 100 days the profile reaches an equilibrium; decreasing the erosion rate of the crest to nearly zero. The total loss of volume in the crest zone after 100 days is approximately 35 cubic yards per feet. From this point the total loss of volume remains relatively constant. However after 150 days, there is a short recovery period present. During the final stage the shape of the crest will still be reworked by the waves. However, there is no significant loss of sand out of the crest zone, indicating that a dynamic equilibrium has been reached. The total loss of sand in the crest zone at this stage varies between approximately 30 cubic yards per feet and 35 cubic yards per feet.

The sand from the erosion zone will settle at the tow of the initial fill, thus causing accretion in this zone. Initially, the increase of volume in the accretion zone is directly proportional to the loss of sand from the crest. However, there is some interaction between the already existing shoal and the fill. Because of this interaction, the total volume of the accretion can be larger then the total eroded volume from the crest zone.

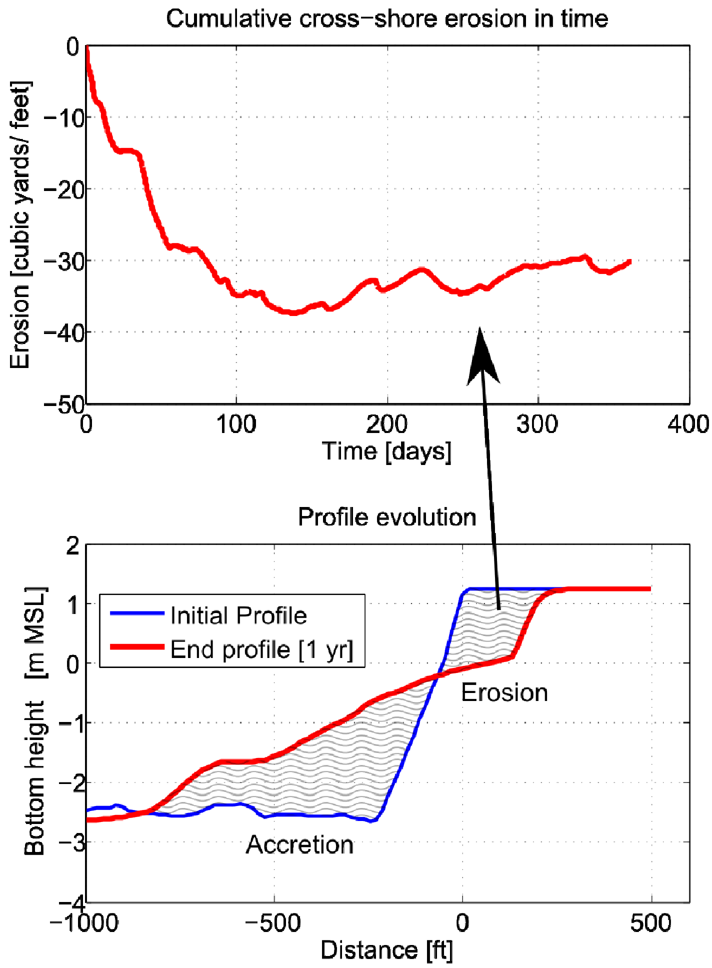


Figure 5-1: Upper graph: Cumulative volume change in time; Erosion at the crest zone. Lower graph: Profile evolution (Gulf side) as result of wave sequence 1

Figure 5-2 shows the evolution profiles at the Gulf side for the different sensitivity runs. Variation in slope and total eroded volume can be observed. The beach slope (up from 0-ft +MSL) for all sensitivity runs is approximately the same; a slope of 1:100. However, the crest erosion width differs from 120 feet to 220 feet, and the resulting slope of the under water profile varies strongly for the different wave sequences, from a 1:100 slope for sequence 1 and sequence 2 (random sequence) to 1:50 for sequence 3 (descending sequence). This gives a bandwidth of the expected profile changes.

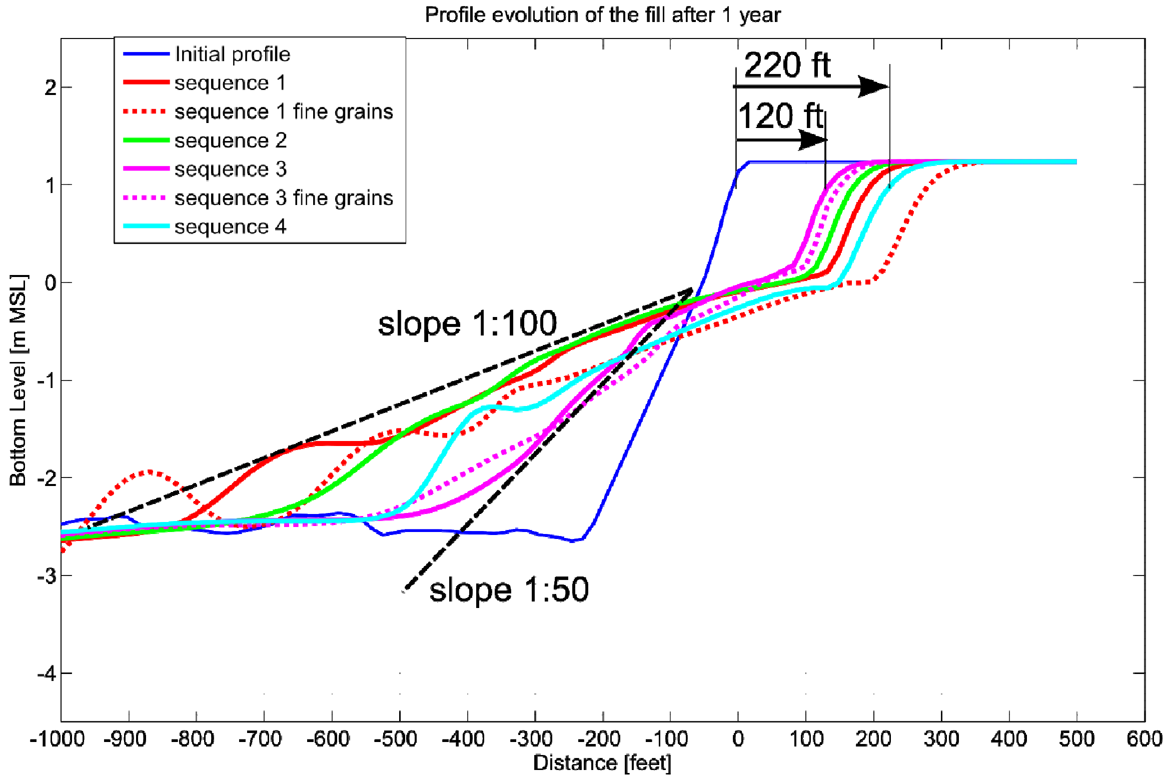


Figure 5-2: Unibest results of profile evolution for different wave sequences at the Gulf Side.

In Figure 5-3 the erosion (in cubic yards per feet) in the crest zone in time for the four wave sequences is shown. The curves for wave sequences 1, 2 and 3 are very similar. After approximately 100 days, the erosion at the crest zone reaches a maximum of 28 to 38 cubic yards per feet. Noteworthy is the recovery of the profile after 150 days which is due to the material being transported back to the crest zone by the moderate waves (natural recovery).

Since the larger significant wave heights of the ascending wave sequence (sequence 4) are at the end of the simulation, the erosion curve is different compared with the curves from wave sequences 1 to 3. However after one year the erosion reaches a maximum of 39 cubic yards per feet, which is similar to the other sequences.

Clearly, the profile evolution depends on the sequencing of the imposed wave conditions. Larger waves will erode the crest and the material will settle along the tow of the fill, making the overall slope gentler. The moderate waves will also rework the slope. However, the smaller waves with longer periods tend to transport some of the material back to the crest zone, causing beach accretion. For steep slopes the recovery during low energy waves is reduced. By first imposing an ascending wave forcing the onshore recovery is therefore probably under-estimated (see also Southgate, 1995 [5])

As expected the total erosion of the crest after one year is larger for the fine grain size. This is shown in Figure 5-2 (dashed curves) for wave sequence 1 and 3. The grain size of the fill material also affects the steepness of the slope. Furthermore, beaches with coarser sediments tend to be steeper. As could be expected, the variability in the model results was also larger with a finer material fill with the calculated crest erosion varying between 200 and 300 ft. On the considered time scales the underwater slope was less affected by the use of fine grain sand. The slope varied between 1:60 and 1:100. The sand eroded from the upper part of the profile was deposited in its lower part. However, a majority of the eroded sand remained within the final template.

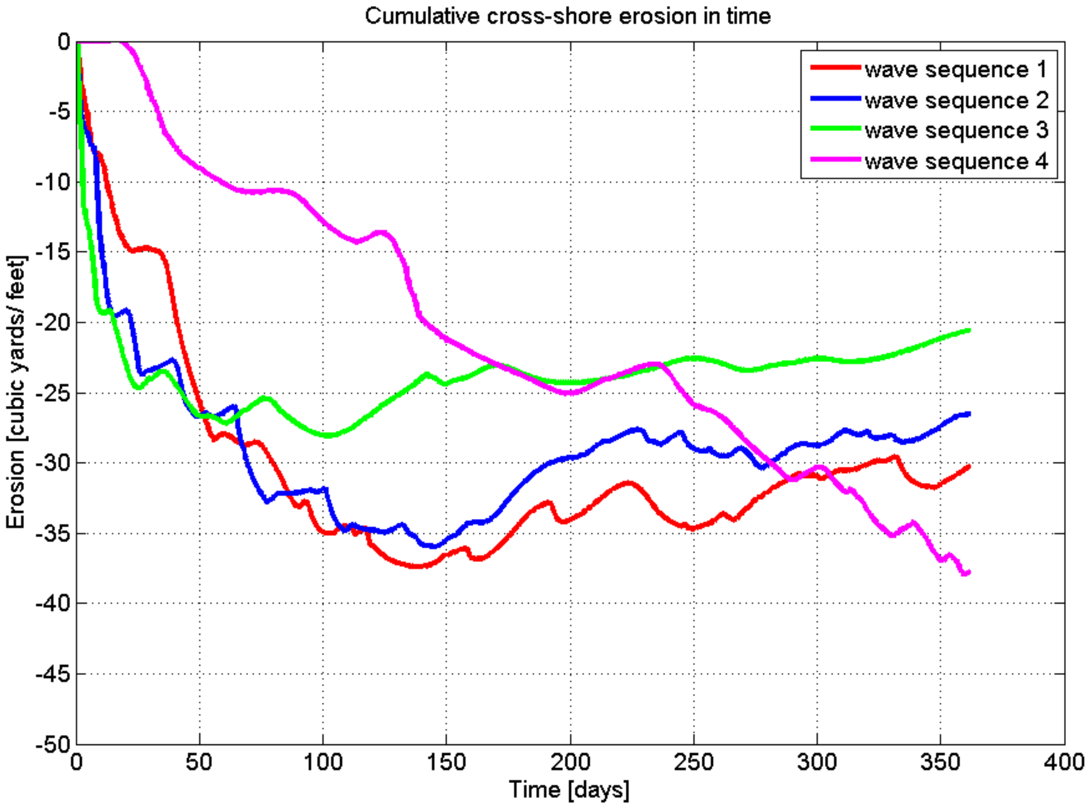


Figure 5-3: Cumulative volume change in the crest zone in time, for four different sequences.

In order to check the consistency of the equilibrium cross-shore profiles of the Unibest-TC model, the results from this study were compared with the empirical Bruun/Dean profile ($h=Ax^m$; Dean (1977) [6,7]).

In Figure 5-4 the cross-shore profile evolution result of wave sequence 3 and 4 were compared with the empirical Dean profile and with an actual cross-shore profile at West Ship Island. The Dean profile and the West Ship Island profile were, except for the beach area, very similar. The cross-shore profile resulting from wave sequence 3 calculated with Unibest-TC shows similarities in the slope of the profile between 0 and 500 feet with the empirical Dean profile and the actual West Ship Island profile.

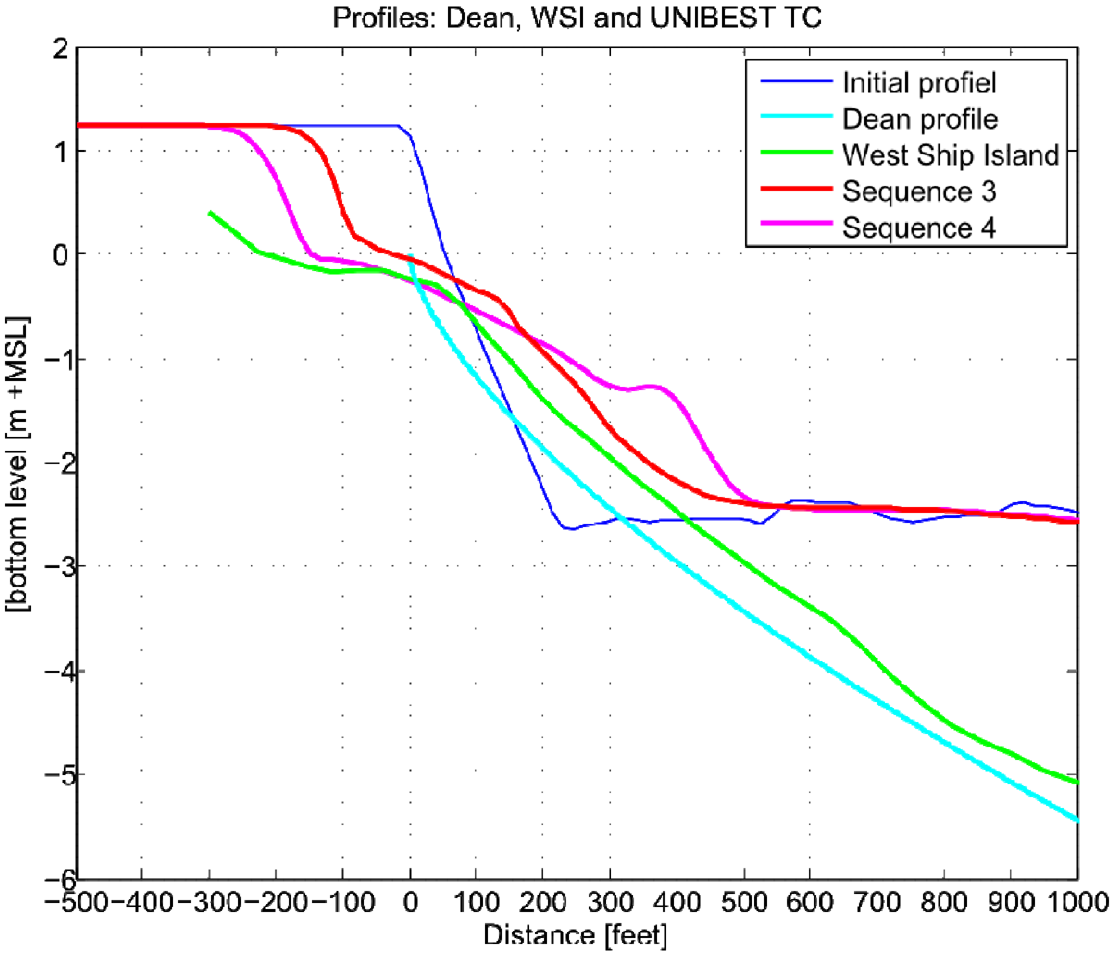


Figure 5-4: Unibest TC results (sequence 3 and sequence 4) compared with empirical Dean profile (light blue) and West Ship Island Beach profile (green).

Sound side

Since only the waves coming from the North-northwest or Northeast can attack the Sound side of the fill, a different wave sequence, which is shorter than the sequences for the Gulf side, was used to model the cross-shore profile evolution of the fill at the Sound side. The assumption was made that this wave sequence is representative for 1 year. Considering the small variability in wave climate on this side of the Ship Island, no sensitivity for the grouping order of wave classes was carried out here.

As can be seen in Figure 5-5 the erosion reached its maximum after 100 days. The maximum erosion is approximately 15 cubic yards per feet. The width of the crest erosion is approximately 120 feet. The slope of the under water profile is 1:33. The evolved slope at the Sound side is steeper than the slope found at the Gulf side (1:50 – 1:100). This is explained by the fact that there are no large waves present in the Mississippi Sound.

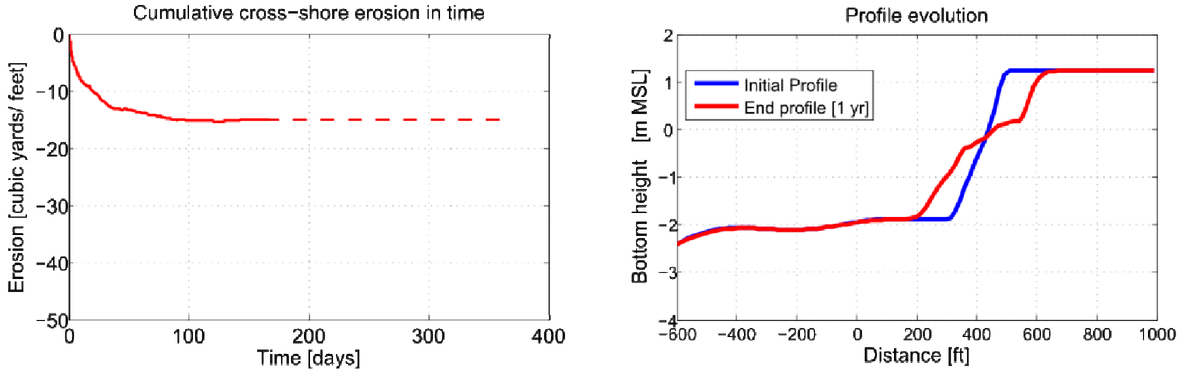


Figure 5-5: Profile evolution Sound side: Cumulative volume change in time (left); Cross-shore profile evolution (right).

Combined (Gulf side and Sound side) profile evolution

The evolved profile after 1 year is shown in Figure 5-6.Two red lines show the expected range of profile deformation. The range analysis was carried out only for the more dynamic Gulf side of the fill, however a certain (smaller) range in the profile deformation at the Sound side is to be expected as well.

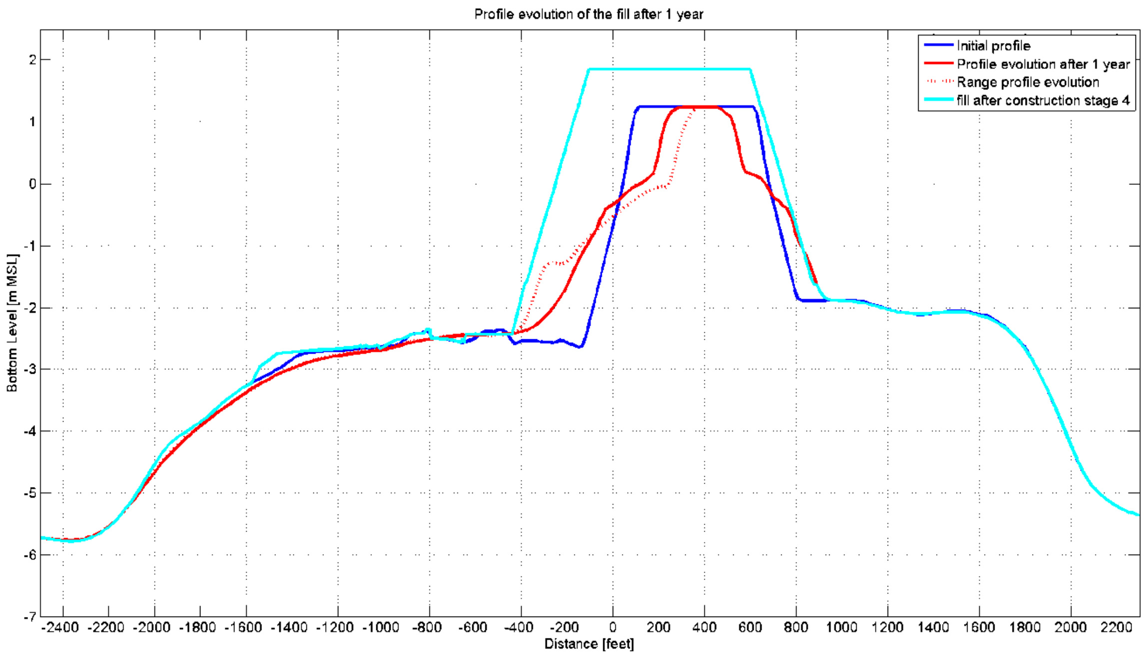


Figure 5-6: Cross-shore evolution of the fill. Left is Gulf side, Right is Sound side. In blue the initial Phase 1 profile, in red the evolution of the cross-shore profile after one year, in cyan the final fill Phase 4 profile.

Conclusions

At the Gulf side the cross-shore evolution profile has a slope between 1:100 and 1:50, where the 1:50 is similar to the slope of the coast of West Ship Island and also to the theoretical Dean profile. The larger waves tend to make a gentler slope. The waves with a long period tend to transport the sediment back towards the fill. The equilibrium slope is thus affected by the larger waves. The erosion at the crest zone is approximately 120 to 220 feet, and the maximum erosion is approximately 40 cubic yards per feet. The time scale for the profile evolution is in the order of 150 days. However, this is strongly dependent of the wave climate and from the timing of closure. If the closure is started during the quiet season, the large erosion could occur later when storms come into the Gulf of Mexico

At the Sound side the calculated final cross-shore profile has a slope of 1:33. The maximum erosion distance at the crest zone is 120 feet. The loss of volume is approximately 15 cubic yards per feet.
The remaining crest width after one year is approximately 200 feet. However, although the erosion rates found with Unibest-TC are considered to be conservative, there is no guarantee that the initial fill will not breach during a heavy storm.

Using fine grain sand for construction results in more erosion from the upper part of the profile. Thus, the evolved profile will be much more susceptible to the variation in wave climate. The erosion of the crest is expected to vary between 100 to 300 feet. The sand eroded from the crest and beach is deposited on the underwater slope which will be slightly milder than with the coarser sand.

According to the model calculations, the evolved profile at the Gulf side of the fill stays within the final construction template, both for the coarse and the fine sediment grain size. At the Sound side, the evolved profile is very close to the northern boundary of the final construction template. It is expected that if the fine grain sand is used for construction, the profile may extend beyond the final construction template at the Sound side, however, this was not examined during this study as discussed earlier.

5.2 Flow patterns through Camille Cut for different closing scenarios

Every tidal cycle a large amount of water will enter and leave the Sound by the inlets between the Barrier Islands with Camille Cut being one of those inlets. With the partial closing of the Camille Cut, the same total amount of water has to enter the Sound through a decreased cross-sectional area. This results in modified discharge volumes through the adjacent inlets and the closure gap.

This section describes the results of the hydrodynamic modeling of three closing scenarios which were initially considered in this study:

1. Closure from East to West;
2. Closure from West to East;
3. Closure from West and East.

Change in hydrodynamics during different stages of closure
Figure 5-7 shows the results of hydrodynamic computations for the East to West closure scenario, at different stages of closure. Results are shown during the maximum ebb currents. In this figure the warm colors represent the high velocities and the cool colors represent the lower velocities.

During the ebb phase the flow is directed in the south to southeastern direction. The depth-averaged flow velocities range from 0.1 to 0.8 m/s. The maximum flow velocities occur in regions where contraction of the current is observed; in the Camille Cut, near the west tip of West Ship Island, and the east tip of East Ship Island. Figure 5-7 shows the changes in flow patterns at different stages of the Camille Cut closure, with the present situation defined as the 0% closure stage. With an increased percentage of closure, the flow velocities in the Camille Cut (and also at both the west tip of West Ship Island and the east tip of East Ship Island) seem to increase slightly, up to about 1.0-1.2 m/s.

Besides the increase of the maximum flow velocities, changes in flow patterns are also observed. One example is the flow pattern near the northern shore of West Ship Island. In the present situation (0% closure), the flow direction near the northern shore of West Ship Island is partly directed westwards and partly eastwards. The point of change in direction is located approximately in the middle of the West Ship Island. With the increase of closure percentage, this point will shift further eastwards, until a totally westward directed flow direction remains. A comparable process could be observed near the East Ship Island.

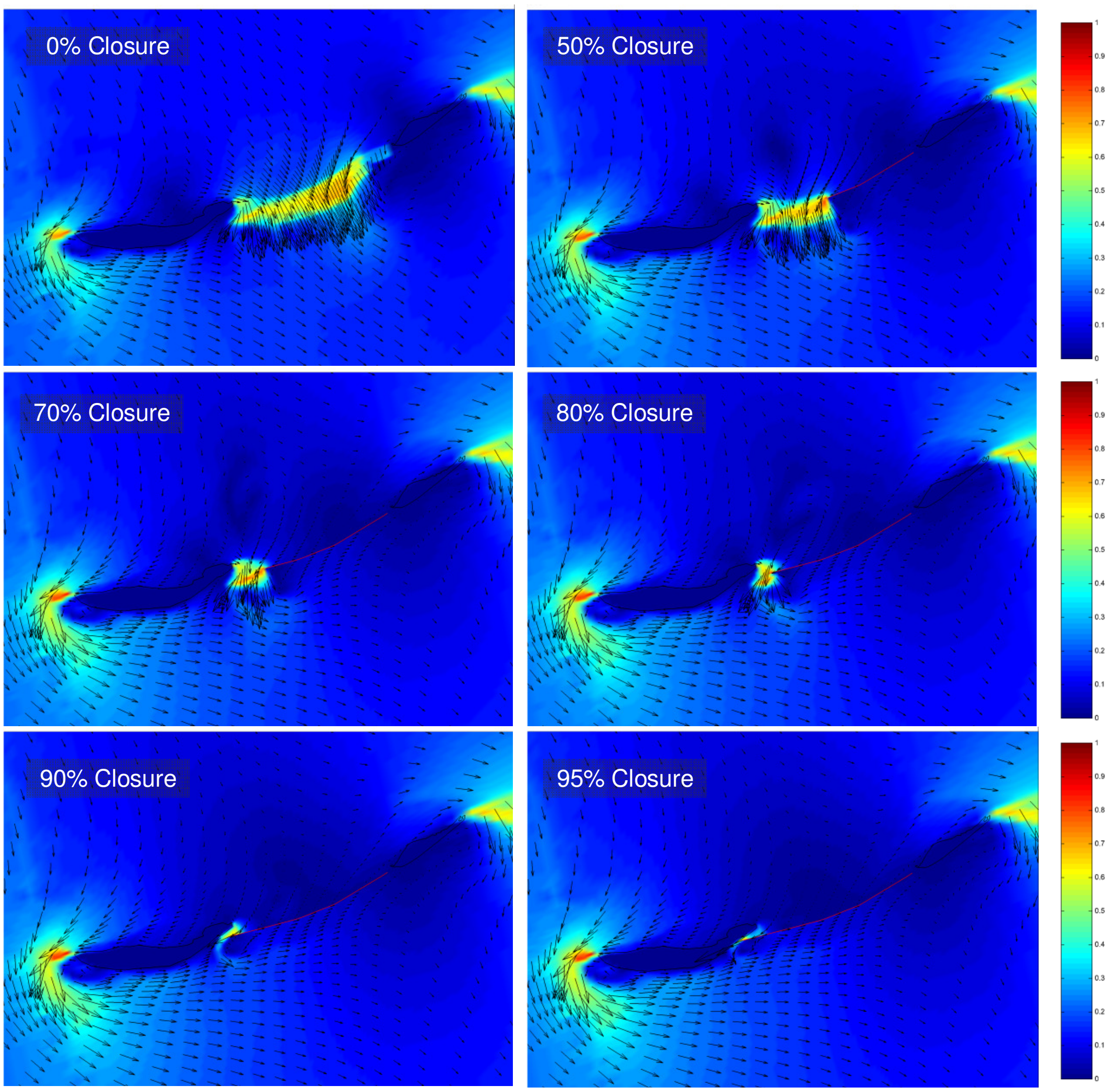


Figure 5-7 Changes in flow patterns through different stages of closure for east to west closure strategy

Comparison of three different closure scenarios

During the closure, the cross-sectional area of the Camille Cut inlet will decrease. Figure 5-8 shows the effect of this decrease in cross-sectional area on the total discharge through Camille Cut for the three different closure scenarios. The maximum discharge through Camille Cut will decrease as the remaining gap width decreases. The decrease in maximum discharge differs for the three different closure strategies.

The “East to West” strategy shows initially lower discharges through the Camille Cut compared with the other two scenarios. From 80% closure until final closure, both the “East to West” and the ”West to East” closure strategies show comparable discharge rates. The flow velocities could however differ in both cases, because the cross-sectional area differs for these both cases (the “East to West” closure ends with the gully, whereas the “West to East” strategy ends with a relative shallow area). By increasing the closing percentage, the total discharge through the remaining gap decreases for all the closing scenarios. However, the discharge rates of the strategy closure from both “West and East” (closure in the middle), remain relatively high for the final closing stages (highest percentages of closure) compared with the other two closure strategies. Higher discharge rates during the final stages of closure could lead to more losses of sediment.

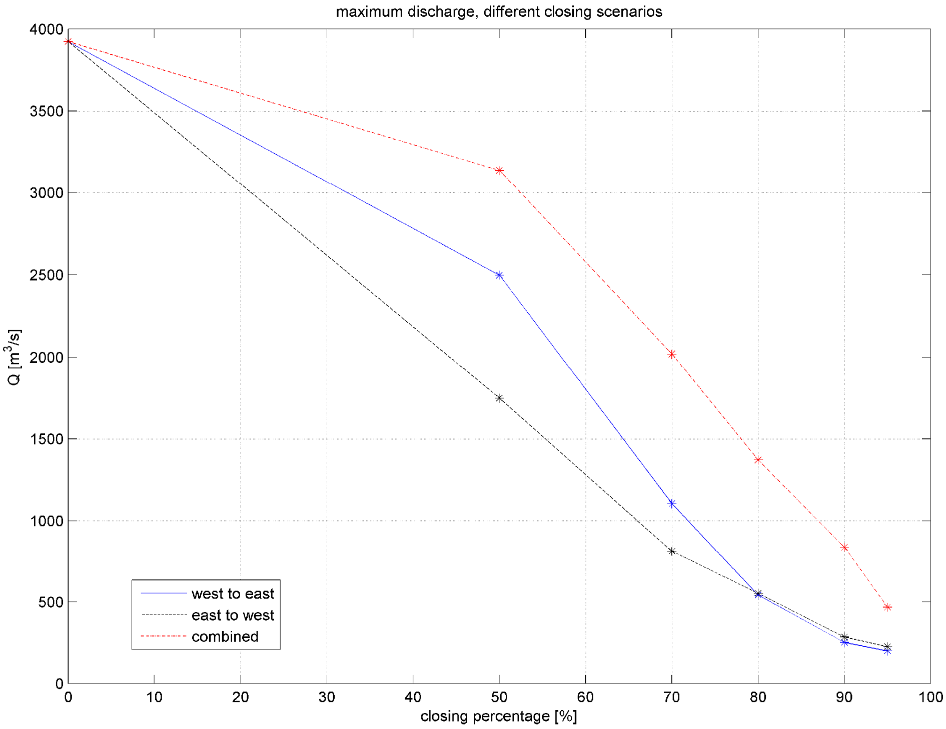


Figure 5-8 Change in maximum discharge through Camille Cut for different stages of closure and different closure strategies

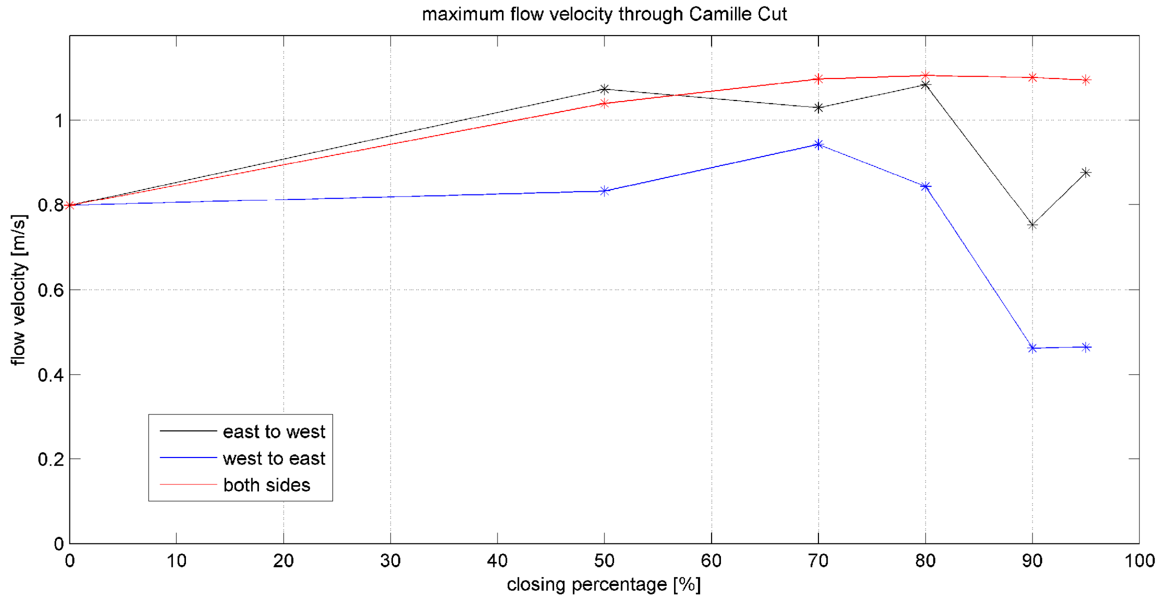


Figure 5-9 Change in maximum flow velocity through Camille Cut for different stages of closure and different closure strategies

The maximum (absolute) depth-averaged flow velocity through the Camille Cut, also changes during different stages of closure (as previously shown in Figure 5-7). Figure 5-9 shows this change in maximum flow velocity for the different closure strategies. Initially, the flow velocities seem to increase for all the three scenarios, up to 50% closure. From the 70% to the 100% closure, changes between the three different closure scenarios were observed. The maximum flow velocities seem to decrease slightly for the "East to West" closure by increase of closure percentage. However, for the "West to East" strategy the velocities intend to drop even more; eventually a maximum of less than 0.5 m/s. The flow velocities for closing strategy from both the east and the west side seem to increase until 1 m/s for the 70% closure stage. This maximum flow velocity seems to continue relatively constant for higher closure percentages. No decrease in flow velocity is observed, which is the case for the other two closing scenarios.

Based on these results, closure from West to East seems to be the most advantageous regarding the flow velocity during the final (and most critical) stages of closure.

The velocities reported in this chapter were derived from simplified modeling of the fill, which is schematized as a screen (a "thin dam"). Furthermore, the model has a certain limited resolution. Locally near the head of the fill higher flow velocity may occur.

Upon results of the hydrodynamic computations, two closure scenarios were selected in consultation with USACE for further investigation:

- East to West (the original USACE scenario)
- Closure from West and East (i.e. closure from both sides)

As already explained in Chapter 4.2.2, the third scenario (closure from West to East) was dropped and replaced by an investigation with a finer grain size.

Two stages of closure for morphological computations

To investigate the effect of the closure strategy on the sediment losses, morphological computations were executed (see Chapter 5.3). For these computations, two stages of closure as shown in Figure 5-10 were selected based on the hydrodynamic computations:

- 70% closure: maximum flow velocity
- 90% closure: representative for the final closure stage.

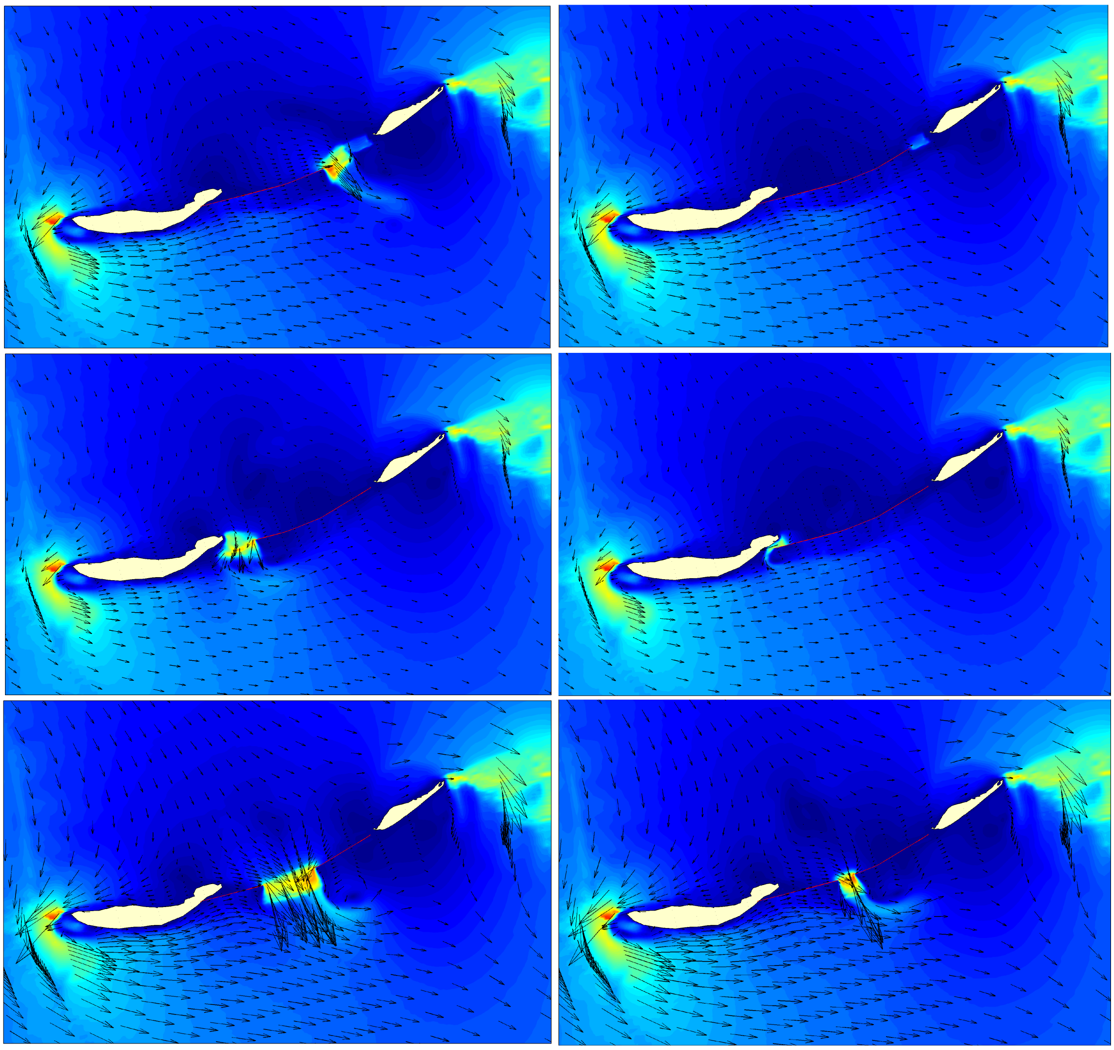


Figure 5-10 Flow patterns at 70% (left) and 90% (right) closure stage for three different closure scenarios, during ebb-flow

5.3 Sediment losses during construction

During the construction of the Phase 1 of the Ship Island restoration project, wind, waves and currents will transport sediment out of the profile. The amount of sediment which is transported out of the profile would normally be defined as “loss during construction”. However, after finishing this first phase of the project, the fill will be widened (and heightened) during the next three phases of the project. Therefore the template which should be used to determine the losses should be the final (Phase 4) template. For different closure scenarios at two different closure stages, the sediment transport rates were simulated using the Delft3D model to get insight in these processes.

With the use of the morphological model, two different stages of closure, 70% and 90%, were examined for three different closing strategies. These three closing scenarios differ from the ones analyzed during the hydrodynamic computations. The following scenarios are defined:

1) Scenario 1 (S01): *Closure from East to West* with coarse grain material from Petit Bois East. This is the basic approach which was proposed by USACE;
2) Scenario 2 (S02): *Closure from West and East* with coarse grain material from Petit Bois East;
3) Scenario 3: the abovementioned scenario 1 (S03a) and 2 (S03b) with finer grain material. USACE has the opportunity to use finer grain material dredged from the Ship Island Borrow area to complete Phase 1 of the closure. The effect of this finer grain material was evaluated in this scenario.

5.3.1 Sediment transport capacity through Camille Cut

Closure of the Camille Cut will be constructed by sand placements. During construction, part of this sediment will be transported out of the construction template immediately by waves and currents. To ensure the successful closure operation, it is crucial that the production capacity, i.e. the amount of sediment which will be placed during a certain period of time, is significantly larger than the amount of sediment which will be transported outside the construction template during the same period. To answer this question, the possible range the sediment transport near the head of the closure was investigated.

With the Delft3D model, sediment transport rates were computed, taking into account both wave- and current driven sediment transport. Near the head of the closure, estimation of the losses which will occur during construction was made. Figure 5-11 shows the transport capacity for the 70% closure stage of Camille Cut for the East to West closure strategy during one spring-tide cycle.

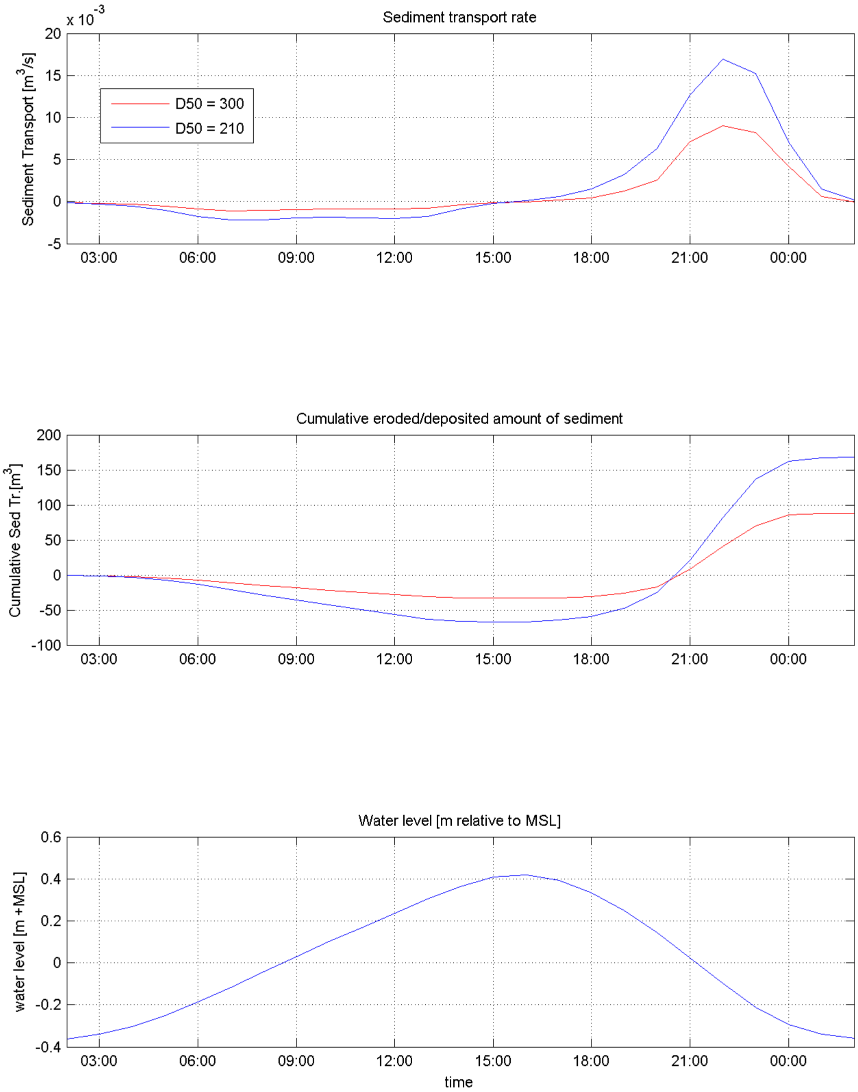


Figure 5-11 Sediment transport rates during spring tide in vicinity of fill for East to West closure strategy with D50 of 300 µm (S01 red line) and D50 of 210 µm (S03a blue line) for 70% closure stage.

The upper panel of Figure 5-11 shows the sediment transport rates. The middle panel shows the total (cumulative) amount of sediment which is eroded (negative value) or accreted (positive value) directly in front of the head of the construction, in a check box (a control area) of 100m x 50m. The lower panel shows the water level. The model results show a back and forth movement of sand out and into the check box. As could be expected, the dynamics of sand movement is larger for the smaller grain size.
The calculation shows erosion during flood (30 m³ for coarse sand and 80 m³ for fine sand) and accretion during ebb (100 m³ for coarse sand, and 170 m³ for fine sand) resulting in net accretion at the head.

In order to eventually close the gap, the production rates should exceed the erosion rates near the construction head. Every 8 hours a total amount of 6000 m^3 is projected to be placed at the head of the fill. This will be significantly more than approx. 100 m^3 which is estimated to be eroded away during flood from the area in vicinity of the head. Although the results of morphological computations generally show high ranges of inaccuracy (typically a factor of 3), the sediment transport figures found here are significantly lower than the production rates. Based on these results, no problems with insufficient production capacity in relation to erosion of the deposited fill material are expected.

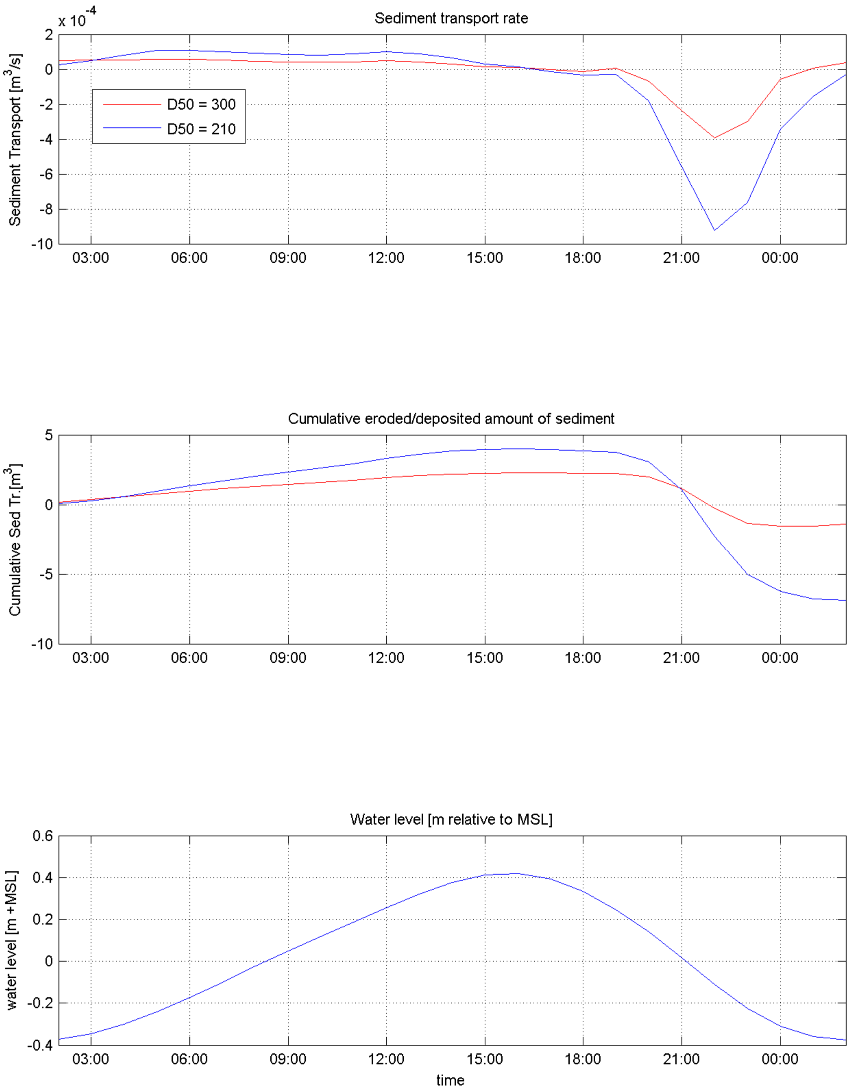


Figure 5-12 Sediment transport rates during spring tide in vicinity of fill for East to West closure strategy with D50 of 300 µm (S01 red line) and D50 of 210 µm (S03a blue line) for 90 % closure stage.

Figure 5-12 shows the results for the 90% closure stage for the East to West closure strategy. The total erosion and sedimentation rates are lower compared with the 70% closure stage. This is explained by the lower maximum flow velocities at this stage, which were found during the initial hydrodynamic computations. Also for this stage of closure, the anticipated production rates are more than sufficient to close the final gap.

The general conclusion is that a sand closure without additional measures to limit erosion is feasible even under less favorable conditions like a spring tidal cycle.

5.3.2 Local bed level changes and stability of fill during construction

During construction process bed level changes within in the remaining gap are to be expected. In general, the morphological processes near the head of the fill (including the closure gap) are:

- erosion of the fill by waves and tidal currents
- erosion in the closure gap caused by the constriction of the flow
- autonomous morphological development.

All these processes need to be considered, as they all determine how much sand is needed to close the gap.

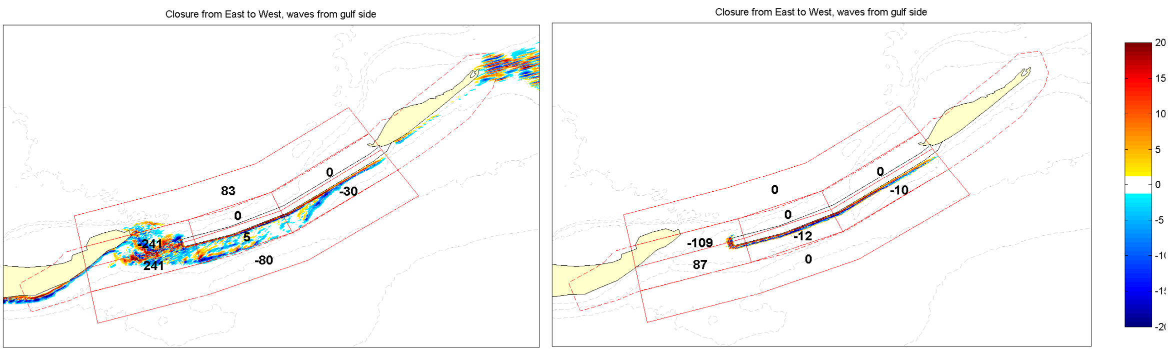
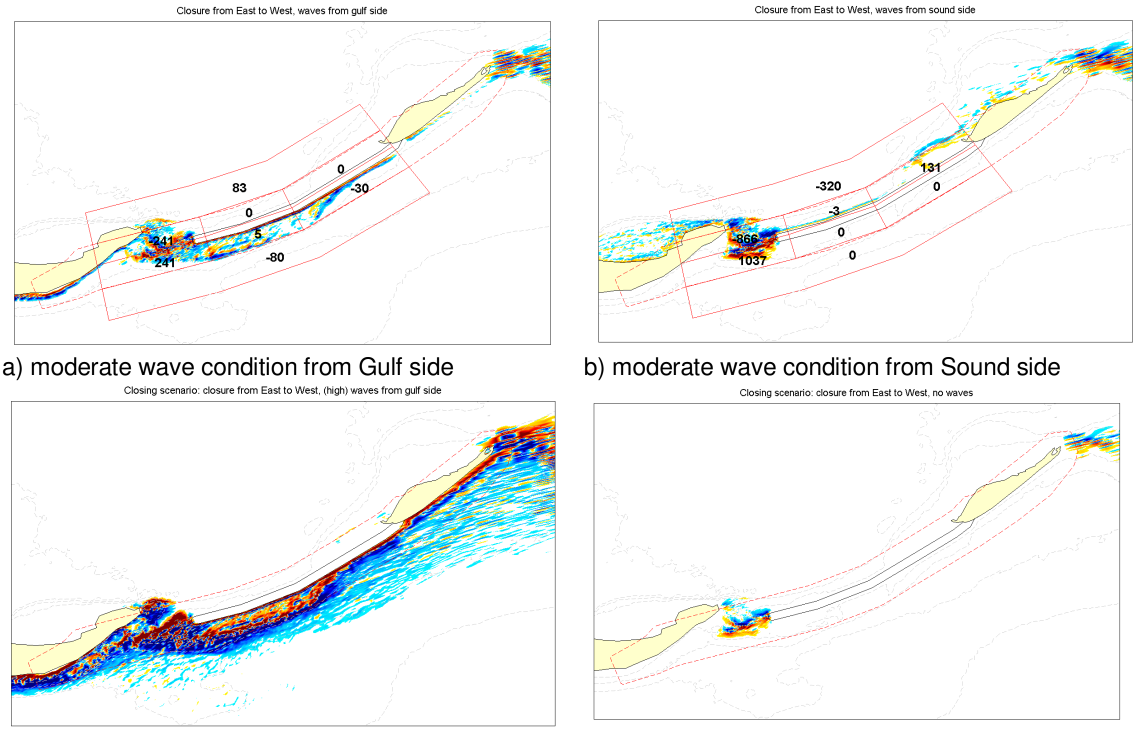


Figure 5-13 Bed level changes for East to West 70% closure. Left: changes in available sediment mass for entire area, right: changes for the fill only.

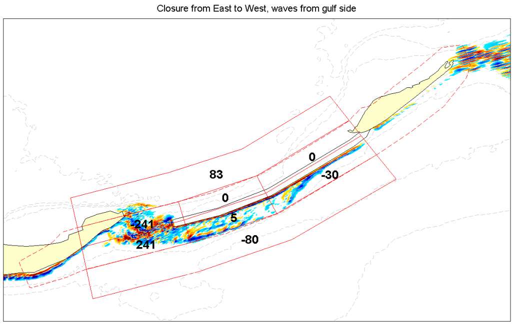
Figure 5-13 shows the computed available sediment mass for scenario closure East to West, 70% closure stage for a sediment grain size of 300 µm. The change in available mass of sediment in a certain area represents the erosion and sedimentation rates in that area (warm colors: sedimentation, cold colors: erosion). Both figures show the change in available mass of sediment after one tidal cycle, with wave conditions from the Gulf side. The left figure shows the changes of the entire area, in which the changes in bed level are partly autonomous and partly induced by the construction of the fill. The right figure only shows the changes of the (new) constructed fill. These results show that the expected bed level changes of the fill are very limited and local. Although the bed level changes of the surrounding area are found for a larger area, the effects are local and will stay almost entirely inside the final Phase 4 template (indicated with the red dashed line). A maximum value of erosion (Figure 5-13) of 20 kg/m² was found. This corresponds to a bed level change in the order of inches. The numbers in the boxes give an rough indication of the total amount of erosion (negative value) and sedimentation (positive value) in m^3 per day in that specific area. It can be seen that no new material (from the fill) moves outside the final template, however, when the total morphology is considered, some material exceeds the final template's boundary. This volume is very small compared to the total production in the same time.



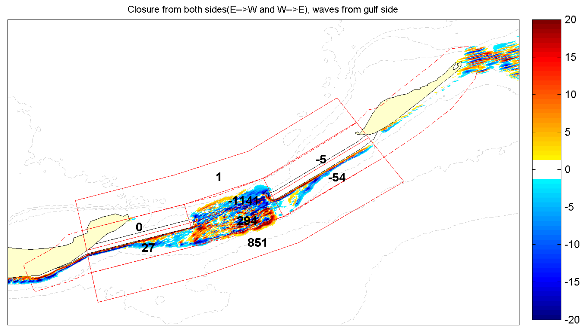
a) moderate wave condition from Gulf side
b) moderate wave condition from Sound side
c) storm condition from Gulf side
d) no waves, only tide

Figure 5-14 Effect of wave conditions on bed level changes for closure scenario East to West (70% closure stage)

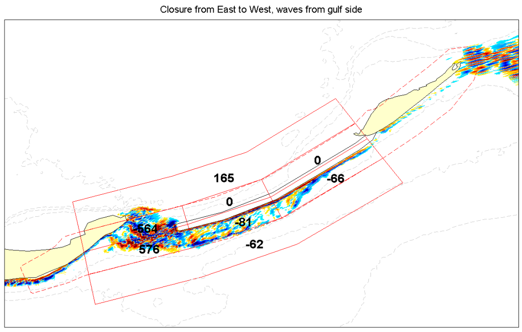
With wave action from the Gulf side, bed level response is expected at the southern part of the construction (Figure 5-14). With waves from the Sound side, the northern part of the fill structure will experience some erosion. The main effects are observed inside the gap. The deposition of the sediment eroded from the Phase 1 template will be local and will stay mostly inside the final (Phase 4) template. Waves have only a limited effect on the bed level changes. The main changes in the gap are induced by tidal currents (compare Figure 5-14d) with both a) and b)). Due to the waves, changes in erosion pattern along the fill structure are observed. The tide-induced bed level changes are slightly increased. A higher (storm) condition from the Gulf side increases the expected bed level changes significantly on the southern part of the construction. However, during these conditions losses are limited because sediment is transported in the direction of the construction. The bed level changes in the closure gap increase during this storm condition, however the amount of sediment which migrates outside of the final template is quite small (Figure 5-14, compare a) and c)). In all considered cases the computed loses outside the footprint of the final construction template are in the same order of magnitude and very limited.



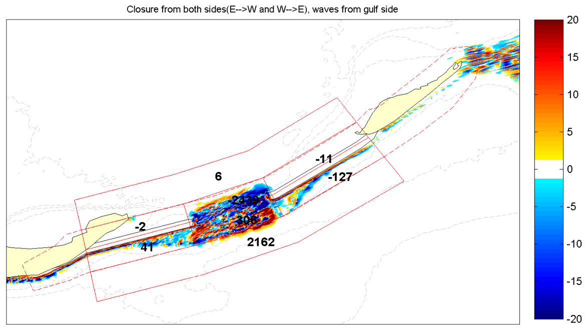
a) Closure from East to West (S01)



b) Closure from West and East (S02)



c) Closure from East to West with finer grain material (S03a)



d) Closure from West and East with finer grain material (S03b)

Figure 5-15 Bed level changes in vicinity of closure

Figure 5-15 shows the results for the different closure scenarios for the combined action of tide and waves from the Gulf side. The numbers in the figure give a rough indication of the eroded (negative) and accreted (positive) volume (in m³) during one day.

It is clear that the “closure from West and East” scenario (b) leads to much more morphological activity in the closure gap compared to the “closure from East to West” scenario (a). In the latter scenario, the activity zone is well within the final template, and only some small loss across the template’s boundary to the Sound side is found. In the “closure from West and East” scenario, there is much more erosion in the closure gap; a large portion of the eroded sediment is transported outside the template’s boundary. The calculated volume of loss for this scenario is 10 times larger than for the “closure from East to West” scenario. This volume is in the order of 500-1000 m³/day, to be compared with the production rate of 18,000 m³/day (24,000 CY/day). When finer grain size sediment is considered, the morphological activity will increase[9] by a factor of 2-3. The calculated loss for “closure from East to West” scenario is still small (approx. 100-200 m³/day), while for the “closure from West and East” scenario loss of more than 2,000 m³/day is calculated. The latter is in the order of 10% of the production rate.

The calculated volumes should be considered as an order of magnitude estimate only, and the approach is rather conservative. The losses for “closure from West and East” can be considered as significantly larger compared to the “closure from East to West” scenario. However, in all cases the sediment is not moved far away from the fill, so from the perspective of natural system it is not “lost”.

[9] Fine grain sediment is used in the whole model, not for the fill only. The calculated loss of 2,162 m³/day is therefore expected to be overestimated.

5.4 Turbidity computations

The suspended sediment assessment was centered on a base case simulation and a range of sensitivity simulations. These sensitivity simulations in which the model and ambient parameters which the model outcomes are most sensitive were varied. These simulations are described in Chapter 5.5. The base case simulations resemble the critical closing scenarios under the average hydrodynamic background conditions and were used as a benchmark for the sensitivity analysis. In this chapter the results of the base case simulations are presented.

Suspended sediment concentrations

To identify the areas where critical suspended sediment concentrations could occur, the maximum excess suspended sediment concentrations of the total of all fines are presented below. These footprints are defined as the envelope around the maximum values predicted in the two-week period. These footprints indicate the upper limit of the excess suspended sediment concentrations. It is noted that these concentrations could occur only for a very short period of time, less than 1-5% of the time.

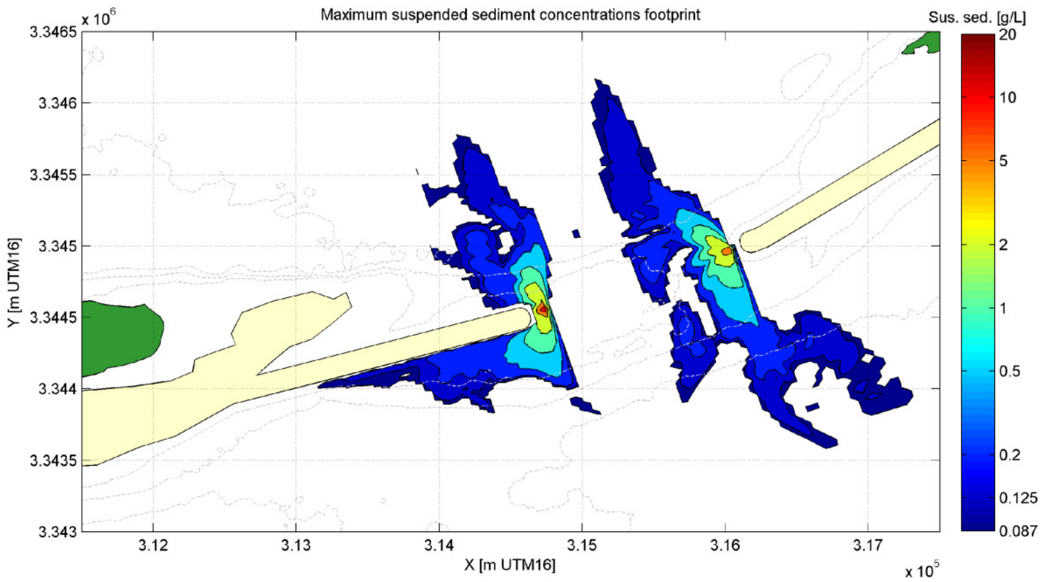


Figure 5-16 Maximum excess suspended sediment concentrations for the Closure from West and East scenario for one spring-neap tidal cycle

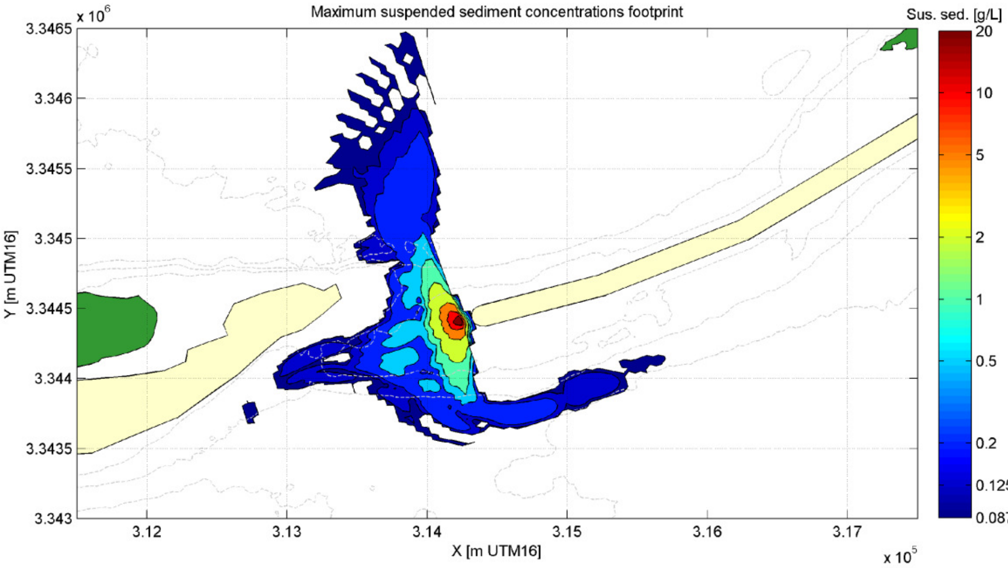


Figure 5-17 Maximum excess suspended sediment concentrations for the East to West scenario for one spring-neap tidal cycle

Both scenarios result in a typical North-South orientated suspended sediment distribution (Figure 5-16 and Figure 5-17). The sediment plumes are largely shaped by the tidal flows while the moderate wave and wind conditions have limited influence. The plume is not expected to extend further than 2 km into the Sound and 1 km into the Gulf. In both scenarios the turbidity levels due to suspended sediments in the sea grass areas (indicated by the green areas) are not exceeding 50 NTU (0.087 g/l). Furthermore, the differences in suspended sediment concentrations and the footprint between the two closing scenarios are small.

Spring-neap tidal cycle

Previous figures show the importance of the tidal currents on turbidity levels, but a difference can be observed between spring (first week of simulation) and neap tide (second week of simulation). Spring tide corresponds to a tidal range in the order of 0.8m and neap tide to a tidal range in the order of 0.3-m.

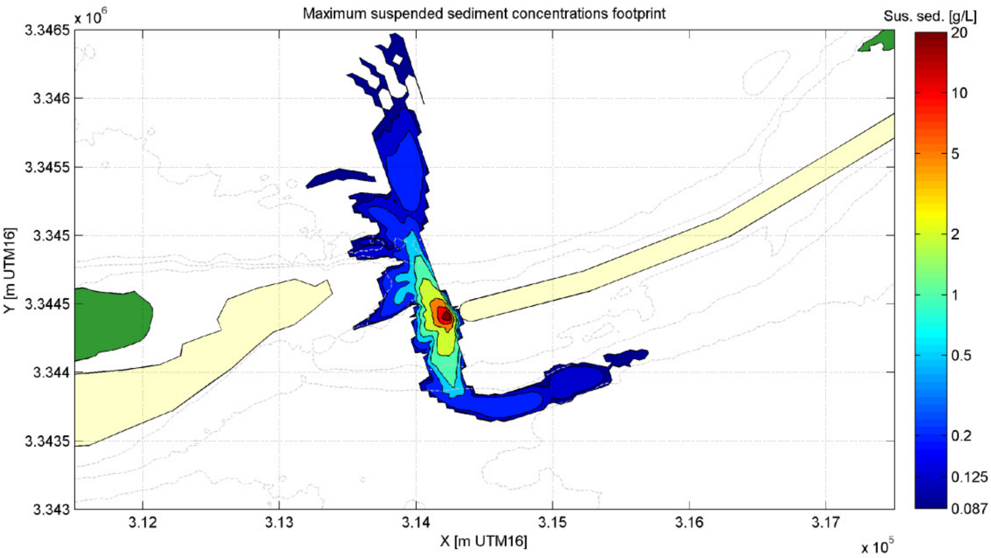


Figure 5-18 Maximum excess suspended sediment concentrations for the East to West scenario for spring tide

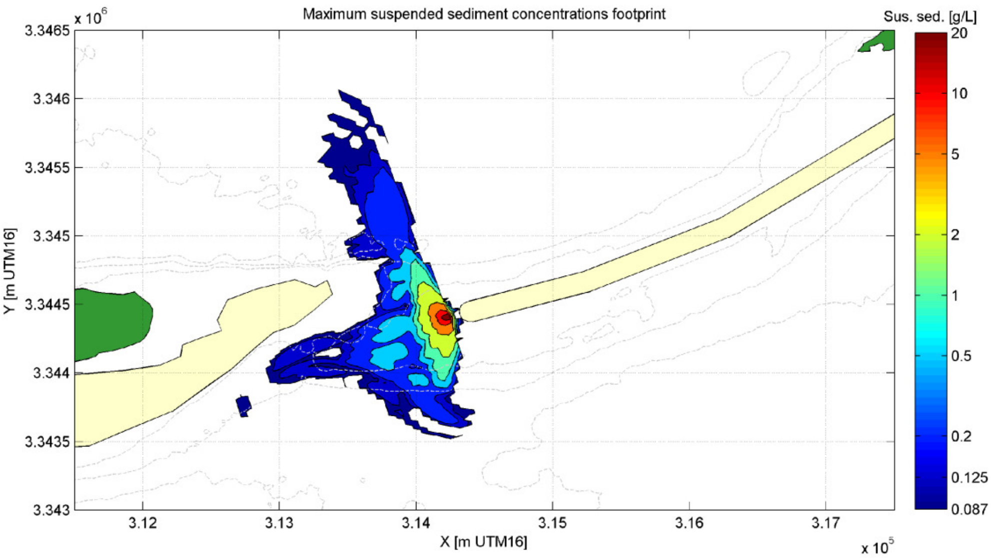


Figure 5-19 Maximum excess suspended sediment concentrations for the East to West scenario for neap tide

During the spring tide (Figure 5-18) the relatively large tidal velocities elongate the suspended sediment plumes in a north-south orientated direction, whereas during the neap tide (Figure 5-19) the plumes are more confined to the discharge. Due to the relatively low tidal velocities, wave/wind induced currents gain importance since the plume is now skewed towards the western Gulf shoreline.

Time of exceedance

Besides the maximum suspended sediment concentration footprints, the time period during which the critical suspended sediment concentration is exceeded is also considered. Long periods of high sediment concentrations/low light intrusion in the water column are likely to result in more negative environmental effects. In the figure below the exceedance times in percentage of the critical value of 0.087 g/l for the East to West closure scenario are given based on the simulated two-week period. Suspended sediment concentrations exceed the critical value of 0.087 g/l more than 2% of the time (i.e. a total of approximately 6.5 hours in 14 days) only in the vicinity of the Ship Island Fill.

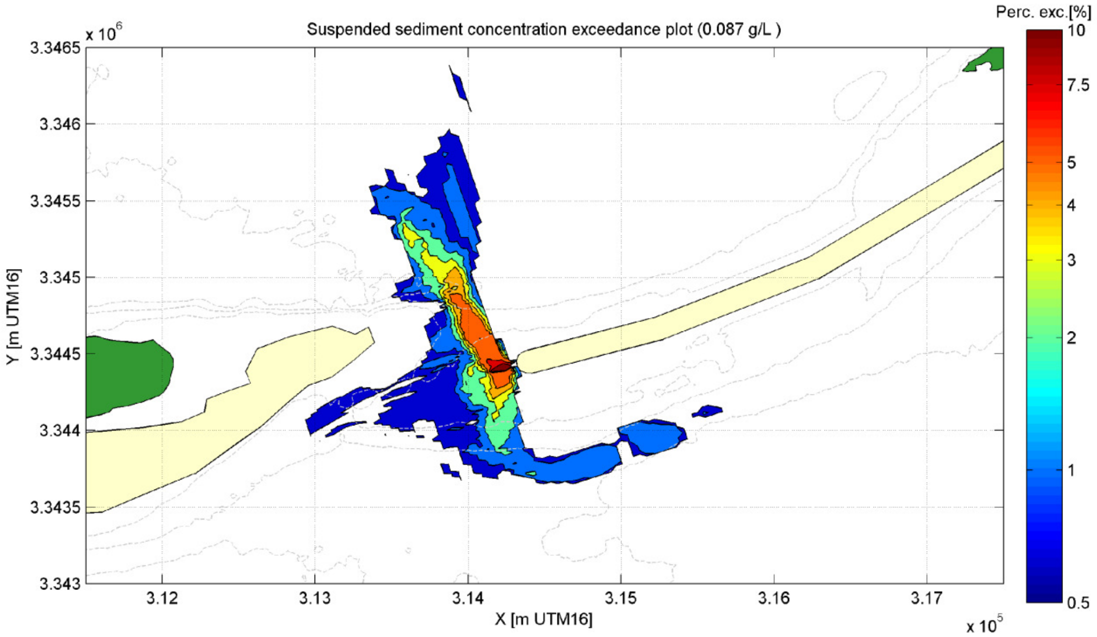


Figure 5-20 Excess suspended sediment concentration exceedance plot in percentages for 0.087 g/L, Scenario East to West

Suspended sediment concentrations per sediment class

To study the influence of the sediment distribution, suspended sediment concentrations are presented by each sediment class. Figure 5-21 to Figure 5-23 show the maximum suspended sediment concentration footprints for the three finest sediment classes.

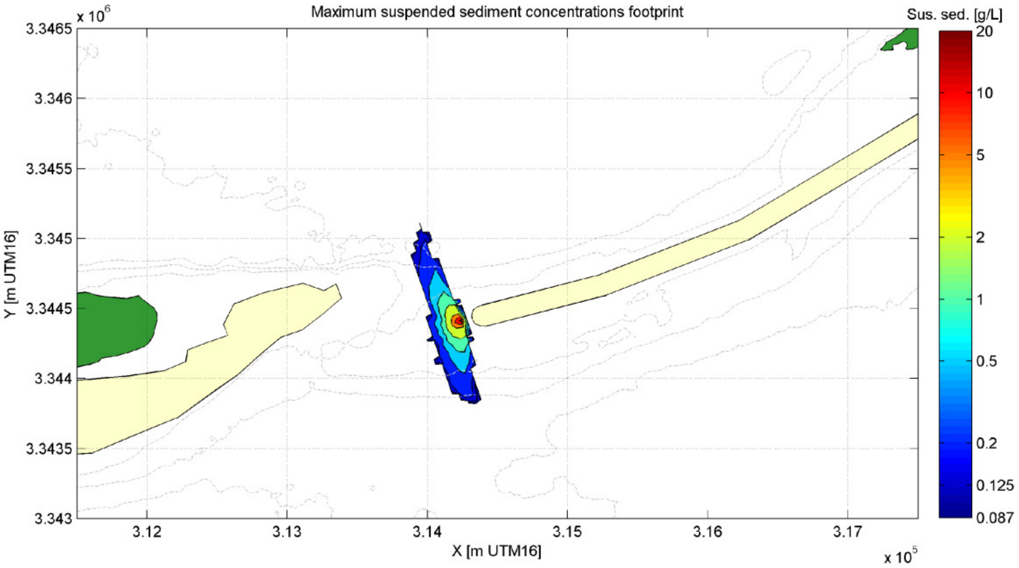


Figure 5-21 Maximum excess suspended sediment concentrations for the East to West scenario for one spring-neap tidal cycle, fines class 1 (d50=50 µm).

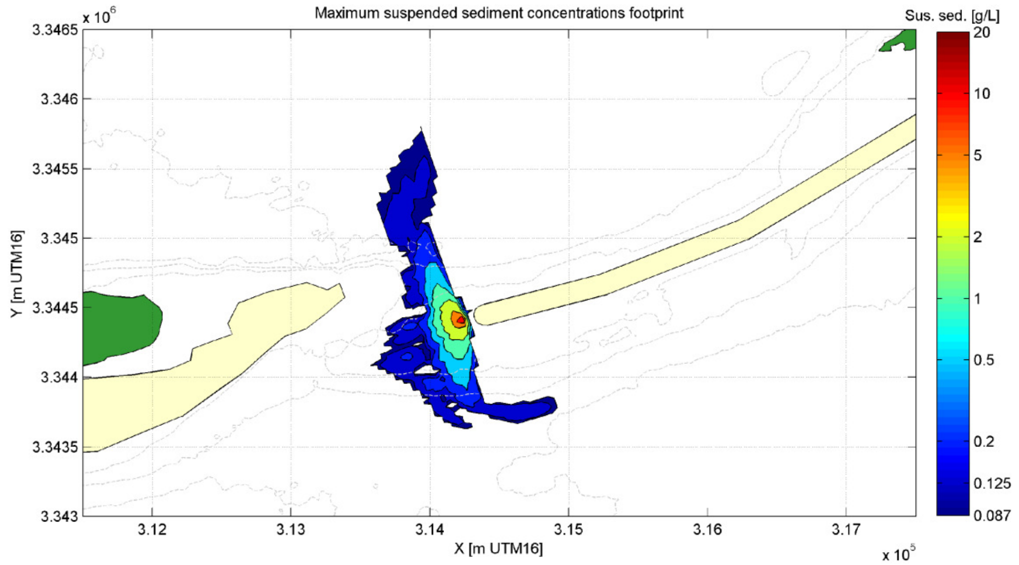


Figure 5-22 Maximum excess suspended sediment concentrations for the East to West scenario for one spring-neap tidal cycle, fines class 2 (d50=30 µm).

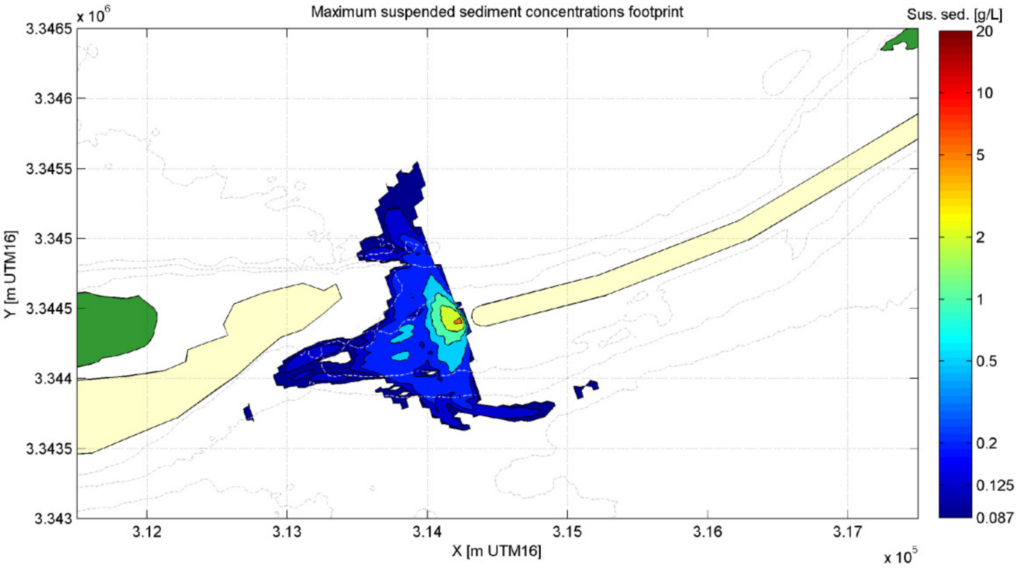


Figure 5-23 Maximum excess suspended sediment concentrations for the East to West scenario for one spring-neap tidal cycle, fines class 3 (d50=10 µm).

The comparison shows that the sediment size has a large influence on the maximum footprint. As expected the finest sediment class results in the largest area of influence. However the largest fine sediment class (d50=50 µm) still influences the suspended sediment concentrations at a distance of 0.5-1 km.

Sea grass areas

Sea grass areas are considered environmentally sensitive areas, which could be sensitive to increased turbidity levels. One such area is located west of the Ship Island Fill and one to the east (indicated by the dark green in the figures). As the 70% closure scenario is in the vicinity of the sea grass area in the West, the figure below presents the time series of the computed total suspended sediment concentrations as well as per sediment class for an observation point in the western sea grass area.

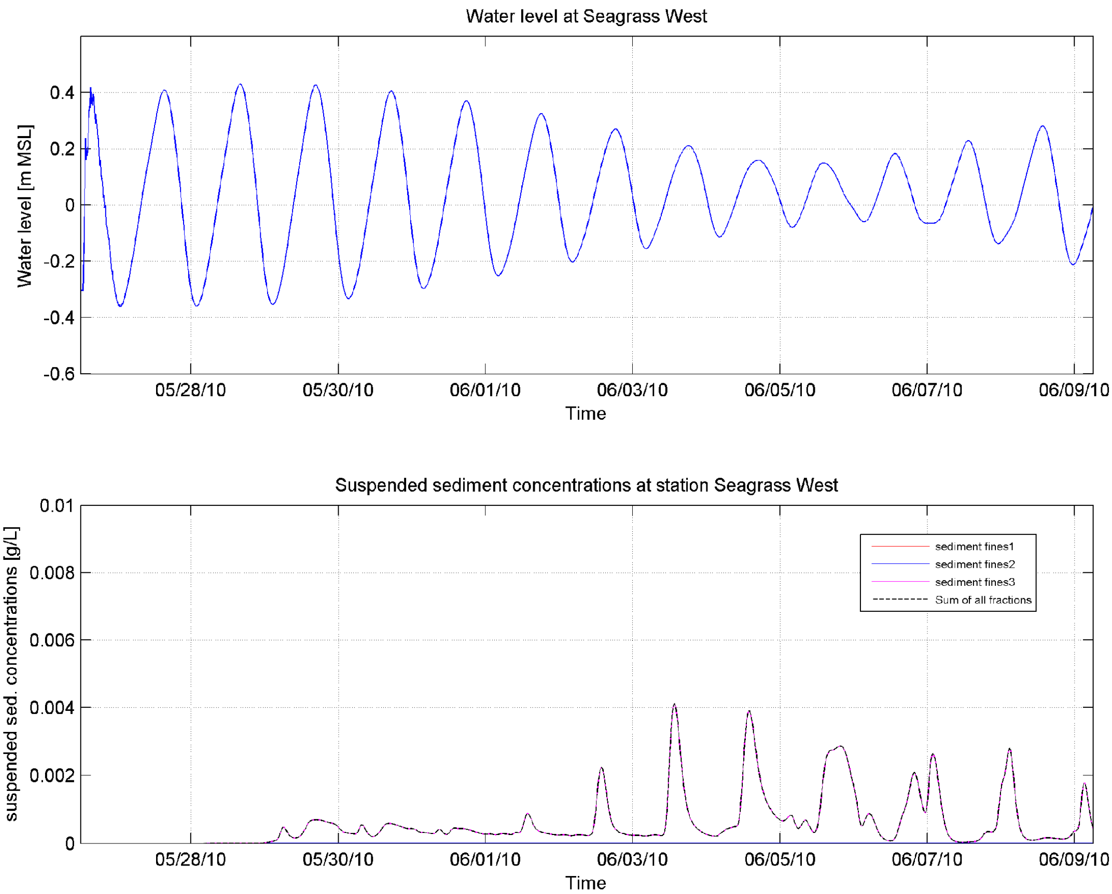


Figure 5-24 Maximum excess suspended sediment concentrations time series for the East to West scenario for one spring-neap tidal cycle in the western sea grass area

Figure 5-24 illustrates the suspended sediment concentration time series for a two week period in the western sea grass area. The influence of tide on turbidity levels is clearly visible, as during neap tide fine sediments remain in the vicinity of Ship Island. Importantly, only the finest sediments are transported to the western sea grass area. Maximum excess suspended sediment concentrations for the western sea grass area are in the order of 0.004 g/l, which is well below the critical turbidity level of 50 NTU above background (0.087 g/l) for the considered modeling scenarios.

Deposition of fines

Besides the turbidity levels, the deposition of fines is an important environmental parameter for dredging activities at Ship Island fill. The figure below illustrates the deposition of fines for the East to West scenario with a lower limit of 2 mm for a period of two weeks.

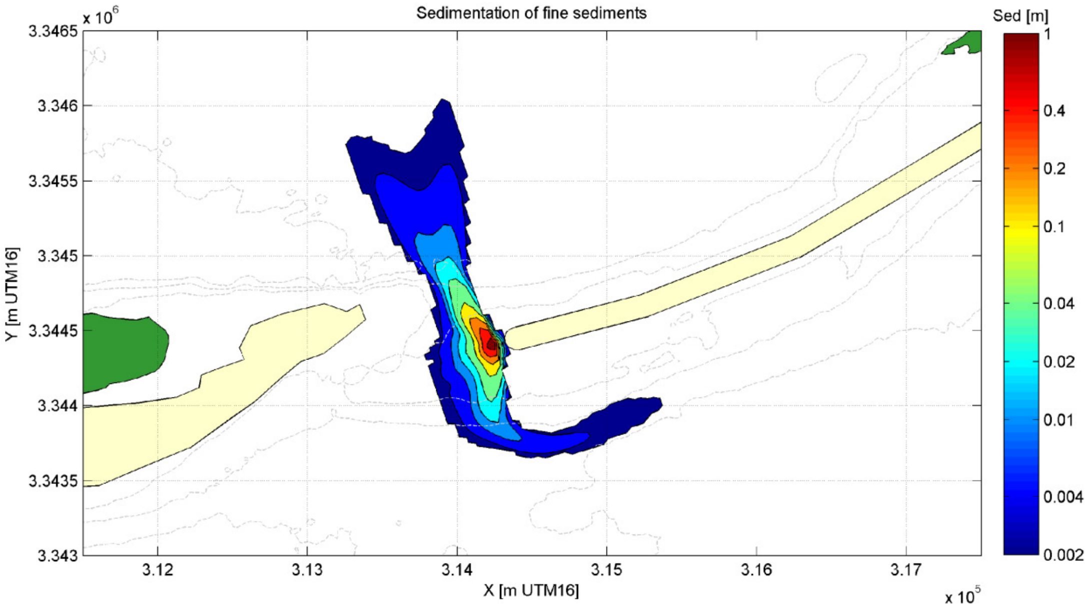


Figure 5-25 Deposited fine sediment for the East to West scenario due to the construction of Ship Island Fill

The area of deposition of fines is almost identical to the area of maximum excess suspended sediment concentrations. The deposition of fines due to the dredging activities remains limited to the area in the vicinity of the Ship Island fill. Re-suspension of fine sediment due to the dredging activities was not considered as in the vicinity of Ship Island substantial areas containing fine sediments are already present.

5.5 Sensitivity of results

To study the sensitivity of the modeling results, a sensitivity analysis was performed. Several numerical and environmental parameters were tested for their influence on the maximum suspended sediment concentrations and the deposition of fines. An overview of parameters subjected to the sensitivity analysis is given. In addition, a description and the results of the sensitivity analysis are given for the parameters that influence the critical suspended sediment concentrations and deposition of fines.

Table 5-1 Description sensitivity tests

Run	Description
1	Base case simulation (70% closure, East to West)
2	Wind/waves from Sound
3	Storm condition
4	Re-suspension of fine sediments
5	90% closing scenario
6	Different sediment distribution i.e. 13% fines
7	a large commercially available hopper dredge, (increase in discharged volumes and different pump capacity)
8	Reduced fall velocity (75 % of w_s)

Wind/wave conditions from Sound

To study the influence of different hydrodynamic conditions, a different wave and wind condition was used. In this simulation the average wind (U=7.6 m/s, θ=12,9^{o}N) and wave condition (Hs=0.6, Tp=3s) from the Sound was used. Because the results are approximately similar to the base simulations, it is concluded that these considerably different wind/wave conditions have a limited impact on the turbidity levels due to the dredging activities (Figure 5-26).

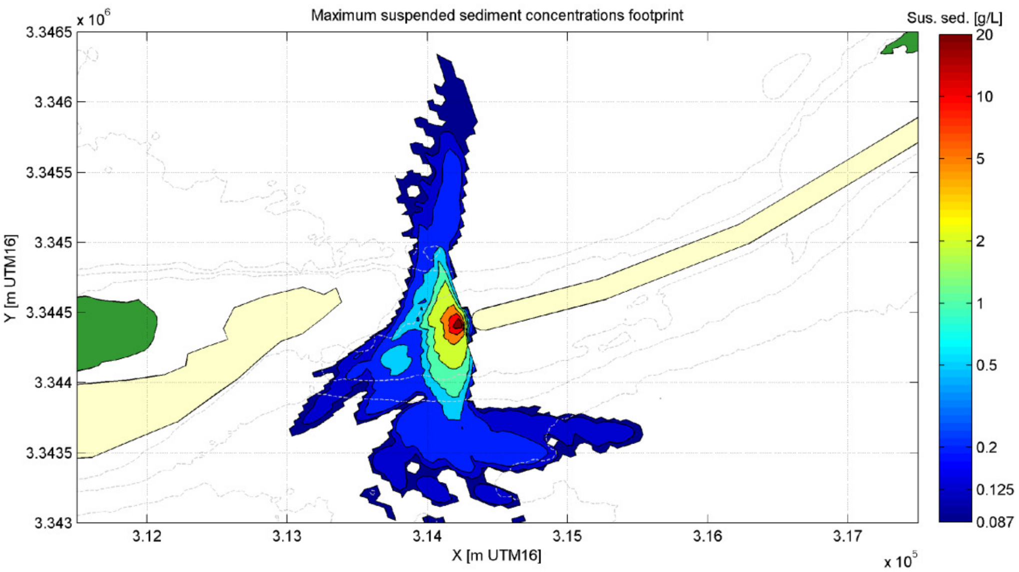


Figure 5-26 Maximum excess suspended sediment concentrations for wave and wind conditions from Sound

Storm condition

In addition to the sensitivity analysis for different wave and wind conditions, a simulation was performed with a storm condition. For the storm condition a wave height of Hs=2.5m, Tp=8.2s, offshore incident wave angle of 147ºN, and wind conditions U=11.9 m/s and θ=147^{o}N was used. The total simulation time was two weeks, although storms are likely to occur only for a few days. This was expected to result in an upper limit for critical suspended sediment concentrations.

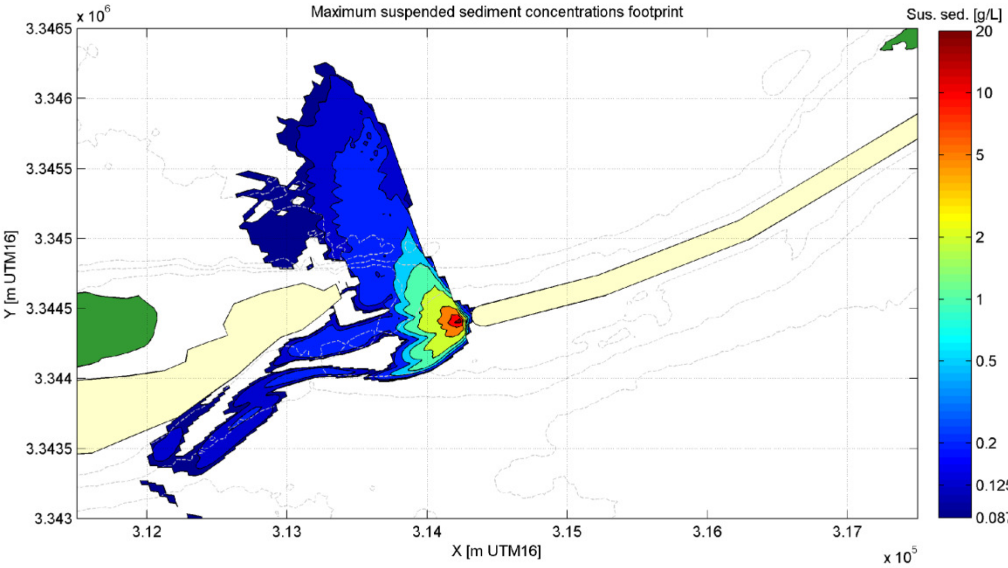


Figure 5-27 Maximum excess suspended sediment concentrations for the East to West scenario with a storm condition

Results show that despite the more westward directed sediment concentrations, there are no significant differences between the base case simulation (e.g. the sea grass areas are not affected) and this considered storm condition. South of Ship Island the wave and wind driven currents become more dominant compared to the tidal currents. This results in the transport of more fine sediment to the west.

Re-suspension of fine sediment

The critical bed shear stress for erosion determines the minimum bed shear stress for fine sediments to come in re-suspension. Whereas for the base case simulation re-suspension of fine sediments was not considered as large areas of fine sediments in the vicinity of the Ship Island fill are already present, in this analysis a value of 0.4 N/m^2 was used. This was considered to be a representative value, taking the sediment distribution and any ‘armoring’ effects of coarse sediment into account. Results indicate no difference compared to the base case simulation. This is explained by the fact that bed shear stress levels larger than 0.1 N/m^2 occur only very locally in the vicinity of the Ship island fill..

90% closure

To test the effect of closing the Ship Island fill, a closing scenario of 90% was simulated. Results show that the area of critical suspended sediment concentrations decreases slightly for the “closure from West and East” and the "closure from East to West” scenario, but in general results are similar to the base case simulation, regarding the extent of the sediment plume.

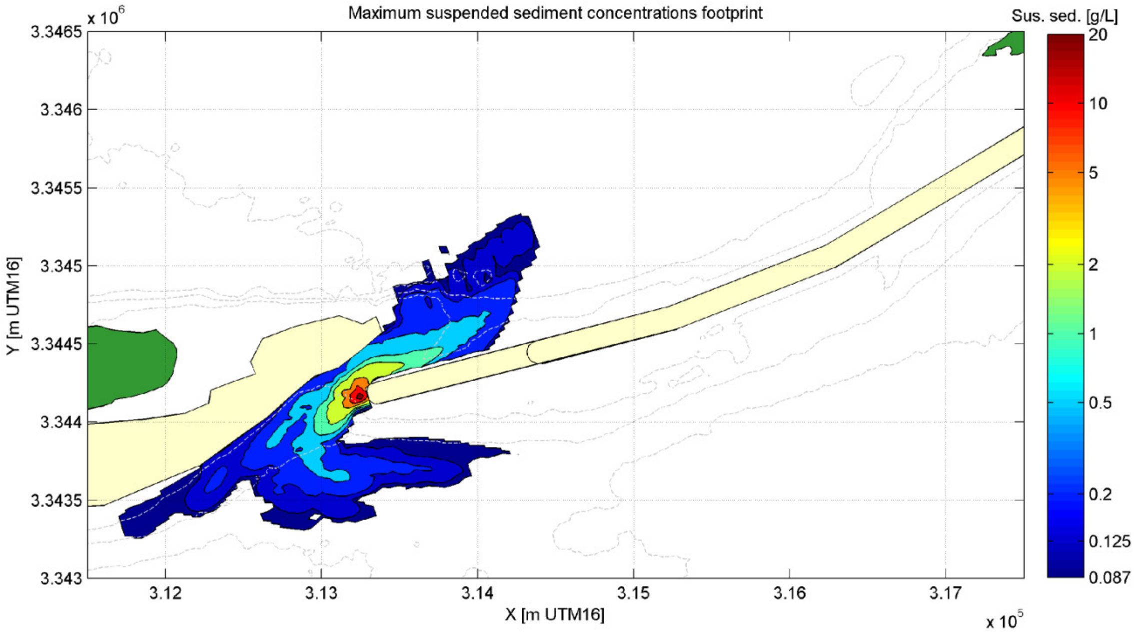


Figure 5-28 Maximum excess suspended sediment concentrations for the East to West scenario for 90% closure

Different sediment distribution e.g. 13% fines

As was shown in Figure 5-21 to Figure 5-23, the distribution of fines has a large influence on the spatial and temporal transport of the fines. In the base case simulation an averaged sediment distribution from the borrow area was used. As a conservative estimate, a sensitivity analysis was performed with a distribution based on the USACE's analysis of samples with the highest fine sediment content from the borrow area, see Table 5-2 below.

Table 5-2 Sediment distribution with 13% fines

Sediment Classes	d50 (µm)	Percentage	Discharge concentration "Closure from East to West" (kg/m^3)	Discharge concentration "Closure from West and East" (kg/m^3)
Fines 1	50	0.3%	8.18	4.09
Fines 2	30	0.4%	10.91	5.46
Fines 3	10	13%	362.82	181.41

As no changes in sediment distribution were taken into account due to the dredging activities such as the filling of the hopper or deposition of fines on the land based fill, this is a conservative approach with upper limits of the turbidity due to suspended sediments. Figure 5-29 shows the maximum suspended sediment concentrations for the East to West scenario for the two-week period with the finest sediment distribution.

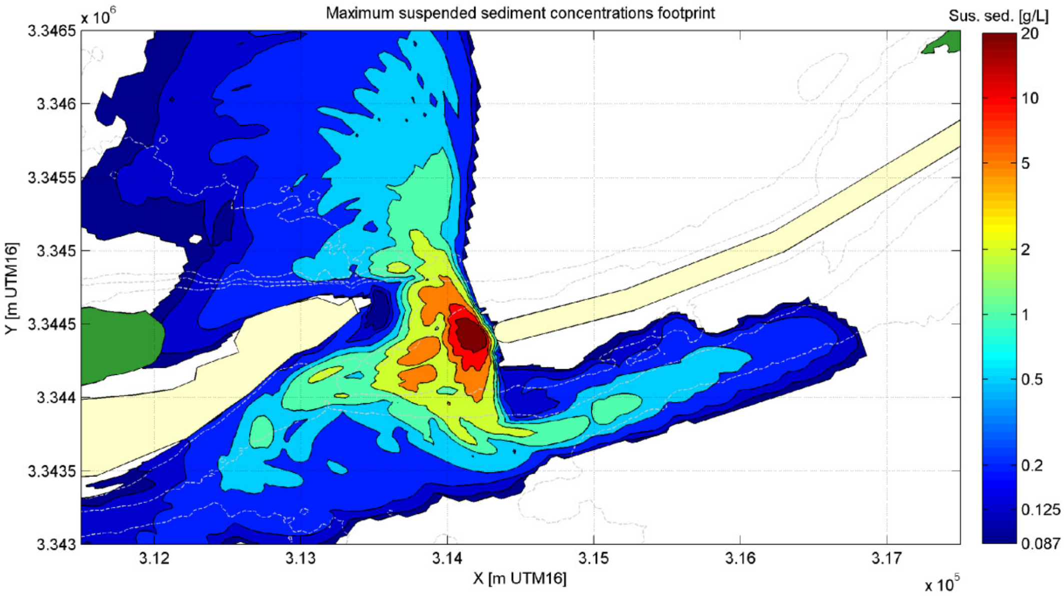


Figure 5-29 Maximum excess suspended sediment concentrations for the East to West scenario for fine sediment distribution

Clearly, the finer sediment distribution resulted in a larger area in which the critical suspended sediment concentrations are exceeded. Compared to the base case simulation the critical levels have increased significantly especially for West Ship Island (compare Figure 5-17 and Figure 5-29). Moreover, the critical suspended sediment concentrations now also partly extends into the sea grass area (Figure 5-29).

Due to the larger percentage of fine sediment, the deposition of fines is also spread out over a larger area. Most of the deposition of fines is in the order of 2-10 mm for the two-week period (higher values are found near the Ship Island fill.)

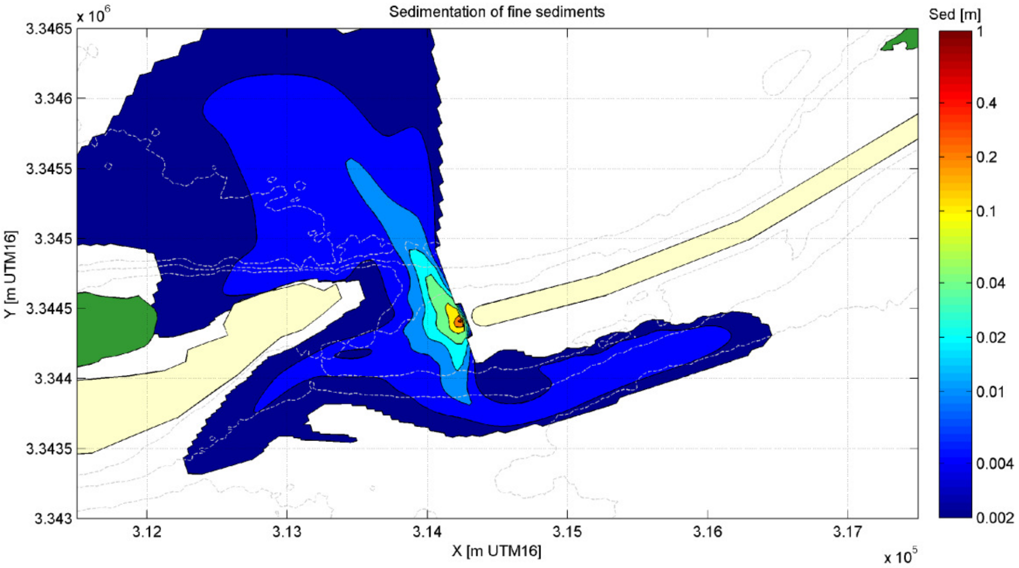


Figure 5-30 Deposition of fine sediment for East to West scenario due to the construction of Ship Island Fill with the finest sediment distribution

A large commercially available hopper dredge

To study the effect of different dredging equipment/strategy, simulations were performed with a larger hopper capacity and lower pump capacity. The pumping time at the Ship Island fill was 120 min, the total cycle time was 520 min. The sediment concentrations per sediment class are changed accordingly, see Table 5-3. The discharge rate remained 1 m^3/s.

Table 5-3 Discharge concentrations according to a large commercially available hopper dredge specifics

Sediment Classes	d50 (µm)	Percentage	Discharge concentration “closure from East to West” (kg/m^3)	Discharge concentration “closure from West and East” (kg/m^3)
Fines 1	50	5%	78.81	39.40
Fines 2	30	3%	47.28	23.64
Fines 3	10	1%	15.76	7.88

The results of the East to West scenario are shown in Figure 5-31 below.

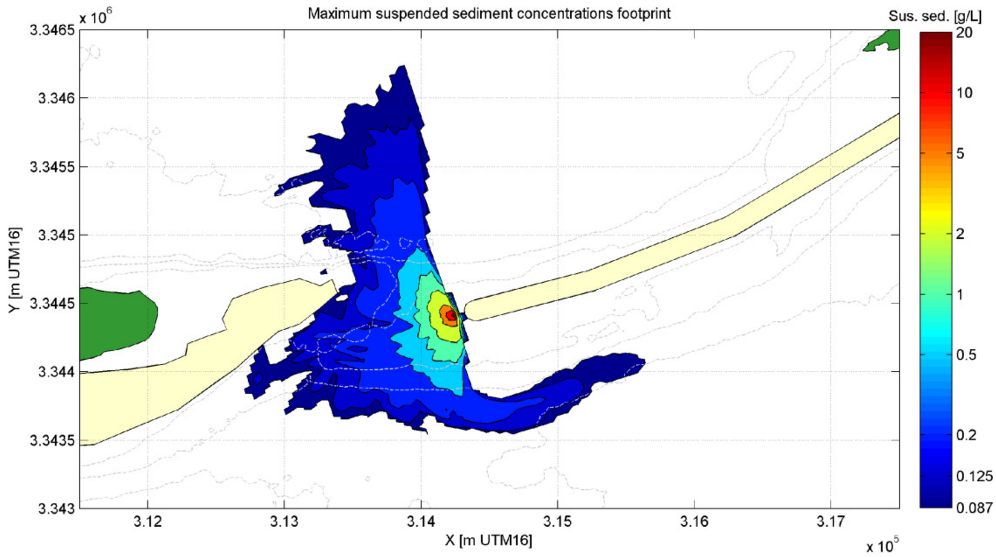


Figure 5-31 Maximum excess suspended sediment concentrations for the East to West scenario using different dredging equipment

Though concentrations of fine sediment are lower compared to the base case simulation, the longer duration and increase of total fine sediments resulted in a slightly larger area of critical suspended sediment concentrations.

Reduced fall velocity

To study the effect of different sediment characteristics, a simulation is performed with reduced fall velocities. For the fine sediment the fall velocity is reduced to an (arbitrary) value of 75%, see Table 5-4.

Table 5-4 Reduced fall velocities

Sediment Classes	D50 (µm)	cohesive/ non cohesive	Ws(mm/s)
Fines 1	50	Cohesive	1.479
Fines 2	30	Cohesive	0.532
Fines 3	10	Cohesive	0.059

Results show limited difference compared to the base case simulation, see Figure 5-31. This is attributed to the fact that the tidal extent is the same as the base case simulation.

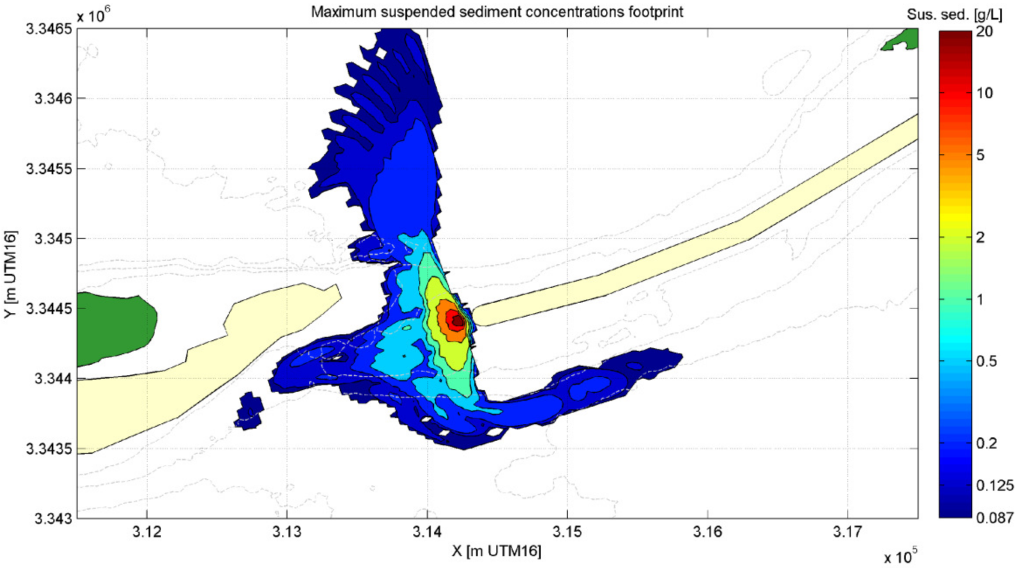


Figure 5-32 Maximum excess suspended sediment concentrations for the East to West scenario with reduced fall velocities

6 CONCLUSIONS

6.1 Addressing key questions

The objective of the present study was to answer five key questions. In this Chapter, the questions are answered in a qualitative manner. More detailed, quantitative conclusions are provided in Chapter 6.2

What are the expected losses from the final construction template?
The Phase 1 fill will be subject to erosion by waves and currents. In particular during the final part of the closure when the gap is reduced to 70-90% of the total length of the Camille Cut, the constricted tidal flow will cause some erosion of both the fill material and the present bed material as a result of the increased current in the closure gap. The calculated sediment loss across the final template's boundary is insignificant for the "closure from East to West" scenario. For the "closure from West and East" scenario, the loss is larger, in the order of a few percent of the production. The eroded material will remain close to the boundary of the final construction template, i.e. it will not be lost from the natural system.
This is valid for normal conditions. During tropical storms and hurricanes, much more loss can occur.

Is the production capacity sufficient to close the final gap?
The production rate estimated using the specifications of the dredging equipment is significantly larger than the potential loss; no problems regarding insufficient production capacity are expected.

What is the expected Phase 1 profile width after 1 year?
After 1 year, the erosion of the crest at the Gulf side is expected to be in the range of 120 to 220 feet, and approximately 120 feet at the Sound side. This means that the original crest width could be reduced by 50-60%. Breaching of the Phase 1 fill is not expected. However, there is no guarantee that the initial fill will not breach during a heavy storm.

What is the impact of using finer sediment for the fill?
Finer grain sediment (210 instead of 300 µm) can be easier mobilized by waves and current. This resulted in larger mobility of sediment, and a larger volume transported across the boundary of the final construction template. The losses increase by a factor 2-3. For the "closure from East to West" scenario the losses are still insignificant, but for the "closure from West and East" scenario the losses are in the order of 10% of the production rate.The erosion of the crest is expected to increase by approximately 50%. According to the calculations, the initial fill will not be breached, but the remaining part of the crest becomes rather narrow (in the order of 100-200 ft).

Are the turbidity limits likely to be exceeded?
The 50 NTU limit at a distance of 750 ft is expected to be exceeded. However, the results show that the turbidity in the sea grass areas is within this limit. However if a very conservative assumptions for the content of very finest fraction (13% of sediment smaller than 30 µm) is used, the 50 NTU limit is also exceeded in a part of the sea grass area near the West Ship Island.

6.2 Detailed conclusions

6.2.1 Cross-shore profile evolution:

- At the Gulf side:
  - The final cross-shore profile consisting of coarse grain sand has a slope between 1:100 and 1:50, where the 1:50 is similar to the slope of the coast of West Ship Island and show similarities with the theoretical Dean profile. For fine grain sand, the profile has a slightly gentler slope (1:60 to 1:100).
  - The erosion at the crest zone is approximately 120 to 220 feet for the coarse gain sand. When fine grain sand is used, the maximum crest erosion increases to 300 feet. The maximum erosion is approximately 40 cubic yards per linear foot of shoreline.
- At the Sound Side (only coarse grain material examined):
  - The final coarse sand cross-shore profile has a slope of 1:33.
  - The maximum erosion distance at the crest zone is 120 feet.
  - The loss of volume is approximately 15 cubic yards per feet.
  - The evolved profile is very close to the northern boundary of the final construction template.
  - It is expected that if the fine grain material is used, the profile may extend beyond the final construction template.
- At the Gulf side of the fill, the evolved profile remains well within the final construction profile. At the Sound side the evolved profile is very close to the boundaries of the final construction profile.
- The remaining crest width after one year is approximately 200 feet (excluding heavy storm or hurricane impact).
- The erosion rates found with Unibest-TC are generally conservative. However, this is no guarantee that the initial fill does not breach during a heavy storm.

6.2.2 Sediment Losses

- Computations were executed for two closing strategies, at two stages of the fill construction. The 70% closure stage appears to be the most critical stage. The results are not very sensitive to wave conditions.
- In vicinity of the head of the construction, sediment transport rates in the closure gap in the order of 100 m3 during one tidal cycle during a spring tide were computed. The assumed production capacity is by far larger than the erosion rates and it is therefore is expected to be sufficient to close the Camille Cut. Sand closure is feasible without additional measures to limit erosion or divert the flow.
- The highest sediment transport rates are found for the 70% closure stage. At 90% closure lower losses are to be expected due to the lower maximum flow velocities.
- The loss across the final template’s boundary for the “closure from East to West” scenario is insignificant for both considered grain sizes (210 and 300 µm). For the “closure from West and East” scenario, the loss is in the order of 5% of the production. When the finer grain sediment is used, this loss increases to the order of 10% of production.
- Local bed level changes are observed. Most of these changes are observed to occur locally. Only a limited amount of sediment lost from the fill will migrate outside of the final phase template;

6.2.3 Turbidity

- Under average hydrodynamic conditions during the 70% closure of the Ship Island fill, the critical excess turbidity level of 50 NTU is likely to extend 1-2 km (0.6 – 3.2 miles) to the North and 0.5-1 km to the South.
- The critical excess turbidity level of 50 NTU due to suspended sediments occurs only a few percent of the time in the vicinity of the closure gap, rapidly decreasing to percentages below 1% further away from the Ship Island Fill.
- Deposition of fines occurs mainly in the area 0- 1 km (0 - 0.6 mile) of the closure gap. On a distance of more than 1km (0.6 mile), deposition of fines decreases to an order of 2 mm per two weeks.
- Under the considered average hydrodynamic conditions (with the lower fine content), maximum suspended sediment concentrations at the sea grass area west of Ship Island are in the order of 0.004 g/l and thus below the critical value of 0.087 g/l (50 NTU). However, scenarios with higher fine content show some increased turbidity levels at the sea grass area.
- The sensitivity analysis shows that for the considered modeling scenarios, the presented predictions are not sensitive for the ambient hydrodynamic conditions and dredging scenarios.
- Turbidity levels and deposition of fines are sensitive to the sediment distribution of fine sediments, i.e. the smaller the fractions the larger the extent of the suspended sediment plume.
- Critical turbidity levels at the sea grass areas were not exceeded with average sediment characteristics for the considered modeling scenarios. However, the limits at 750 ft from the source are exceeded.
- Critical turbidity levels are exceeded in the simulations using large content of small fines (13% of fines).

Considering the extent of the plume, during other stages of the construction of the Ship Island fill critical turbidity levels due to suspended sediments are likely to reach the Eastern and Western sea grass areas. These sea grass areas will only be affected during limited periods of time (the source with fines is moving with the progress of work), when construction takes place in vicinity of the islands, Model results show an impact on sea grass areas only when the (very conservative) high content of small fines (13%) is used as fill material. Given the fact that the turbidity plumes are more confined during neap tides, these tidal periods are most critical. In addition, background turbidity levels and re-suspension of fine sediments are not considered. Results should be interpreted as suspended sediment concentrations due to dredging activities in addition to possible background turbidity levels (not included in the model simulations).

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[3] US Army Corps of Engineers – Mobile District, Specifications for MSCIP COMPREHENSIVE BARRIER ISLAND RESTORATION PHASE I, Draft tender documents, May 2012

[4] Van Rijn, L.C., 1993. Principles of Sediment Transport in Rivers, Estuaries and Coastal Seas, Aqua Publishing, Amsterdam

[5] Southgate, H.N. (1995), The effects of wave chronology on medium and long term coastal morphology. Coastal Engineering, 26, pp. 251-270

[6] Dean, R.G., 1977. Equilibrium beach profiles: U.S. Atlantic and Gulf Coasts, Ocean Engineering Report, 12.University of Delaware, Newark, DE

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7 COLOPHON

Client	:	US Army Corps of Engineers
Project	:	Mississippi Barrier Island Restoration
File	:	AC8767-101-106
Length of report	:	61 pages
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APPENDIX 1 Memo Design Workshop

To	:	Elizabeth Godsey (USACE)
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Copies to	:	David Stejskal (CH2MHILL), Dirk-Jan Walstra (Deltares)
File	:	AC8767
Project	:	Mississippi Barrier Island Restoration
Subject	:	Design Review Workshop report
Our ref	:	LW-AF20121519/RK
Date	:	28 June 2012
Classification	:	Client confidential

INTRODUCTION

Following the Pre-solicitation meeting with the dredging contractors for the MsCIP Comprehensive Barrier Island Restoration Plan - Phase I, the technical teams of USACE and CH2MHILL/DHV/Deltares held a workshop to discuss various design issues related to the work to be undertaken by Consultants. This memo summarizes the discussions and the choices to fine-tune and finalize the scope of works.

USACE were represented by Tom Smith, Justin McDonald and Elisabeth Godsey.
Consultants were represented by David Stejskal (CH2MHILL), Dick Kevelam, Linda Mathies, Marius Sokolewicz, Johan Henrotte (all DHV), Dirk-Jan Walstra and Hans de Vroeg (Deltares).

ISSUES DISCUSSED

Purpose of the work

This assessment is intended as a means to provide more detailed information on the hydrodynamic and morphological processes during closure of the Camille Cut. This information will help the contractors to identify possible problems, and to reduce their risk profile. With reduced risk, lower bid could be expected.

Phasing of the project

The Ship Island restoration project will be constructed in 4 phases, under separate contracts. Phase 1 comprises initial closing of the gap, Camille Cut, between the East and West Ship Island, with a 500 ft wide berm up to +5ft NAVD88. A total amount of 6.1 MCY. of sediment will be placed during the first phase. In the following three phases, this berm will be widened to the full width of 1100 ft and raised to the final level of +7 ft NAVD88 (phase 3 and 4). Also large beach nourishment on the south side of East Island will be carried out (phase 2). Relatively coarse sand (320 µm) from the Petit Bois borrow pit will be used for most of the construction, finer sand from the Ship Island borrow pit will be used for the cap on the island.
Presently, a contract for Phase 1 is being prepared; this phase was also the subject of consultations with dredging contractors on 14 June 2012. The construction activities for Phase 1 are expected to start in March-April 2013 and last 1 year.
Work undertaken by DHV/Deltares relates to Phase 1.

Construction vs design template

The initial profile constructed by the contractor will be a temporary equilibrium slope which will adjust by itself to the wave energy conditions. An underwater slope of 1 in 20 is assumed in the *construction template*. In many similar projects, actually steeper slopes have been observed. In time, the slope will adapt to the governing wave conditions. Shape of the resulting profile (for the *design template*) has been estimated by USACE based on the historical observations and equilibrium profile considerations.

Use of coarse vs fine sand

USACE assumed use of coarse sand for the core and slopes of the fill, and capping of the fill with finer sand from the nearby borrow site. Some dredging contractors suggested using fine sand as core, and capping the fill with coarse sand. Considering that island should sustain (fresh water) vegetation, it is of paramount importance that a fresh water lens can develop in groundwater, keeping the precipitation apart from sea water. Using fine sand for the core would considerably worsen the conditions for the forming of such a lens, hampering development of vegetation. Furthermore, in case of breaching, finer sand will be eroded away from the core easier than in case coarse sand is used.

Sand losses

Strong flows through the closure gap may erode the fill causing the losses. However, sand eroded away from the Phase 1 construction profile will not be considered loss if it remains within the final design template. In the project assumptions of USACE, up to 30% of loss from the construction template in Phase 1 could be considered acceptable provided that the largest part of this sand will stay within the final template. For the total project (Phases 1 through 4), loss of 10% is assumed.

Environmental issues

In the (already completed) contract for nourishment near the Mississippi Fort, sea grass areas had to be protected from turbidity by placing screens made of geoxtile. For the Phase 1 works, the sea grass areas are located further away. The risk of high turbidity negatively impacting the sea grass areas is subject of investigations in the present assignment to DHV/Deltares. 50 NTU is to be used as a critical value.

Method of work

The present tender (in preparation) calls for use of hopper dredger(s), in combination with hydraulic pumping and/or small barges. Such work method is considered coherent with the local site conditions (shallow depths limiting use of large equipment). Sufficient production capacity must be available to close the final gap (the minimum required production capacity will be checked with model simulations by DHV/Deltares).

During the meeting with the contractors, also alternative work methods were proposed by some contractors (e.g, use of a cutter dredger). For the purpose of the work by DHV/Deltares, use of a hopper dredger and hydraulic pumping will be assumed.

Closing strategies

The basic strategy to close the Camille Cut as envisaged by USACE is to fill the gap from East to West, following the direction of littoral transport. The way of thinking here is that as the (prior to hurricane Katrina) Camille Cut actually nearly closed itself by the natural processes, the best closing strategy will be to follow the direction of natural processes. This way of working implies that the rather deep (ebb) gully near the eastern tip of the West Ship Island will be closed as last. With some wind, head difference may develop across the final stage closure gap, creating strong flow ($u = \text{sqrt}(g\ \Delta h)$, assume $\Delta h = 0.3m \rightarrow u = 1.7$ m/s).

Some contractors suggested closing this gully with a temporary sheet pile. However, National Parks Service objects using any non-natural materials, even as temporary structure.

Another strategy would be to close the Camille Cut from both sides, or starting from West to East. This will be investigated by DHV/Deltares.

Attenuation of wave energy
In case erosion by waves is considered a problem, a simple solution would be to use floating breakwaters. They are quite effective in waves up to 1 meter high, and could be applied in this case. However, considering the large length of required protection this is not expected to be a cost-effective solution; increasing production capacity to shorten the period of exposure of the uncompleted fill is expected to be more effective.

REFINED SCOPE OF WORK

Task 1. Optimization of the Profile Design for the Restored Ship Island Fill
The original scope mentions 3 different fill alternatives. It is acknowledged that the underwater slope will form under influence of forces of nature and cannot be reshaped by the contractor. Therefore, only one profile (= construction profile as devised by USACE) will be considered. DHV/Deltares will use it to run a 1D cross-shore sand transport model for a longer period of time (max. 1 year), and to compare the profile development (Gulf side and Sound side) with the design profile. This should give an indication of the profile erosion during storms, and whether the eroded sand will remain within the active transport zone or it will be lost to deeper water. The calculated sand loss from the initial profile will be compared with the 10% loss assumed by USACE.
Different time scales will be considered (till max 1 year). Cold fronts will be addressed.

Task 2. Estimation of Sand Losses during Construction of the Ship Island Fill
In this task, three initial closure scenarios will be considered:

1. closing from East to West;
2. close gully in the west, and process further from the east;
3. to be defined upon hydrodynamic investigations

DHV/Deltares will first study in detail the hydrodynamic conditions in the closure gap. To that extent, the gap will be closed in the model in several steps (e.g. 50%, 75%, 90%, 95%), from East to West and vice versa, and the velocities in the gap will be examined. The third scenario will be proposed, to be approved by USACE. All selected scenarios will be presented and discussed with USACE.
The final gap to be considered in detail in morphologic simulations will be selected taking into account the production capacity (size of gap that can be closed within 1(?, tbd) week).

USACE will provide the grain size and the production capacity to be used in the simulations. It is noted that the coarse sand will remain close to the flow pipe, in the simulations smaller D50 will be used; the reduction factor will be selected from experience of DHV in earlier projects.

Task 3. Identification of Protection Measures to Minimize Turbidity during Construction
From the initial assessment of hydrodynamic conditions in task 2 also scenarios for task 3 will be derived. The approach remains as described in our proposal.

REPORTING

The report should be clear to non-technical people; however sufficient technical details need to be provided. It will be included as an addendum to the main report of the modeling study, but should be readable as a separate document.
Animations from simulation results will be made to illustrate the processes and support the conclusions.

APPENDIX 2 Overview provided data

1. SHIP ISLAND WORK equilibrium template_0.32mm.dwg- USACE, 08/13/2012
2. Pre-solicitation Presentation_14June12.pptx- USACE, 06/26/2012
3. Phase I Barrier Island Restoration - SPECS.pdf- USACE, 06/26/2012
4. Phase I - Draft Plans.pdf - USACE, 06/26/2012
5. Petit Bois East Borrow Geotechnical Summary.xlsx - USACE, 06/26/2012
6. MsCIP_2010_SAVs.shp - USACE, 03/07/2012 – USACE, 09/25/2012
7. MsCIP Barrier Island Restoration Construction Production Estimates.docx - USACE, 03/07/2012
8. Mississippi State Turbidity Mixing Zone Standards.docx – USACE, 03/07/2012
9. USACE Pre-solicitation Presentation_14June12.pdf– email Justin McDonald, 06/28/2012

APPENDIX 3 Wave Conditions

Offshore wave conditions at the wave model boundary

Scenario	Class	Number of events	Duration (%)
1	345.0<Dir>15.0,0.0<Hs>0.5	281	0.8994
2	15.0<Dir>45.0,0.0<Hs>0.5	363	1.1618
3	45.0<Dir>75.0,0.0<Hs>0.5	392	1.2546
4	75.0<Dir>90.0,0.0<Hs>0.5	245	0.7842
5	90.0<Dir>100.0,0.0<Hs>0.5	221	0.7073
6	100.0<Dir>110.0,0.0<Hs>0.5	273	0.8738
7	110.0<Dir>120.0,0.0<Hs>0.5	301	0.9634
8	120.0<Dir>130.0,0.0<Hs>0.5	429	1.3731
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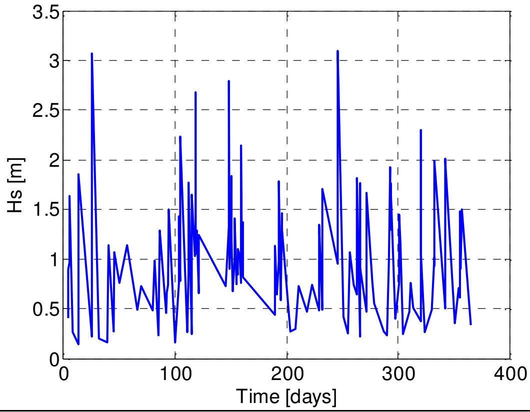
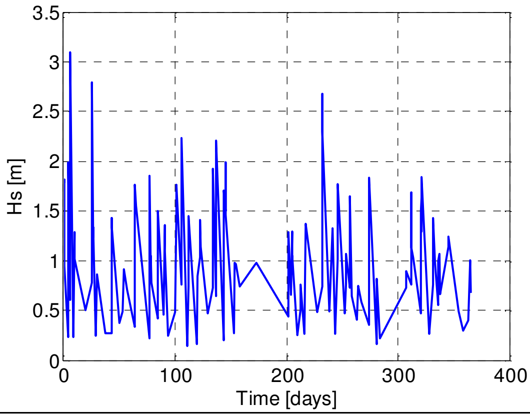
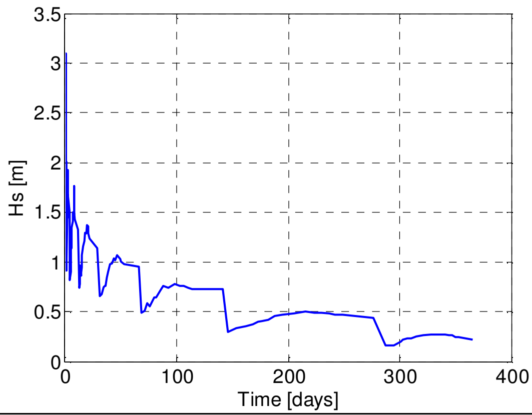
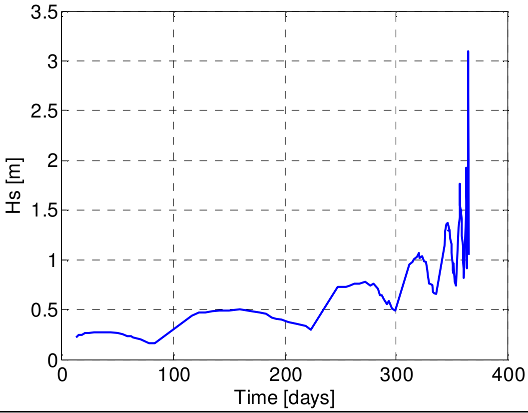
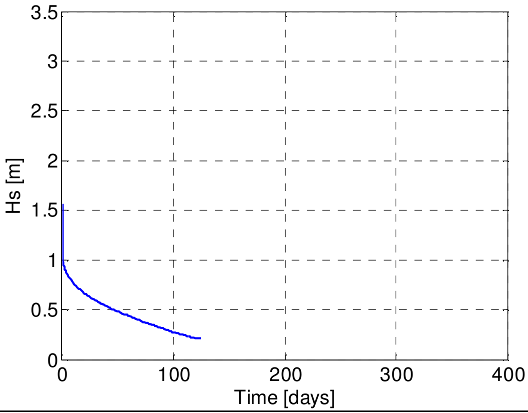
154	285.0<Dir>315.0,3.5<Hs>4.0	10	0.032
155	315.0<Dir>345.0,3.5<Hs>4.0	2	0.0064
156	75.0<Dir>90.0,4.0<Hs>Inf	5	0.016
157	90.0<Dir>100.0,4.0<Hs>Inf	4	0.0128
158	100.0<Dir>110.0,4.0<Hs>Inf	2	0.0064
159	110.0<Dir>120.0,4.0<Hs>Inf	5	0.016
160	120.0<Dir>130.0,4.0<Hs>Inf	4	0.0128
161	130.0<Dir>140.0,4.0<Hs>Inf	2	0.0064
162	140.0<Dir>150.0,4.0<Hs>Inf	5	0.016
163	150.0<Dir>160.0,4.0<Hs>Inf	3	0.0096
164	255.0<Dir>285.0,4.0<Hs>Inf	1	0.0032
165	285.0<Dir>315.0,4.0<Hs>Inf	5	0.016

Table 5.3 Binned wave climate.

Schematization wave climate used in UNIBEST-TC modeling

Run	Description	
GULF Side		
Wave sequence 1	Random 1 (mixed high and low waves)	
Wave sequence 2	Random 2 (mixed high and low waves)	
Wave sequence 3	High significant wave heights first	

Wave sequence 4	Low significant wave heights first	
Sound Side		
Wave sequence 3A	Sound side wave climate (High significant waves heights first)	

APPENDIX 4 Sediment characteristics for turbidity simulations

The model requires the input of a sediment concentration (kg/m^3) with a certain discharge intensity (flux, m^3/s) as a single source. In order to find the correct sediment concentrations the process of filling is considered as follows:

- The mixture of sediment and (additional process) water is pumped from the hopper into the fill with a discharge intensity of about 5 m^3/s;
- The sediment mass concentration in this mixture is about 435 kg/m^3 assuming a mixture density of about 1,300 kg/m^3;
- Most of the coarser sediment obviously settles directly into the fill, but the finer sediment will be carried out further into the surrounding water. This is the source of sediment we have to use in the model.

Example:
The total sediment mass concentration in the mixture is about 435 kg/m^3 and suppose that this sediment mass contains 9% fines. Since the discharge intensity of 5 m^3/s will not significantly change after settling of the coarser sediment (in terms of volume most of the mixture leaving the discharge pipe is water), the sediment mass concentration of fines is about 10% of the sediment mass concentration of the mixture, or in this example around 44 kg/m^3. In a similar way we can find the sediment mass concentrations for the different grain sizes according the distribution in the sediment.

It is noted that the model does not include jet flow modeling and that the results are not depending on the discharge intensity itself as long as the mass amount of sediment discharged is about correct. For reasons of model stability we use a mixture discharge intensity of 1 m^3/s in stead of the more realistic 5 m^3/s for a 900mm discharge pipe line. In order to discharge the proper amount of sediment (flux) as a source into the model we have to multiply the sediment mass concentration with a factor 5. This has no effect on the modeling results as the flux of fines is correct.

In the model, five different sediment classes are defined within the source. The parameters used are summarized in Table 7-1.

Table 7-1 Overview of sediment classes used in turbidity modeling

Sediment nr	Sediment class	D50 [µm]	% of total weight [%]	Amount of sediment [kg/m^3]
Fines 1	40-74 µm	50	5%	136
Fines 2	30-40 µm	30	3%	82
Fines 3	0-30 µm	10	1%	27

A sediment class (e.g. 40-74 µm) is represented by a single grain size, in this case 50 µm. The sum of the three classes (fines 1, 2 and 3) is the total fraction of fines, 9%, as defined in Chapter 3.1.1 in this report. It is noted that at the start of the study, no actual data was available on the subdivision of the fractions below 74 µm. This subdivision has been estimated by rule of thumb and therefore only provides a general impression on the potential dispersal of the finest fractions within the fill material.

The model covers both flow and wave induced sediment transport for fractions above 74 µm and dispersive transport for fractions below 74 µm. Source induced dispersive transport is mainly governed by the fall velocity of the particles in water.

In September 2012, when the modeling work was already far advanced, USACE provided additional information on the fines. Using the 15 samples that were lab-tested for fines, the geotechnical lead of the USACE tried to match up the category sizes with what was tested for, and came out with different figures for each category:

- Fines 1 (40-74 µm): 0.3%;
- Fines 2 (30-40 µm): 0.4 %;
- Fines 3 (0-30 µm): 13 %.

It is noted that these 15 samples were selected as having the highest fines content; therefore, this information can be considered as very conservative. It is used in the present study as a worst-case scenario, as the content of fines in the hopper can be influenced either by avoiding areas with very high content (the amount of sediment available in the pit is larger than required for the operation), or by overflowing.

In order to assess the effect of this high content of very fine material, an additional sensitivity simulation is executed with using the values defined in Table 7-2.

Table 7-2 Overview of sediment classes used in turbidity modeling for sensitivity computation

Sediment nr	Sediment class	D50 [µm]	% of total weight [%]	Amount of sediment [kg/m^3]
Fines 1	40-74 µm	50	0.3%	8.18
Fines 2	30-40 µm	30	0.4%	10.9
Fines 3	0-30 µm	10	13 %	362.82

APPENDIX 5 Unibest-TC model

The Unibest-TC model comprises coupled, wave-averaged equations of hydrodynamics (waves and mean currents), sediment transport, and bed level evolution. Straight, parallel depth contours are assumed throughout. Starting with an initial, measured cross-shore depth profile and boundary conditions offshore, the cross-shore distribution of the hydrodynamics and sediment transport are computed. Transport divergence yields bathymetric changes, which feed back to the hydrodynamic model at the subsequent time step, forming a coupled model for bed level evolution. The phase-averaged wave model is based on Battjes and Janssen (1978) extended with the roller model according to Nairn et al. (1990) and breaker delay concept (Roelvink et al., 1995) to have an accurate cross-shore distribution of the wave forcing. The wave height to depth ratio, γ, of Ruessink et al. (2003) was used as it results in accurate estimates of the wave height across bar-trough systems. The vertical distribution of the flow velocities are determined with the Quasi-3D approach of the Reniers et al. (2004) 1DV model. Based on the local wave forcing, mass flux, tide and wind forcing a vertical distribution of the longshore and cross-shore vertical velocities are calculated. These advective currents are combined with oscillatory wave motion in such a way that the resulting velocity signal has the same characteristics of short-wave velocity skewness, amplitude modulation, bound infragravity waves, and mean flow as a natural random wave field (Roelvink and Stive, 1989). The transport formulations distinguish between bed load and suspended load transport. The bed load formulations (Ribberink, 1998) are driven by the instantaneous velocity signal. The suspended transports are based on an integration over the water column of the sediment flux. The wave-averaged near bed sediment concentration is prescribed according to Van Rijn (1993) which among others is driven by a time-averaged bed shear stress based on the instantaneous velocity signal. A detailed description of the Unibest-TC model can be found in Ruessink et al. (2007) and Walstra et al. (2012).

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APPENDIX 6 Overview Delft3D model runs

Base Runs

		Conditions			
Closure scenario	**Closure percentage**	**Waves from gulf**	**Waves from sound**	**High waves from gulf**	**No waves (only tide)**
East-West	**70 %**	*run06*/ run13	run07/ run14	run10	run03
	90%	run15/ run20			
Both sides	**70%**	*run06*/ run13	run07/ run14	run10	
	90%	run15/ run20			

Sensitivity Runs

		Sensitivity runs (base case run06)					
Closure scenario	**Closure percentage**	**Timestep (decrease)**	**Critical shear stress**	**Fall velocity**	**13% fines**	**Increased discharge duration**	**Larger hopper size**
East-West	**70 %**	run02		run19	run17	run16	run18
	90%						
Both sides	**70%**		run09	run19	run17	run16	run18
	90%						