RPS

Rosslare Dredging & Beach Nourishment Study

Sediment Transport Modelling

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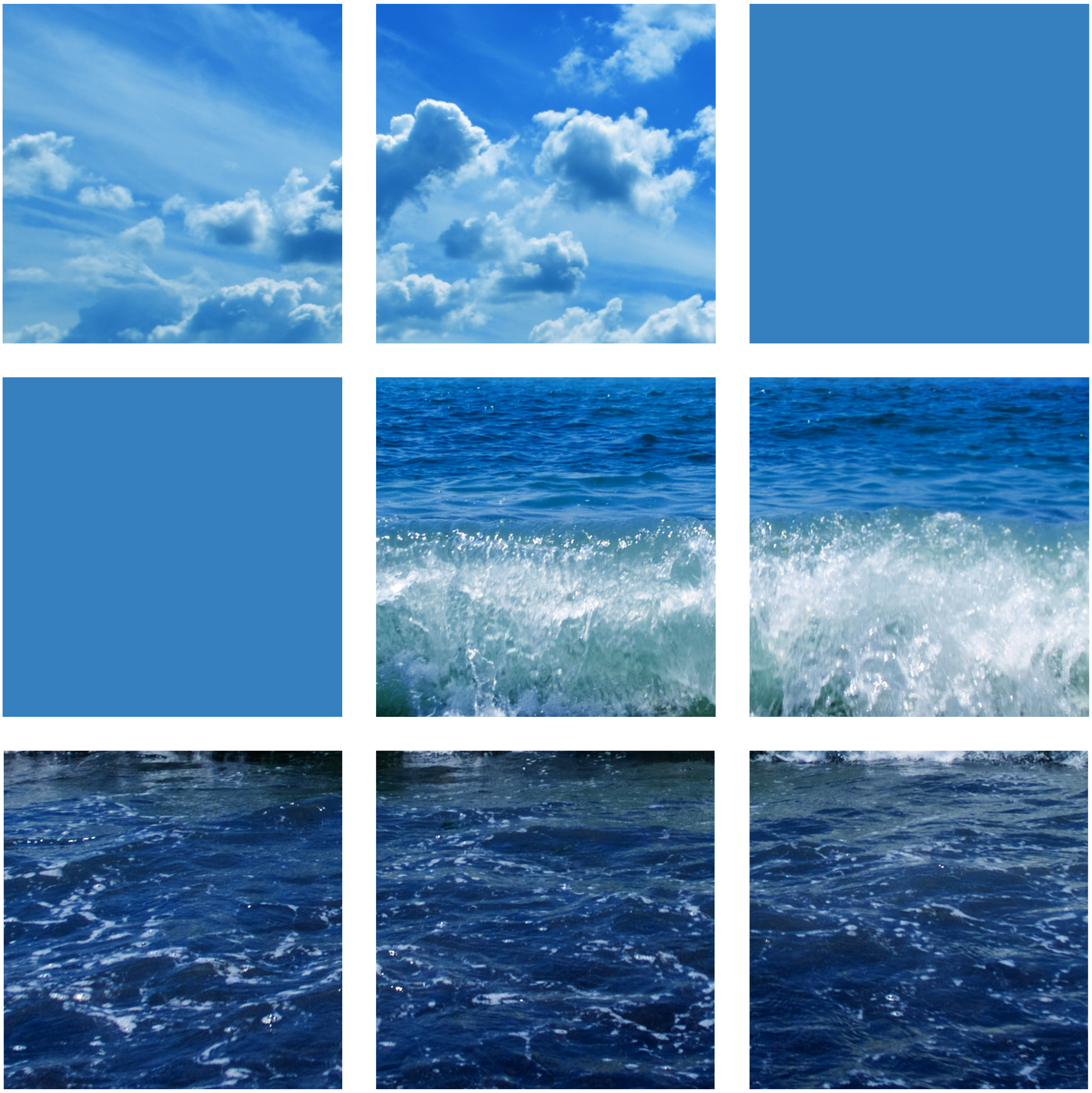

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1 INTRODUCTION

1.1 OVERVIEW

As a result of winter storms during January and February 2014 significant sediment transport and deposition has taken place in the Rosslare area. As a consequence, maintenance dredging is required at Rosslare Europort to allow continued provision of the full operational facilities. In previous campaigns maintenance dredging has been integrated with beach re-nourishment and it is proposed to adopt this approach with the dredging necessitated by the recent storm activity.

RPS previously carried out the modelling associated with the former dredging and re-nourishment campaign and in this study used an existing integrated flexible mesh model with some adaptation to suit the specific needs of the project.

1.2 METHODOLOGY

The modelling was undertaken using the MIKE suite of software developed by DHI of Denmark using a model RPS had previously developed and calibrated. The coupled flexible mesh model was used to incorporate tidal currents, wave climate (using Spectral Wave modelling) and sediment transport.

The model was updated and refined to the reflect the specific needs of this modelling in order to provide the necessary resolution within the areas under examination. The model was then used to simulate the following conditions to determine the fate of material arising from the dredging/ beach re-nourishment campaign.

- Calm tidal conditions
- Wind waves under storm (F6) conditions from the east, north east and south east
- Wind and swell storm conditions from the south east.

The first scenario relates to the re-nourishment campaign as it is undertaken and the latter cases examine the subsequent transport characteristics under storm conditions following the dredging/placement programme.

2 TIDAL MODELLING SYSTEM

The tidal flow simulations which formed the basis of the study were undertaken using the MIKE21 FM flexible mesh modelling system. The FM Module is a 2-dimensional, depth averaged hydrodynamic model which simulates the water level variations and flows in response to a variety of forcing functions in lakes, estuaries and coastal areas. The water levels and flows are resolved on a mesh covering the area of interest when provided with bathymetry, bed resistance coefficient, wind field, hydrodynamic boundary conditions, etc.

The system solves the full time-dependent non-linear equations of continuity and conservation of momentum using an implicit ADI finite difference scheme of second-order accuracy.

The effects and facilities incorporated within the model include:

- Convective and cross momentum;
- Bottom shear stress;
- Wind shear stress at the surface;
- Barometric pressure gradients;
- Coriollis forces;
- Momentum dispersion (e.g. through the Smagorinsky formulation);
- Wave-induced currents;
- Sources and sinks (mass and momentum);
- Evaporation;
- Flooding and drying.

3 TIDAL MODEL

An existing tidal model was further developed for the assessment of the Rosslare re-nourishment study; the main aspects of the model are outlined in the following sections.

3.1 MODEL DOMAIN

The tidal domain covered a large area of St George's Channel as shown in Figure 3.1; this enabled the tidal currents to be accurately simulated within the model. The model resolution varied across the domain with coarser cells at the model boundaries and smaller cells, in the order of 10m, in the vicinity of the re-nourishment site. The model resolution at the site is illustrated in Figure 3.2. This flexible mesh approach meant that the detailed bathymetry of the area could be depicted whilst maintaining computational efficiency.

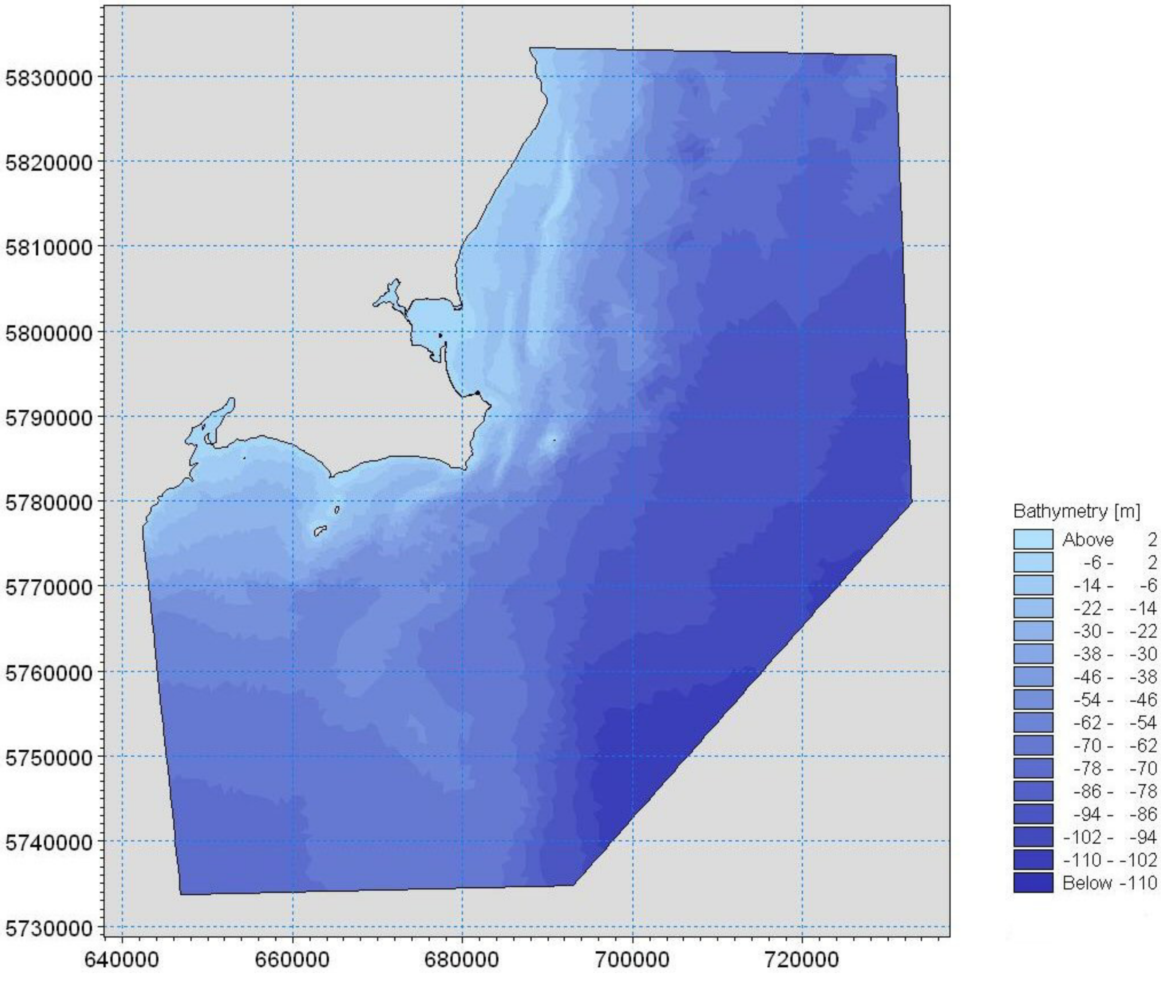

Figure 3.1: Model domain of the Rosslare coastal model

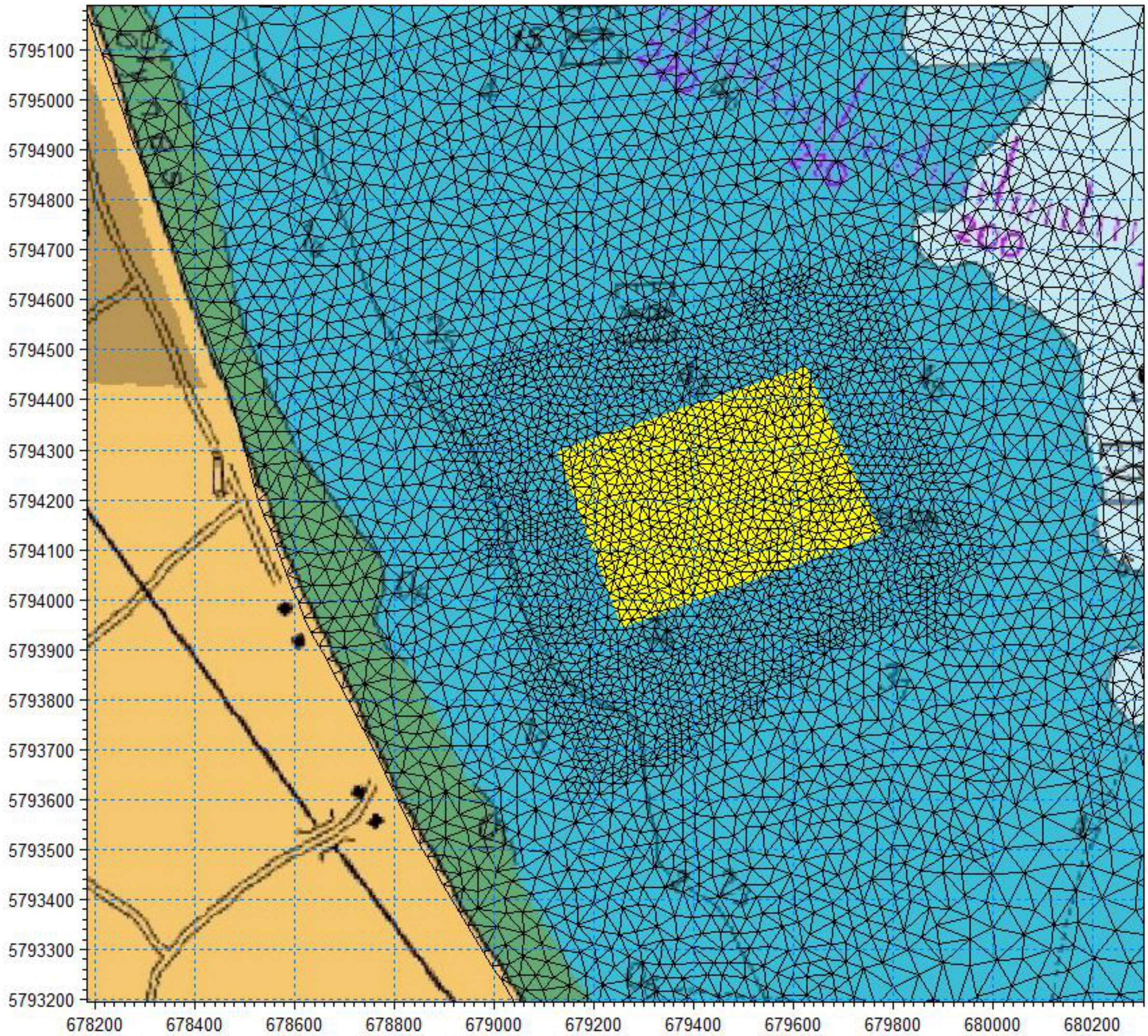

Figure 3.2: Mesh detail at re-nourishment site (shown in yellow)

3.2 DATA SOURCES

The data used to define the bathymetry of the model was derived from various sources. Firstly the offshore areas utilised digital chart data. A number of recent bathymetric surveys were also incorporated into the model this included a survey carried out by Hydrographic Surveys for related projects. The model also integrated previous surveys dating back to 2007 as shown in Figure 3.3. Where bathymetric survey data was available from multiple surveys for the same area the most recent data was used.

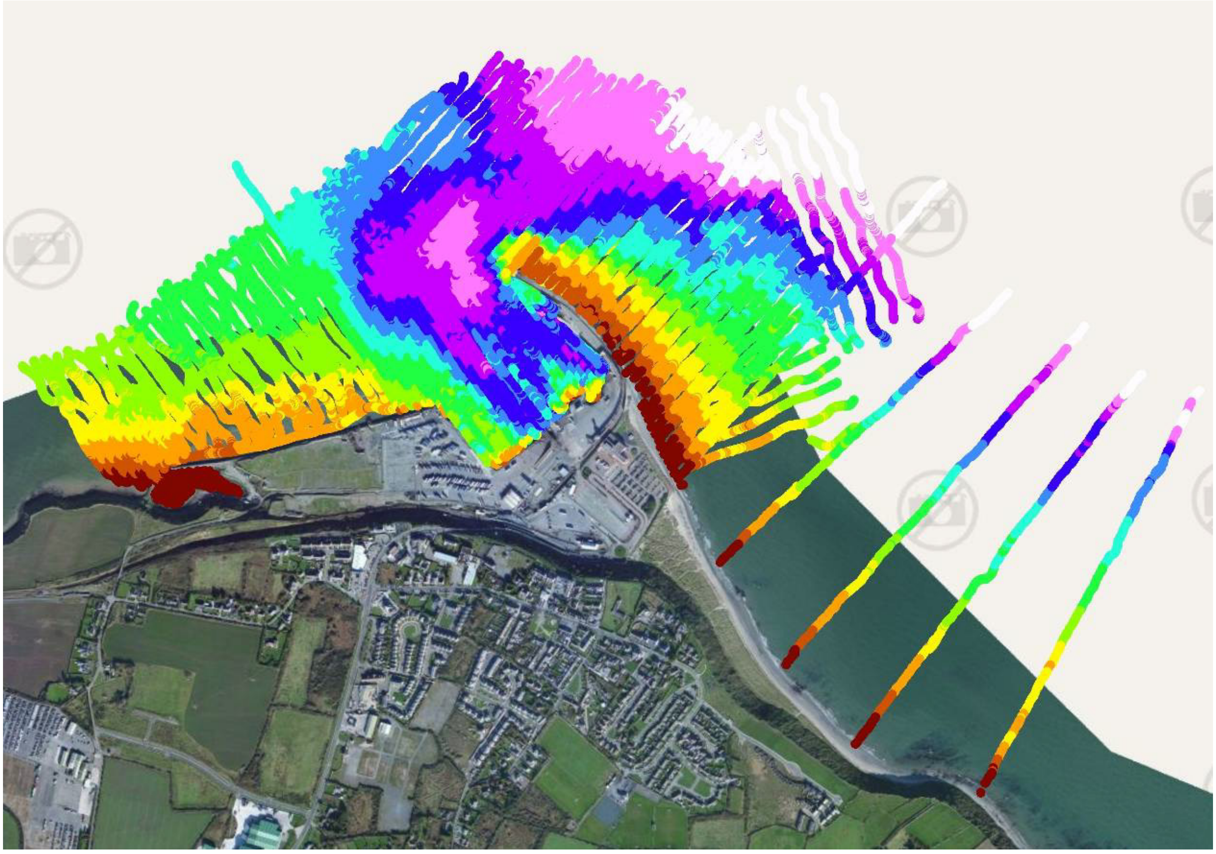

Figure 3.3: Example of bathymetric survey data available

3.3 BOUNDARY CONDITIONS

The tidal level boundary used for the Rosslare model was simulated by RPS' Irish Sea Surge model. The Irish Sea model stretches from the North-western end of France including the English Channel as far as Dover out into the Atlantic to 16° west, including the Porcupine Bank and Rockall. In the other direction it stretches from the Northern part of the Bay of Biscay to just south of the Faeroes Bank. Overall the model covers the Northern Atlantic Ocean and UK continental shelf up to a distance of 600km from the Irish Coast as illustrated in Figure 3.4.

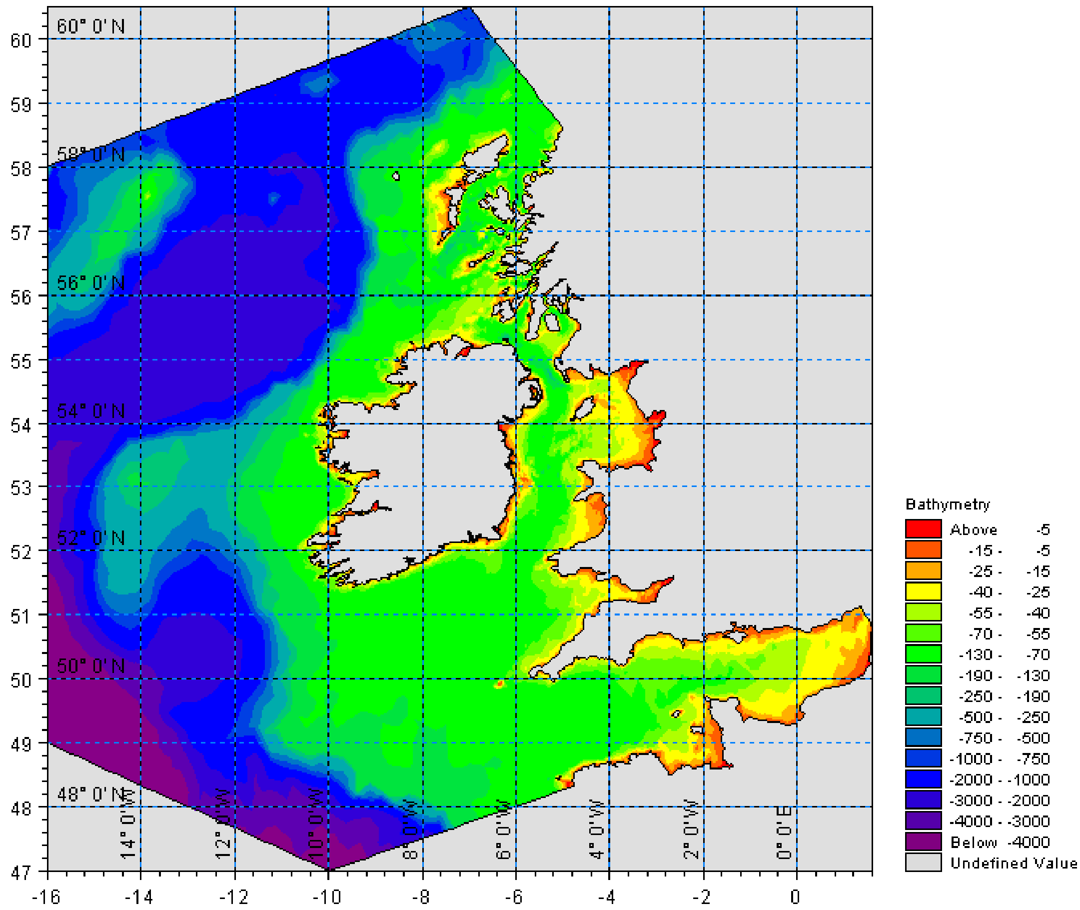

Figure 3.4: Extent of the RPS Irish Seas Tidal Surge model

This model was also constructed using flexible mesh technology; along the Atlantic boundary the model features a mesh size of 13.125' (24km). The Irish Atlantic coast has been described using cells of on average 3km size while in the Irish Sea the maximum cell size is limited to 3.5 km decreasing to 200m along the Irish coastline. The bathymetry was generated from a number of different sources including digital chart data and surveys of several banks and coastal areas. The model is driven by astronomic tides generated using a global tidal model designed by a team at the Danish National Survey and Cadastre Department (KMS).

4 MODELLING SIMULATIONS

4.1 OVERVIEW

MIKE 21 Flow Model FM is a modelling system based on a flexible mesh approach. The modelling system was developed for applications within oceanographic, coastal and estuarine environments. It is composed of following modules:

- Hydrodynamic Module
- Transport Module
- ECO Lab Module
- Mud Transport Module
- Sand Transport Module

The Hydrodynamic Module is the basic computational component of the entire MIKE 21 Flow Model FM modelling system providing the hydrodynamic basis for the Transport Module, ECO Lab Module, Mud Transport Module and Sand Transport Module.

The Rosslare Study utilised the Mud Transport Module and also the Transport Module (which further includes Spectral Wave modelling). Each of these aspects are described further in the appropriate sections of this document.

4.2 EXISTING TIDAL FLOWS

The numerical model was run to provide baseline data in order to assess accuracy of the model and also to inform the design of the re-nourishment programme. The flows in the region were simulated over a spring and neap tide cycle, for the purposes of brevity spring tidal plots are presented in this document. Figure 4.1 and Figure 4.2 show the typical ebb and flood pattern within the Rosslare / South Bay area respectively. These are 'snapshots' of the flow patterns at mid-tide when the current speeds are at their greatest. It can be seen that the principle flow directions are parallel to the coast and that, at these points in the cycle, the flood tide is marginally stronger than the ebb. However the ebb and flood tide have different characteristics resulting in dissimilar levels of sediment transport associated with each element of the tide.

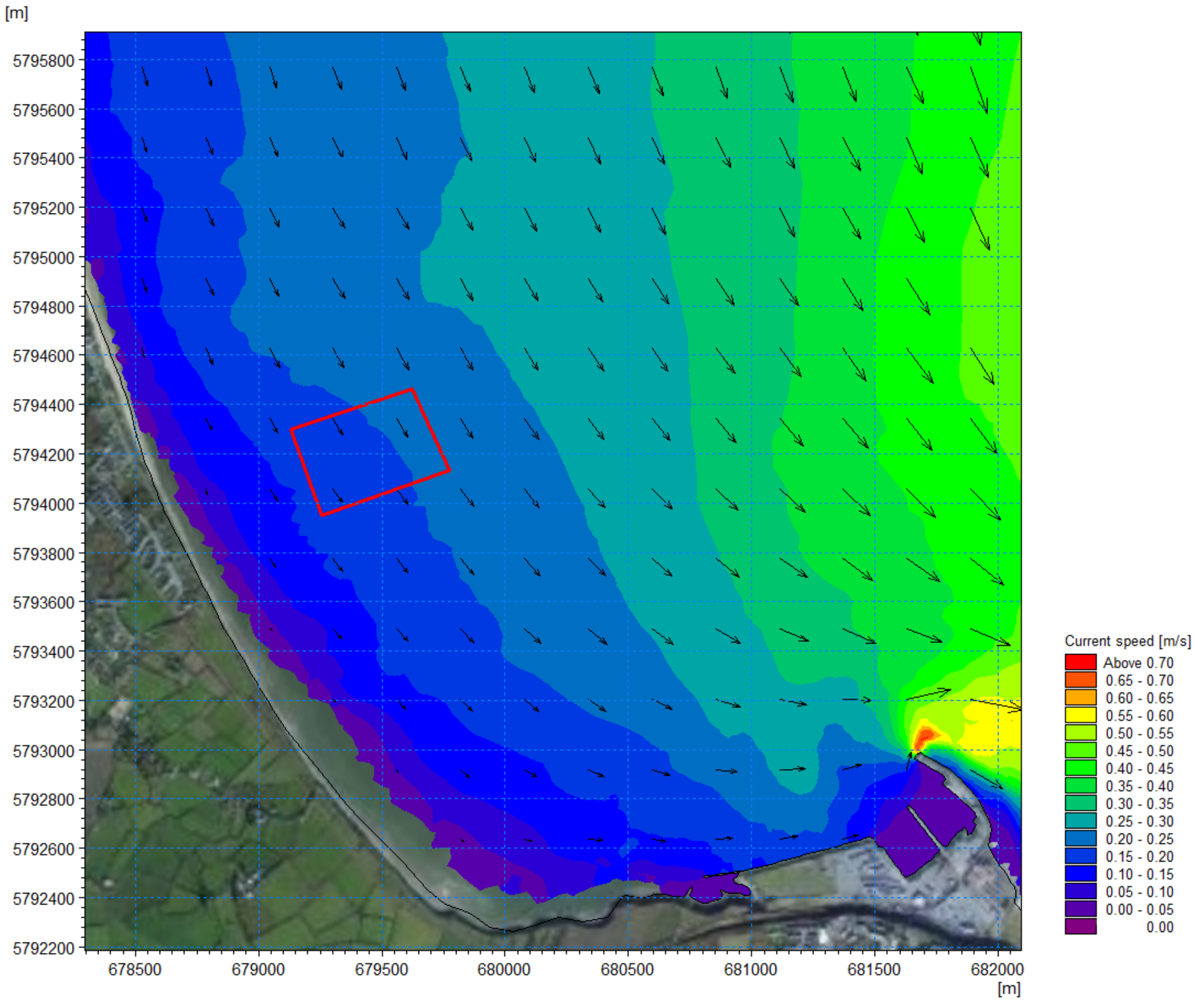

Figure 4.1: Typical ebb flow pattern

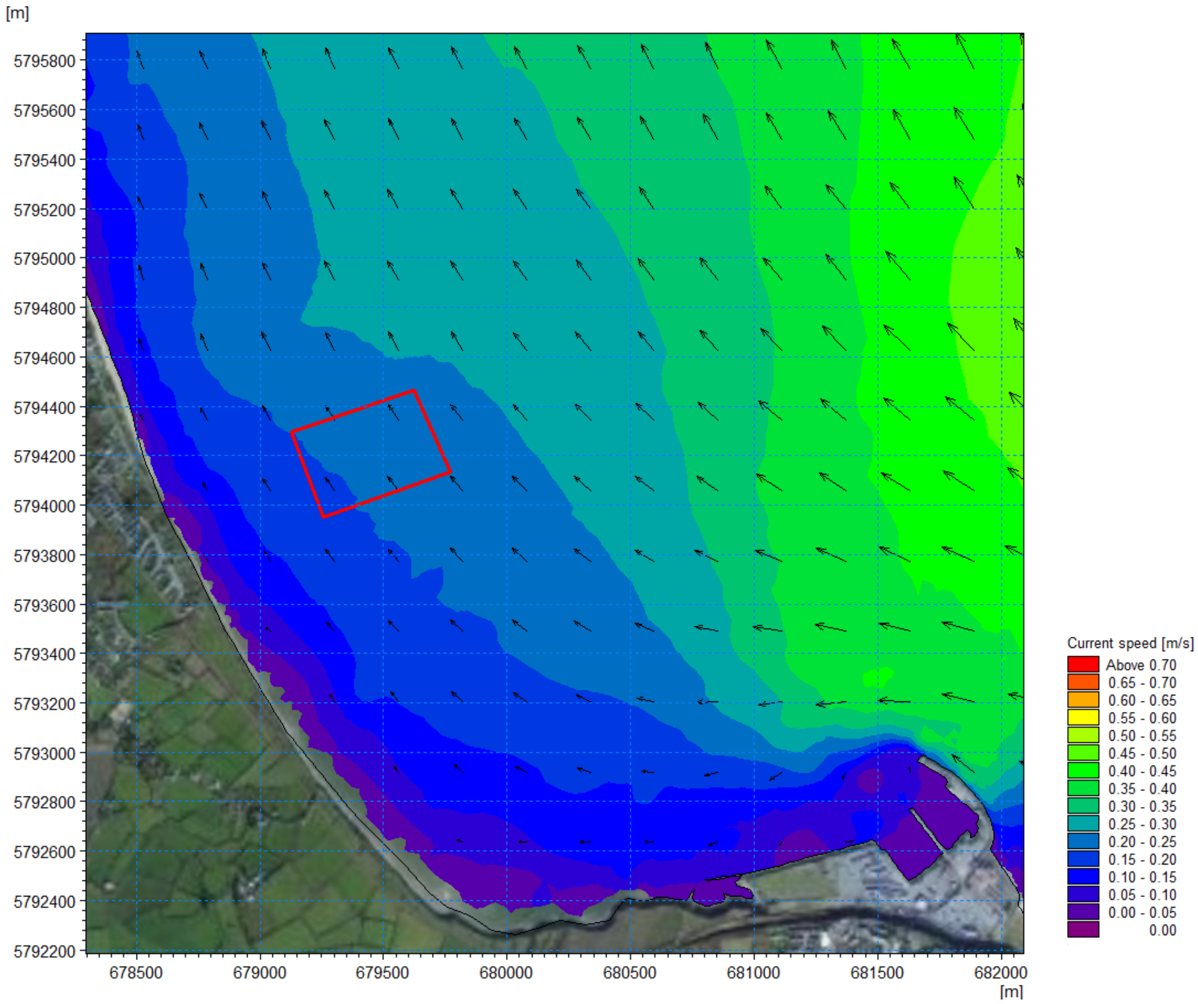

Figure 4.2: Typical flood flow pattern

The residual current is determined by calculating the average current in each direction (north-south & east-west) over a tidal cycle – the result being the net or residual current which is responsible for sediment transport due to tidal currents. These may vary slightly from one tide to another but the general transport regime may be assessed from this information. An example of the residual current in the Rosslare area is shown in Figure 4.3 and demonstrates that these currents are significant offshore. Along the South Bay shoreline the net sediment transport is in a south westerly direction. It should be noted that during storm events, depending on direction, net sediment transport may also be northward on occasion.

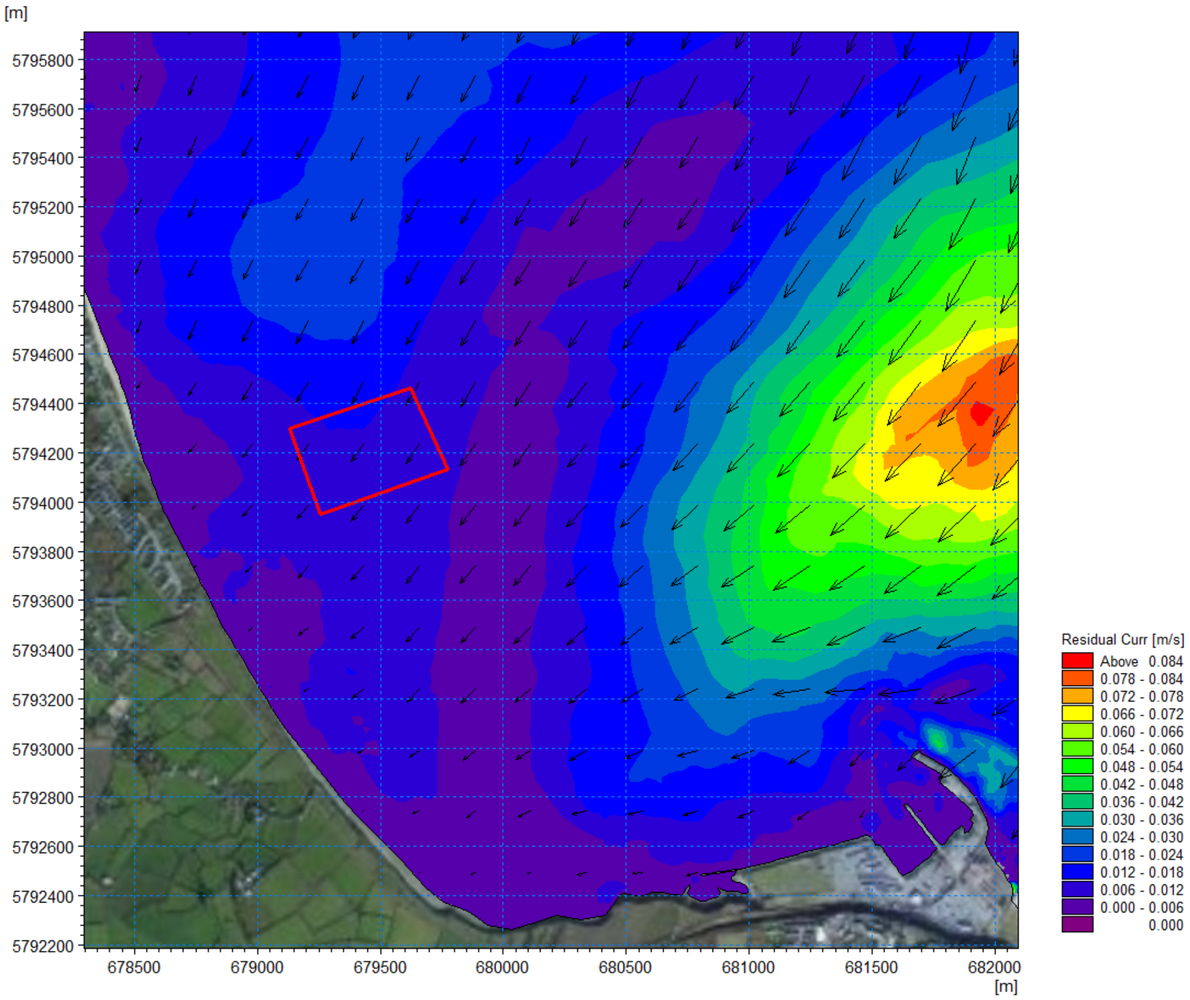

Figure 4.3: Residual current

4.3 MODEL CALIBRATION

The model was calibrated using published Admiralty tidal diamonds to ensure that the complex eddying system around the Rosslare and Wexford Harbour area was accurately recreated. The tidal diamonds are generally related to a limited amount of drogue data and will not be associated with the same period in time as the modelling; but they can be used effectively to ensure the relevant flow patterns are simulated. In the case of the diamond located offshore of the Rosslare Europort (Chart 1787F / Chart 1772B) the ebb tide currents are double that of those on the flood tide and the duration of the flood is shorter due to eddying. This eddying and asymmetric tide gives rise to the large offshore residual currents. The location of this diamond is shown in Figure 4.4. Figure 4.5 and Figure 4.6 show the modelled data compared with the spring diamond data for current speed and direction respectively. It can be seen that the current speeds are of the right order of magnitude and the eddying persists for the correct proportion of the tidal cycle within the model.

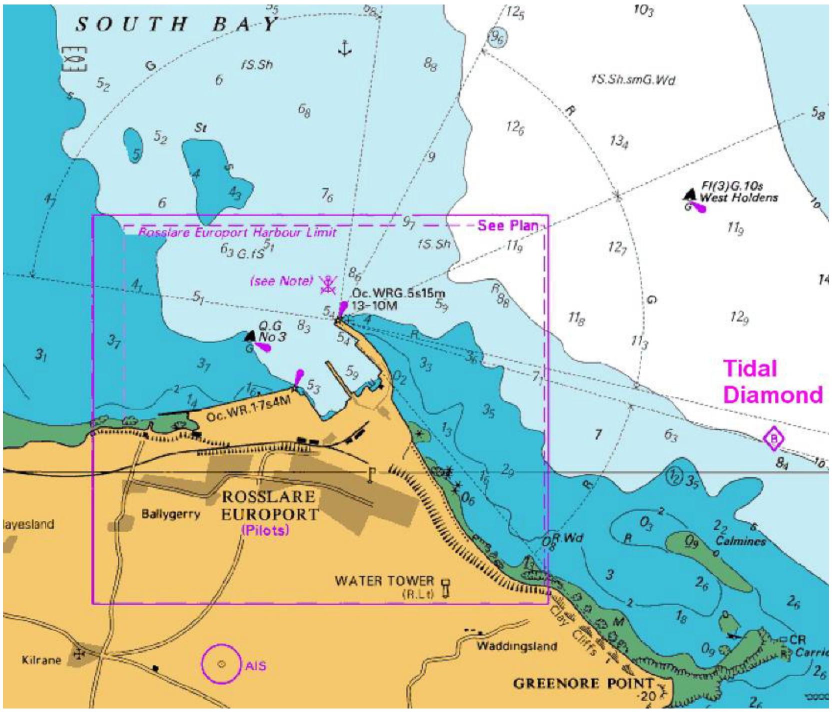

Figure 4.4: Location of Admiralty tidal diamond 1772B

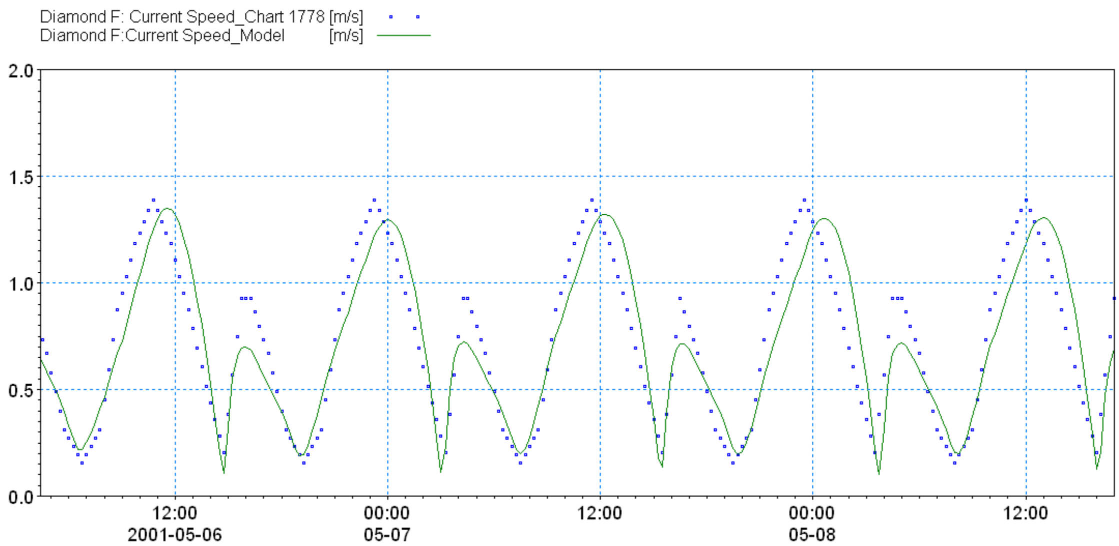

Figure 4.5: Current speed Admiralty diamond 1772B - Rosslare

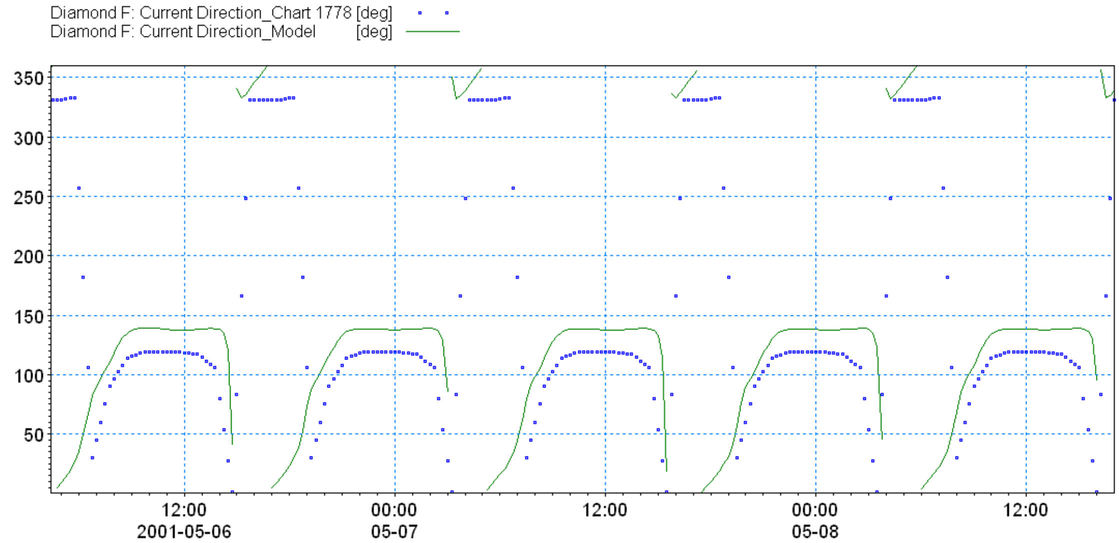

Figure 4.6: Current direction Admiralty diamond 1772B - Rosslare

4.4 MODEL RATIONALE

The scope of the study identified two phases of modelling; the placement of the dredged material under the action of tidal flows and the subsequent transport of material during storm conditions. These are presented separately in the following sections.

4.5 BEACH NOURISHMENT

The first area to be examined is the placement of the dredged sandy material within the re-nourishment area, as shown in Figure 4.7, and bounded by the following co-ordinates:

A	52° 16.19' N	06° 22.48' W
B	52° 16.27' N	06° 22.04' W
C	52° 16.09' N	06 °21.92' W
D	52° 16.00' N	06° 22.38' W

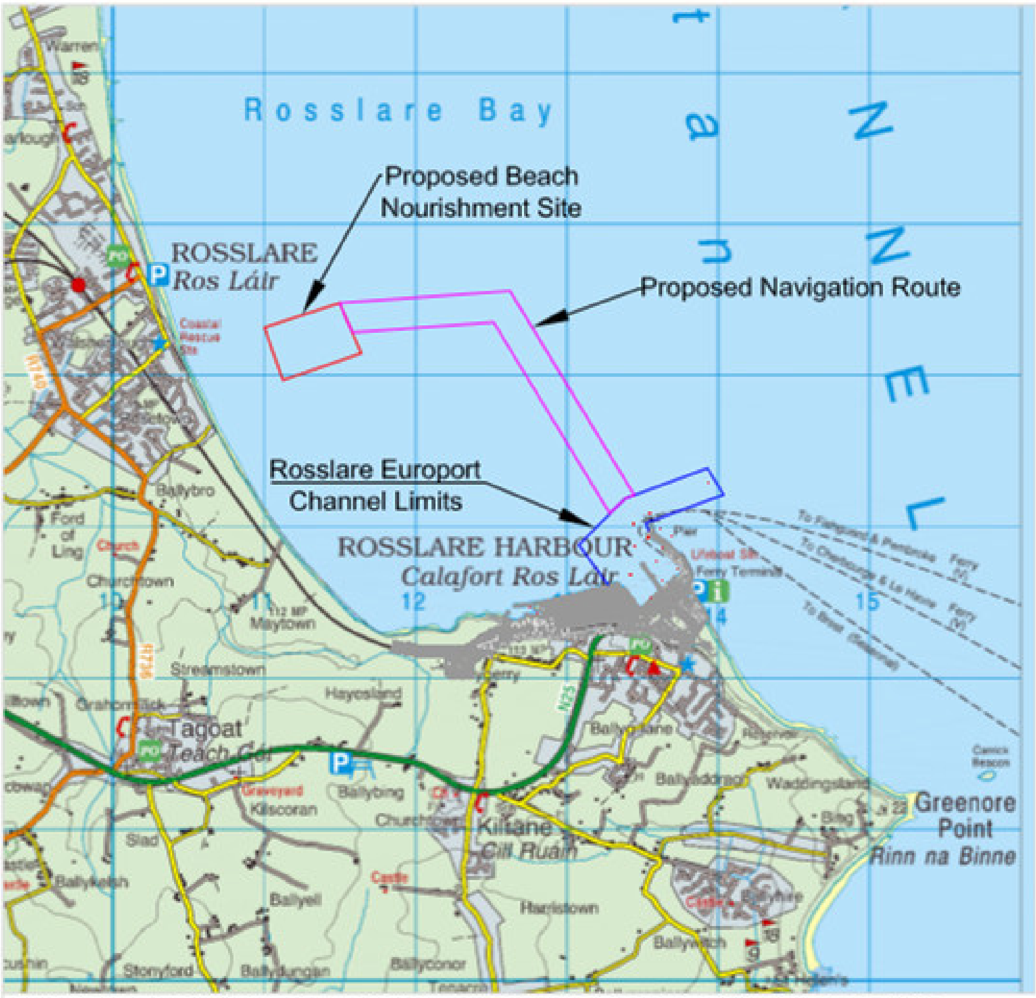

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Figure 4.7: Layout of dredging and nourishment sites

4.5.1 Modelling System

The Mud Transport (MT) module of MIKE 21 Flow Model FM describes erosion, transport and deposition of mud or sand/mud mixtures under the action of currents and (if appropriate) waves. The hydrodynamic basis for the MT Module is calculated using the Hydrodynamic Module of the MIKE 21 Flow Model FM modelling system and the MT is implemented as a couple model with the two running concurrently. The MT module is applicable for mud fractions alone, and also sand/mud mixtures.

The following processes may be included in the simulation.

- Forcing by waves
- Salt-flocculation
- Detailed description of the settling process

- Layered description of the bed, and
- Morphological update of the bed

In the MT-module, the settling velocity varies, according to the salinity, if included, and the concentration taking into account flocculation in the water column. Bed erosion can be either non-uniform, i.e. the erosion of soft and partly consolidated bed, or uniform, i.e. the erosion of a dense and consolidated bed. The bed is described as layered and is characterised by the density and shear strength.

4.5.2 Model simulations

The model simulations for the placement of the re-nourishment material were designed to reflect the anticipated programme as closely as possible. The works would be undertaken using a trailer suction hopper dredger with a 1,500m^3 hopper capacity, carrying out the dredging works over a 15 to 20 day period on a 24/7 basis.

The volume and composition of the material to be dredged and subsequently used for re-nourishment was examined. Figure 4.8 shows the area within the Harbour to undergo dredging (outlined in red) along with the location of the sediment samples taken within this area. It was noted that although S08A is located within the dredging area it is in a very sheltered location and unlikely to be representative of the majority of material to be removed. The sediment characteristics derived from the sampling programme are presented in Table 4.1 and indicate that the material is largely comprised of medium sand and ideally suited for re-nourishment. The modelling was undertaken based on a quantity of 80,000m^3 being removed during the course of the dredging / re-nourishment operation.

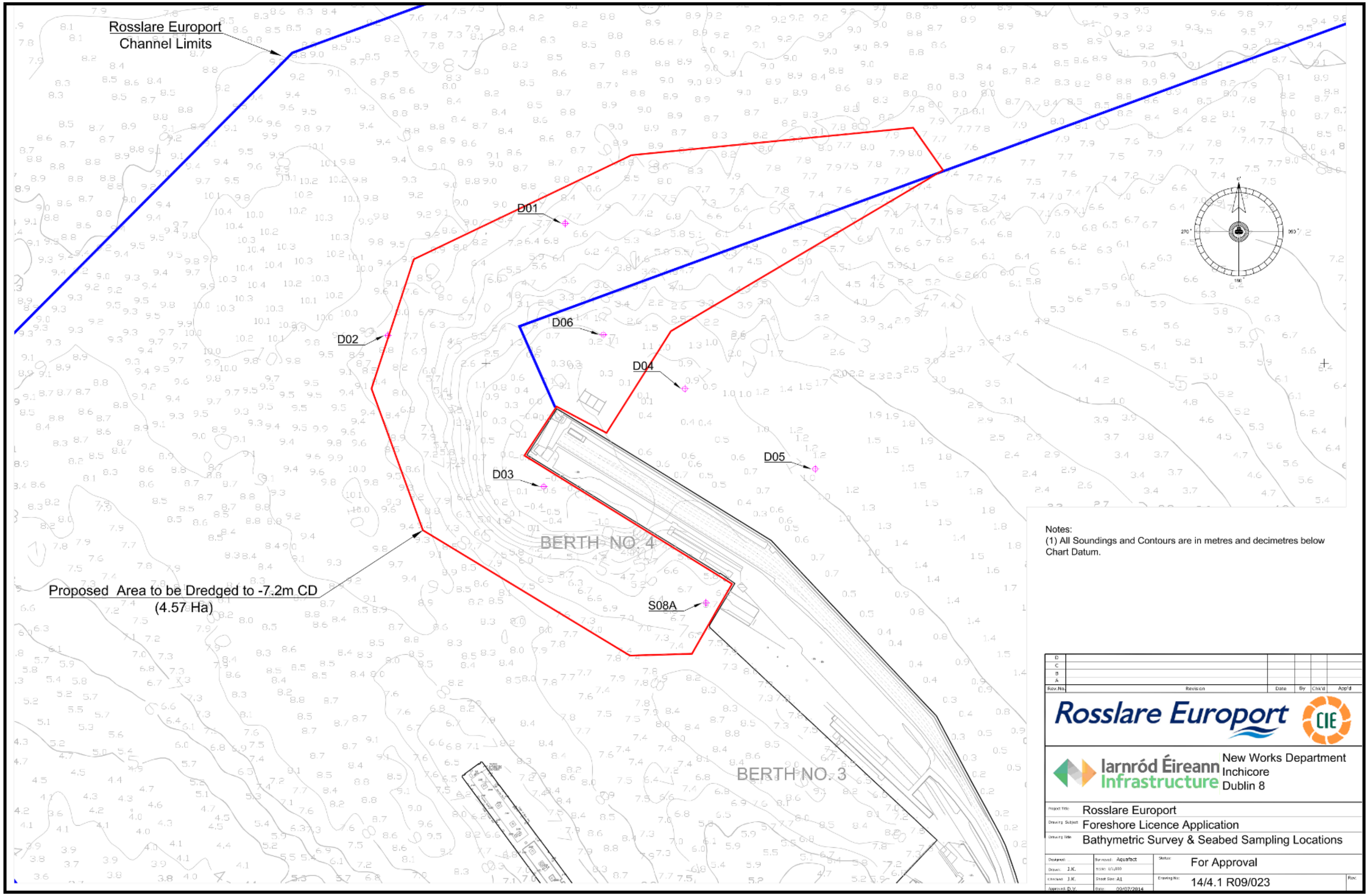

Figure 4.8: Dredging area (red outline) and site sampling locations

Table 4.1: Rosslare Sediments: Physical Characteristics

Sample Point	Visual Observations	Density (g/ml)	Water content (g)	% Moisture	% Gravel (>2mm)	% Sand (< 2mm)	% Mud (63µm)
D01	Muddy medium and fine sand, with some shell fragments and gravel, light grey/brown. No odour	2.23	84.23	16.11	19.5	80.2	0.2
D02	Medium to coarse sand, with some shell gravel and stone, light brown. No odour	1.80	64.56	11.61	26.5	73.4	0
D03	Medium to fine sand, beige-brown. No odour	2.05	95.14	19.43	0.2	99.4	0.4
D04	Medium to fine sand, light brown. No odour	1.97	117.94	20.46	0.4	99.6	0.1
D05	Medium sand, some fine shell/gravel, light brown. No odour	1.95	128.71	18.06	2.5	97.5	0.1
S08A	Muddy fine sand, some weed, terebellid polychaete, greyish brown. No odour	1.63	208.85	47.46	0	79.5	20.5

The placement programme implemented within the modelling accounted for technical aspects which would be encountered in reality. The material was deposited over the course of a spring-neap tidal cycle, which not only reflects the duration required but also ensures all tidal states and their influence on the dispersion of the dredged material was included. The model did not include the impact of wind or wave action; as the re-nourishment programme itself could only be undertaken during a suitably calm sea-state.

The use of a 1,500m³ capacity hopper dredger means that sufficient underkeel clearance would be required to permit safe access to the relatively shallow deposition area (circa 4m CD); therefore the placement of the dredged material was limited to periods when suitable tidal conditions afforded this. During the simulation the timing of each discharge was varied slightly to allow for natural variability, however a slight bias to flood tide was also introduced to counter residual currents which run to the south west of the re-nourishment site, as discussed in Section 4.2. The spill cycle with respect to the tidal cycle is shown in Figure 4.9

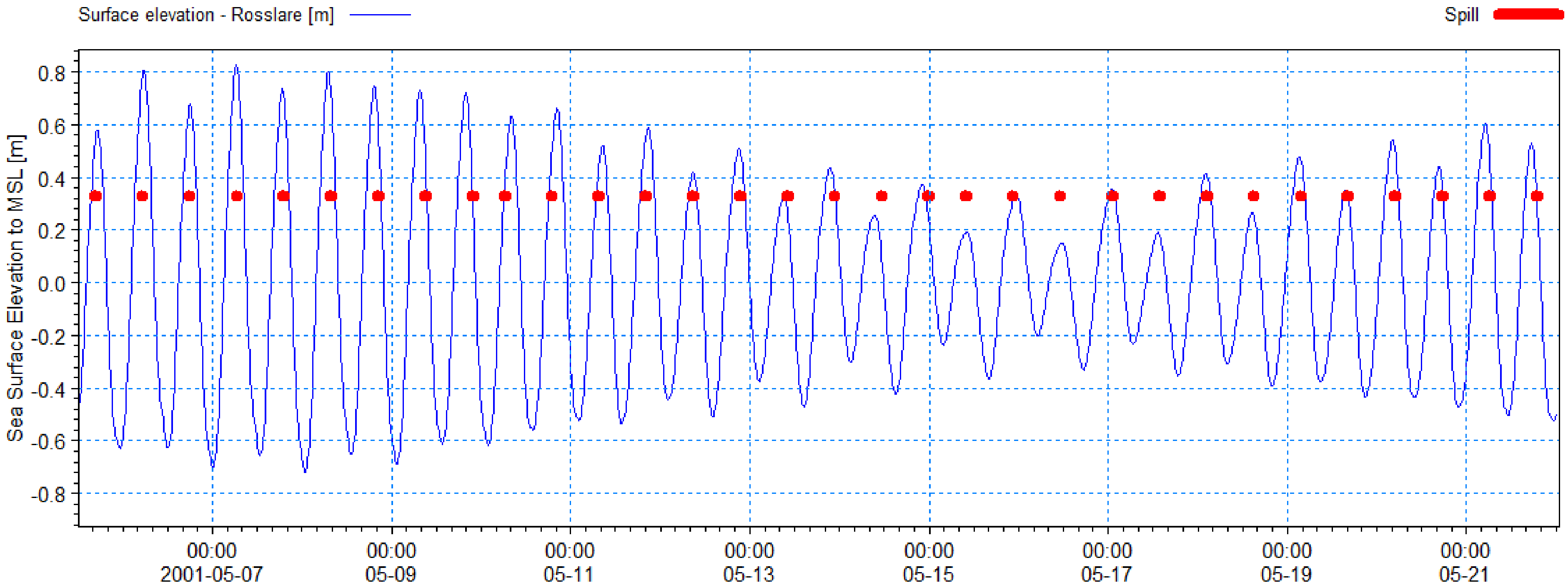

Figure 4.9: Re-nourishment timing with respect to tidal phase

The sediment was introduced into the model in the regime outlined previously. The spill was released near the water surface to emulate the discharge from a split hopper barge. These releases were undertaken during a 'pass' of the re-nourishment site. Hence the sand was released across the entire site and allowed to settle through the water column under the influence of the tide. In line with the sampling, the sediment modelled had the material properties of fine-medium sand. The three classification used are given in Table 4.2

Table 4.2: Modelled Material Properties

Class	Size (mm)	Settlement (m/s)	Proportion (%)
Fine sand	0.15	0.01353	20
Medium sand	0.25	0.02908	40
Coarse sand	0.4	0.04875	20

4.5.3 Summary Results

The principle output required in relation to the placement of the re-nourishment material is to ensure that the material released at the surface within the confines of the site reaches the desired location and that during the course of the re-nourishment programme no adverse impacts are encountered due to increased suspended sediment levels in the vicinity.

Figure 4.10 shows the deposition thickness following the re-nourishment programme, where the red outline indicates the boundaries of the re-nourishment site. It can be seen that almost all of the material remains within the site boundary and the resulting thickness is in line with an even distribution of the material across the site. The lower levels of deposition to the southern boundary of the site is related to the 'skew' afforded to the deposition cycle to compensate for subsequently residual currents which carry material to the south.

The maximum suspended sediment plume envelope is shown in Figure 4.11. This is the maximum suspended sediment concentration which was experienced in each mesh element over the course of the simulation. These values may therefore not have occurred simultaneously nor have persisted for any significant period. It should be noted that a log scale has been used to demonstrate the range of values encountered. The values seen within the site are relatively high as these are associated with the initial release of material into the water column, whilst beyond the site boundary the values are very small.

The sandy nature of the material coupled with the spill being initiated when there is sufficient draft, which is predisposed to being during periods of lesser current speed, means that there in little or no impact on water quality beyond the immediate vicinity of the re-nourishment site

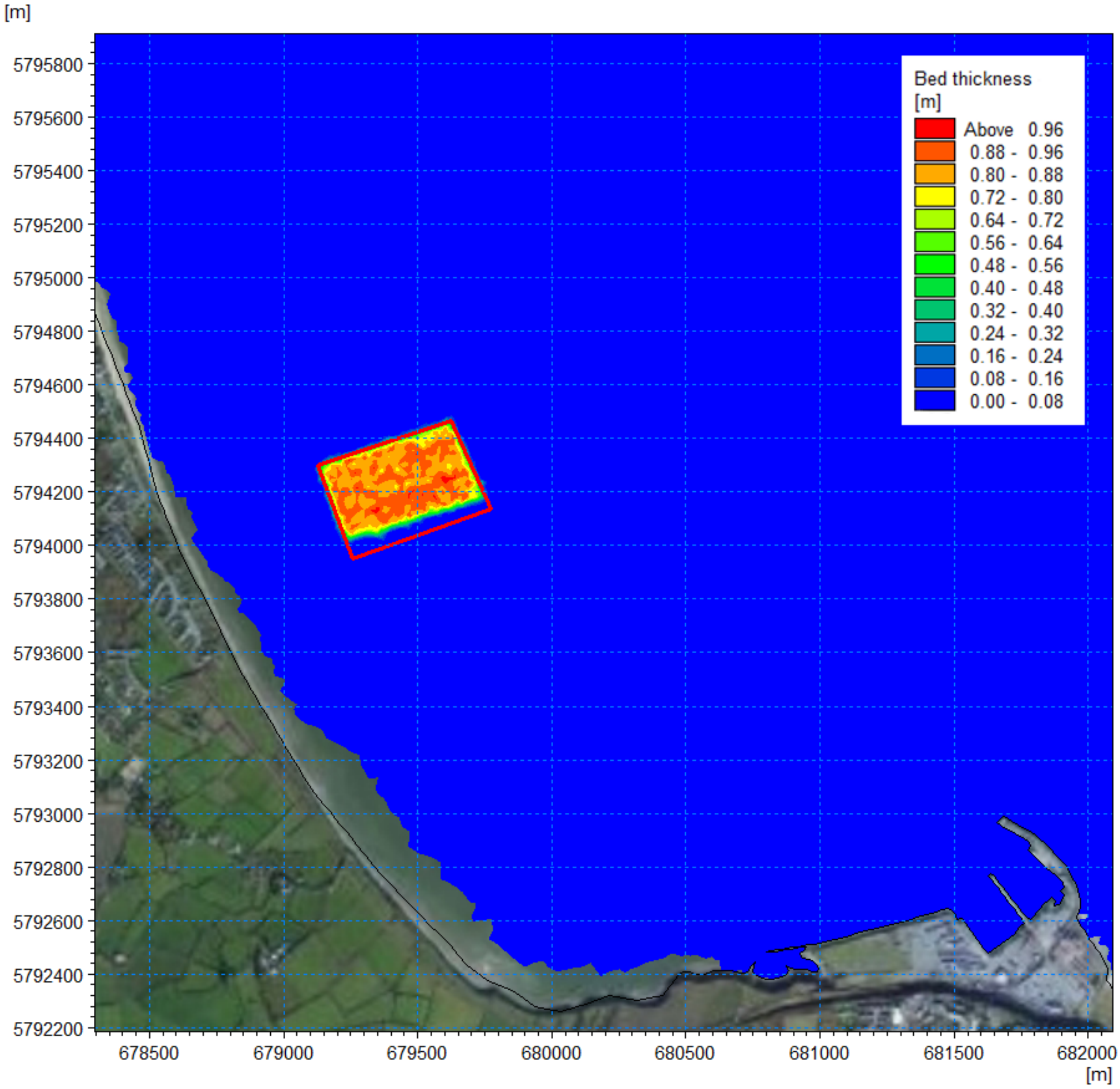

Figure 4.10: Deposition Thickness following Re-nourishment

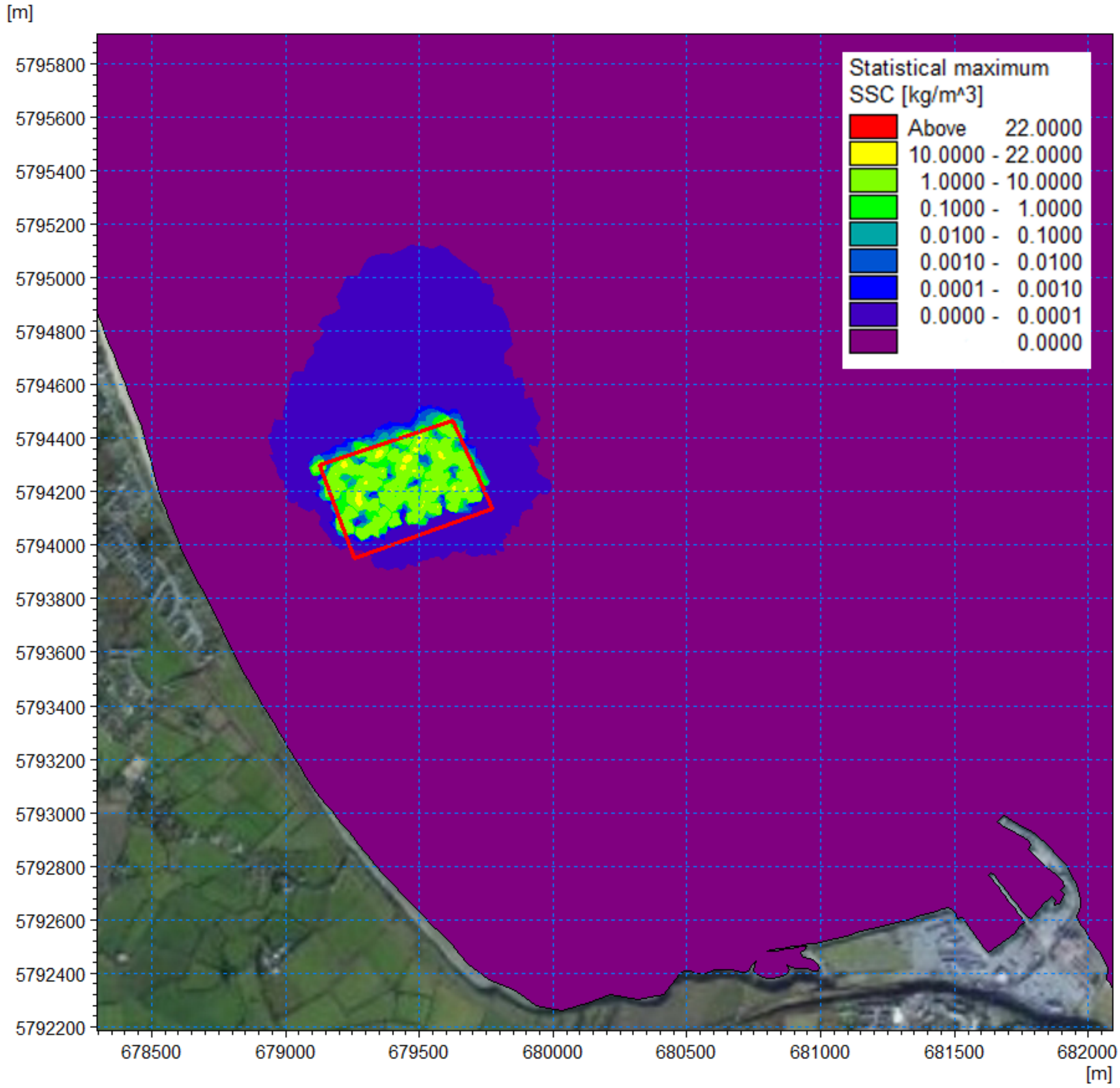

Figure 4.11: Maximum Suspended Solids Concentration Envelope for re-nourishment programme

4.6 SEDIMENT TRANSPORT

The second area of study is where material would be transported under relatively frequent storm conditions. These were modelled for each of the principle directions from which waves would approach the re-nourishment site.

4.6.1 Modelling System

The hydrodynamic basis for the Transport Module is calculated using the Hydrodynamic Module of the MIKE 21 Flow Model FM modelling system. The transport module calculates the resulting transport of material based on these flow conditions coupled with the other appropriate aforementioned modules. For this specific stage of the study this is the wave modelling module. A number of components may be specified with each component defining a separate transport equation. The time integration of the transport (advection-dispersion) equations is then performed using an explicit scheme to calculate the resulting sediment transport.

The wave climate was derived using the Mike21 Spectral Wind-wave Flexible Mesh model (SW). The SW model is a third generation spectral wind-wave model with two modes of operation, using either the directional decoupled parametric or fully spectral formulations. For this study, the directional decoupled parametric formulation was used, as it was not necessary to separate out the individual wind and swell components of the waves. The SW module describes the propagation, growth and decay of waves in nearshore areas. The model can take into account the effects of refraction and shoaling due to varying depth, local wind generation and energy dissipation due to bottom friction, white capping and wave breaking. It may also include non-linear wave-wave interaction, wave-current interaction and the effect of time varying water depth and flooding and drying. The SW model has an optimal degree of flexibility in describing bathymetry and ambient flow conditions using depth-adaptive and boundary-fitted unstructured mesh.

4.6.2 Model Simulations

Four scenarios were examined with respect to wave induced sediment transport. In each case a wind of Force 6 (12m/s) was applied across the model domain in addition to the tidal current. The four scenarios were:

- A storm approaching from the north east
- A storm approaching from the east
- A storm approaching from the south east
- A storm approaching from the north east including offshore swell conditions

These represent 'typical' conditions experienced in the area and were used to examine the stability of the beach re-nourishment material and the performance of the re-nourishment site. Under more extreme conditions there would be greater levels of sediment transport however this would also involve the movement of sediment in the wider domain.

4.6.3 Summary Results

Each of the scenarios was run separately. In each of the four individual cases the sea bed thickness that resulted from the sediment deposition under calm conditions presented in Section 4.5.3 was used as the starting conditions. Each storm was run in over a period of two complete tide cycles using the appropriate wind/wave climate conditions and the change in bed profile and sediment transport was evaluated.

Figure 4.12 and Figure 4.13 show the transport response of the re-nourishment material during both the north east and easterly storms respectively. In each case the average transport load during the course of the event is presented along with the residual transport vectors. This illustrates the net transport during the course of the storm taking account of tidal currents. They demonstrate that the effect of the typical wave climate is to transport material in a westerly direction towards the shoreline whilst the residual currents give rise to a small amount of southerly sediment transport.

Similarly, the transport profiles are presented in Figure 4.14 and Figure 4.15 for the south easterly event, excluding and including swell waves respectively. For the event without the inclusion of the swell component of the wave climate the transport is largely related to residual tidal currents however there is some contribution to shoreward transport due to wave reflection around the Port. As anticipated a greater amount of material is moved with the inclusion of the longer period swell waves. These waves are also reflected around the Port and provide movement of material in a south-westerly direction

It may therefore be concluded that, during storm conditions from any direction, the deposited material is transported towards the shoreline and will consequently provide the required beach nourishment.

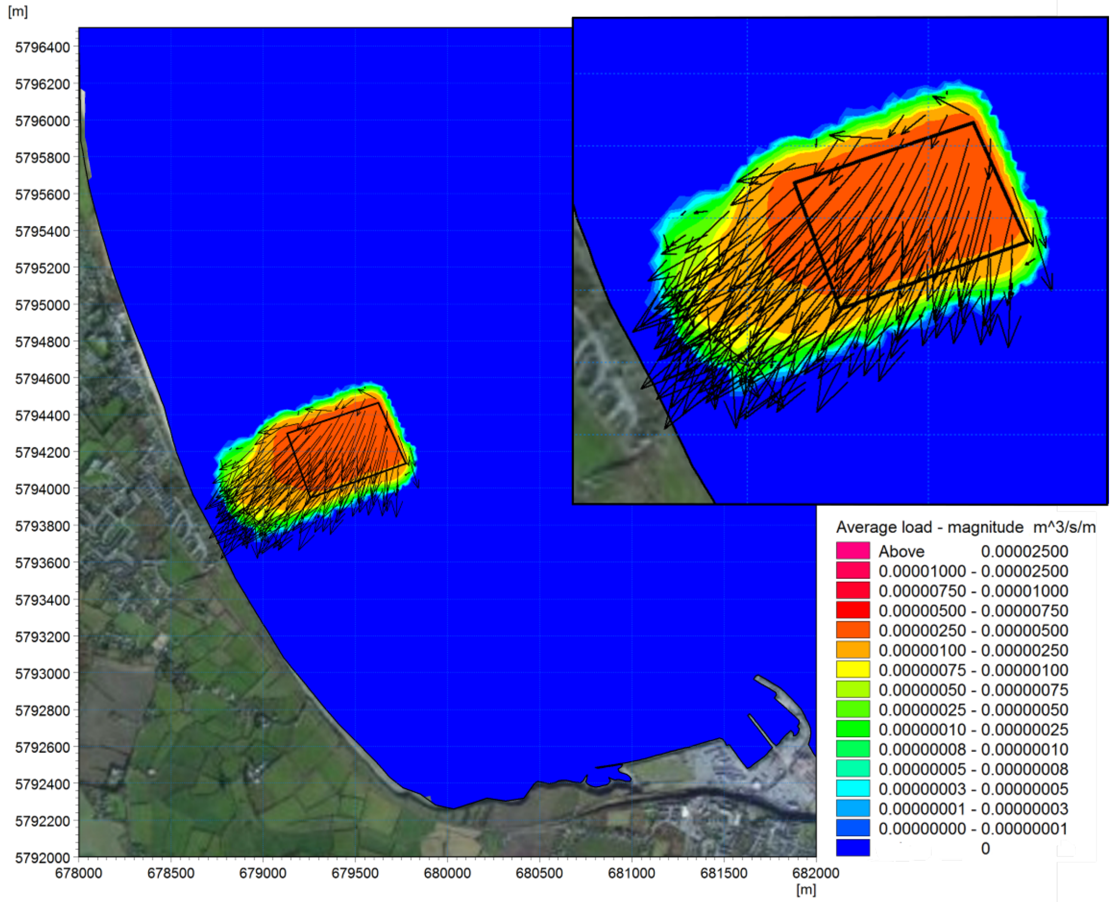

Figure 4.12: Net movement of nourishment material due to F6 Storm from North East

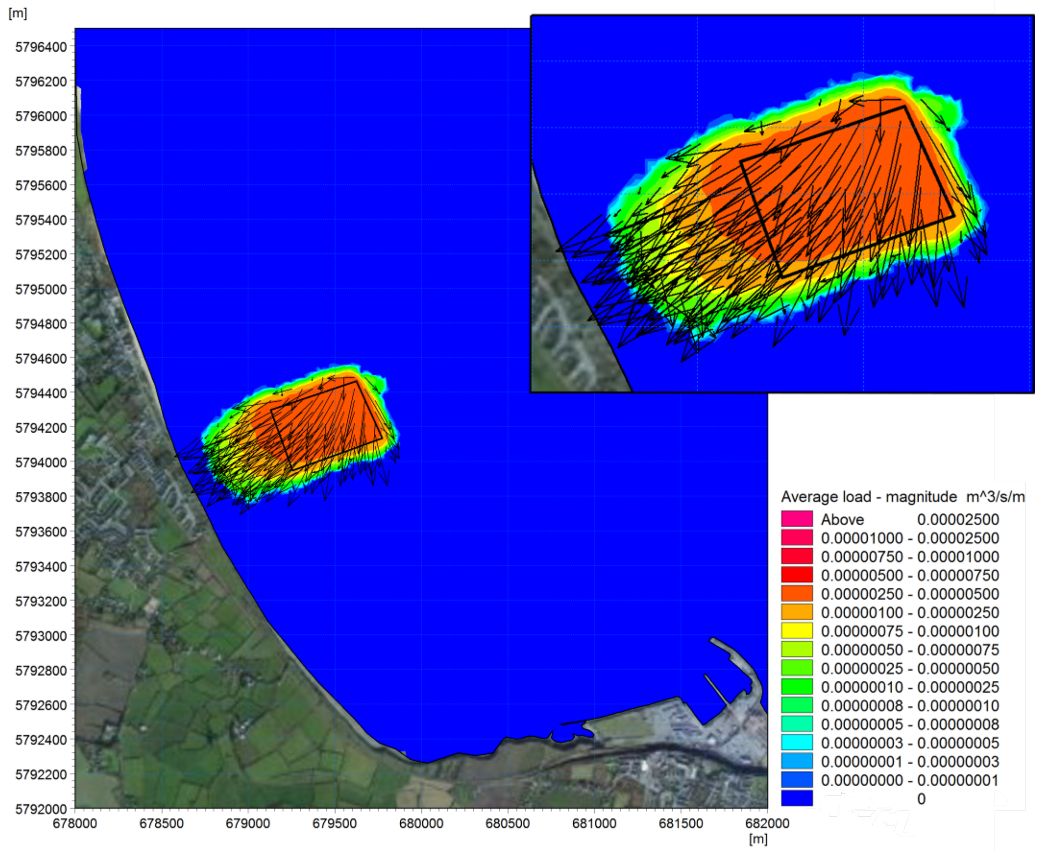

Figure 4.13: Net movement of nourishment material due to F6 Storm from the East

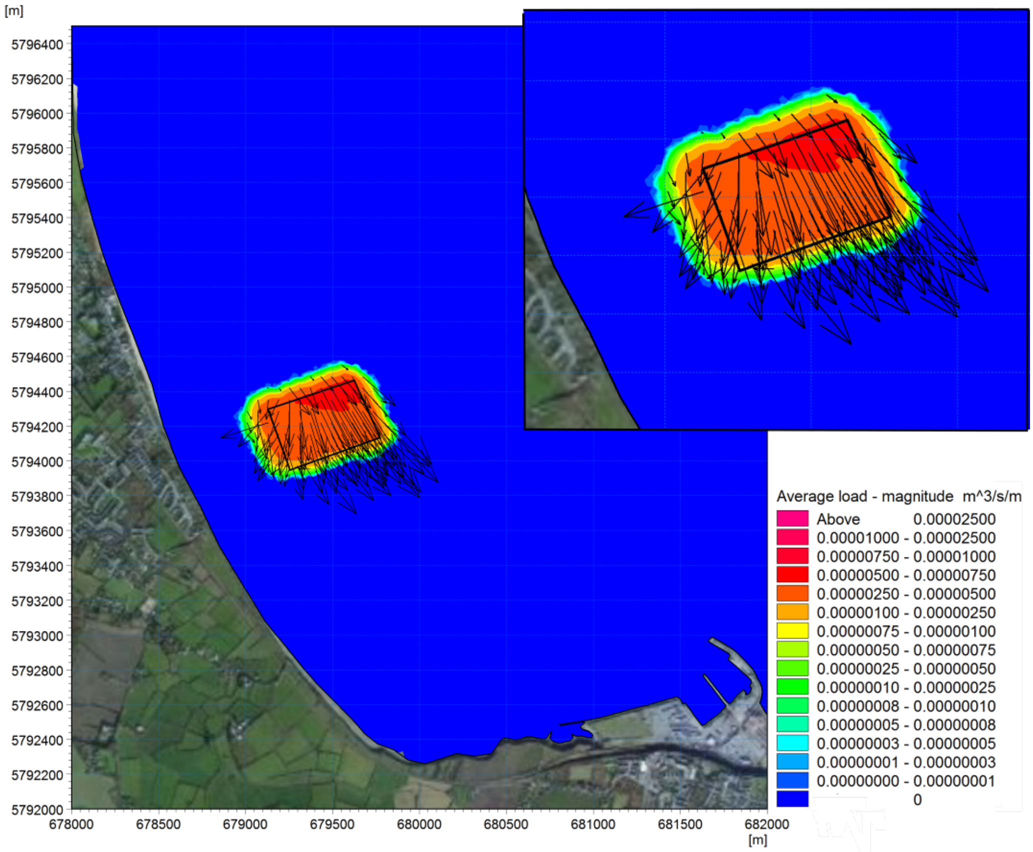

Figure 4.14: Net movement of nourishment material due to F6 Storm from South East

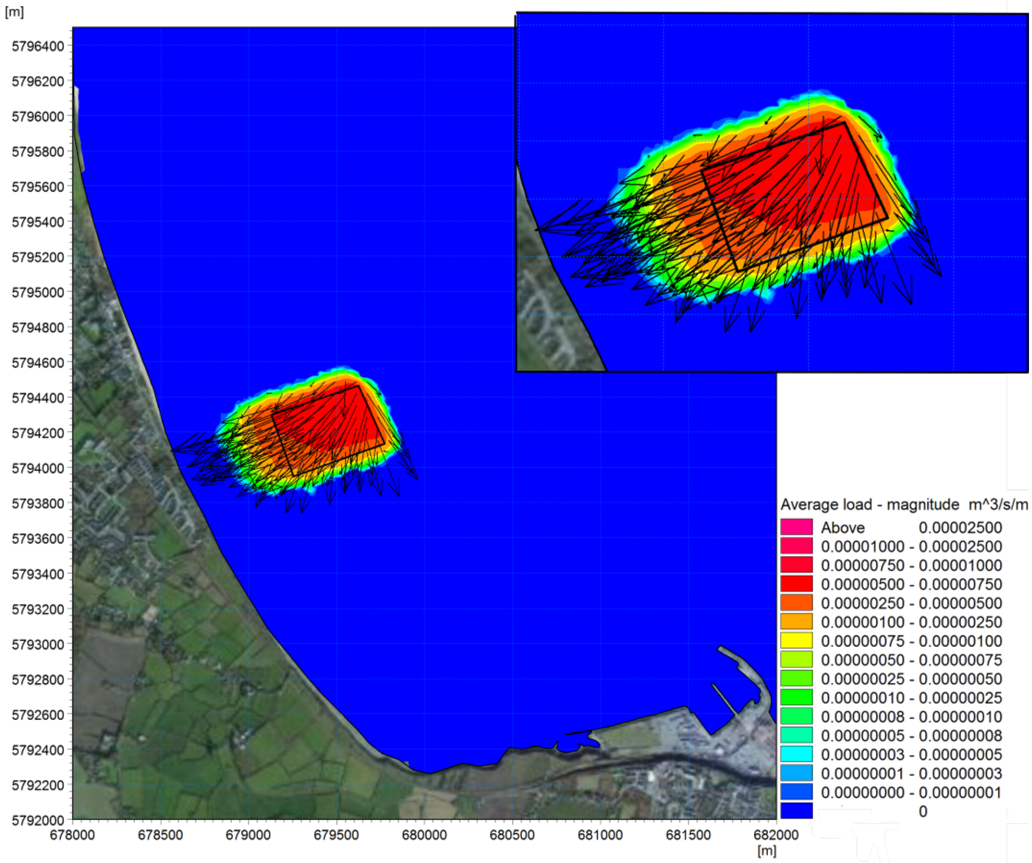

Figure 4.15: Net movement of nourishment material due to F6 Storm from SE & Swell

5 SUMMARY & CONCLUSIONS

A range of numerical modelling techniques were used examine sediment transport characteristics relating to both the placement of beach nourishment material and subsequent sediment transport following dredging at Rosslare Europort.

Due to the relatively shallow water, the placement of material is to be carried out during suitable sea-state and tidal conditions that permit sufficient underkeel clearance for the dredger to safely access the site. Due to the sandy nature of the material and the low flow conditions associated with the placement, the material was seen to settle within the confines of the beach re-nourishment area and did not cause significant increases in suspended sediment concentration during the placement. Therefore very little in the way of a discharge plume was observed and the operation is not anticipated to impinge on the sensitive berthing/fishing areas to the south of the site.

The movement of the deposited material was modelled under storms conditions with Force 6 wind and swell waves approaching for a range of directions. It was concluded that, during typical storm conditions from any direction, the deposited material is transported towards the shoreline and will consequently provide the required beach nourishment.