9 COASTAL PROCESSES

9.1 Introduction and Methodology

The proposed ferry from Greenore to Greencastle may potentially have effects on coastal processes due to the ferry infrastructure (jetties, slipways, etc.) therefore an assessment was carried out to address these concerns. The impact of the proposed construction on the hydrodynamic and sediment regime was assessed using computational modelling techniques based on the MIKE 21 suite of coastal process modelling software developed by the Danish Hydraulics Institute.

The modelling took place using the existing bathymetry to derive the tidal current field and the wave climate during force 8 gale conditions. The modelling was then repeated using the bathymetry following building of the infrastructure and associated piling to give post-development conditions. The changes in tidal currents were then examined to assess the impact on coastal processes, in particular identifying changes to tidal currents in the immediate vicinity of the construction. Figure 9.1 shows the extent over which the tidal modelling took place. The following sections detail the model development and the predicted impact of the proposed infrastructure construction.

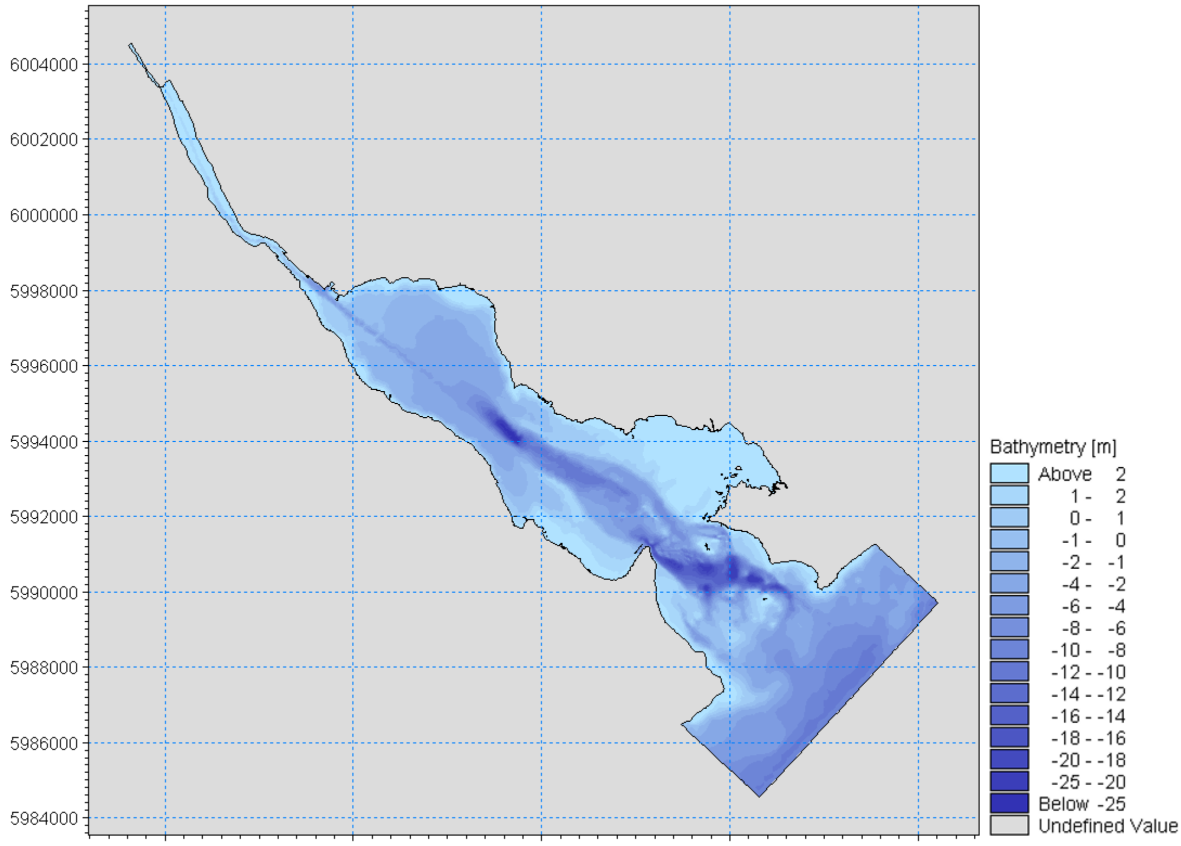

Figure 9.1: Tidal Model Extent and Bathymetry

9.2 Data and Models

The numerical modelling used two modules from the MIKE21 suite. The tidal regime was simulated using the MIKE21 HD (hydrodynamic module) which is a 2D depth averaged tidal flow model which is applicable for the well mixed water within the Lough. The modelling of the wave transformation was based on unstructured (flexible) mesh and was undertaken using the Mike21 spectral wind-wave model, m21 SW. The model simulates the growth, decay and transformation of wind-generated waves and swell in offshore and coastal areas. The model takes into account the effects of refraction and shoaling due to varying depth, local wind generation and energy dissipation due to bottom friction and wave breaking.

Bathymetry data for the models was largely taken from digital chart data and was supplemented by additional local surveys carried out by Hydrographic Surveys Ltd. Current speed and direction had been measured in the vicinity of the proposed development at Greenore as part of a previous study and this data was utilised in this coastal processes study. The location on the monitoring is marked on Figure 9.2 below. The plot also indicates the location of the proposed ferry slipways; shown in red.

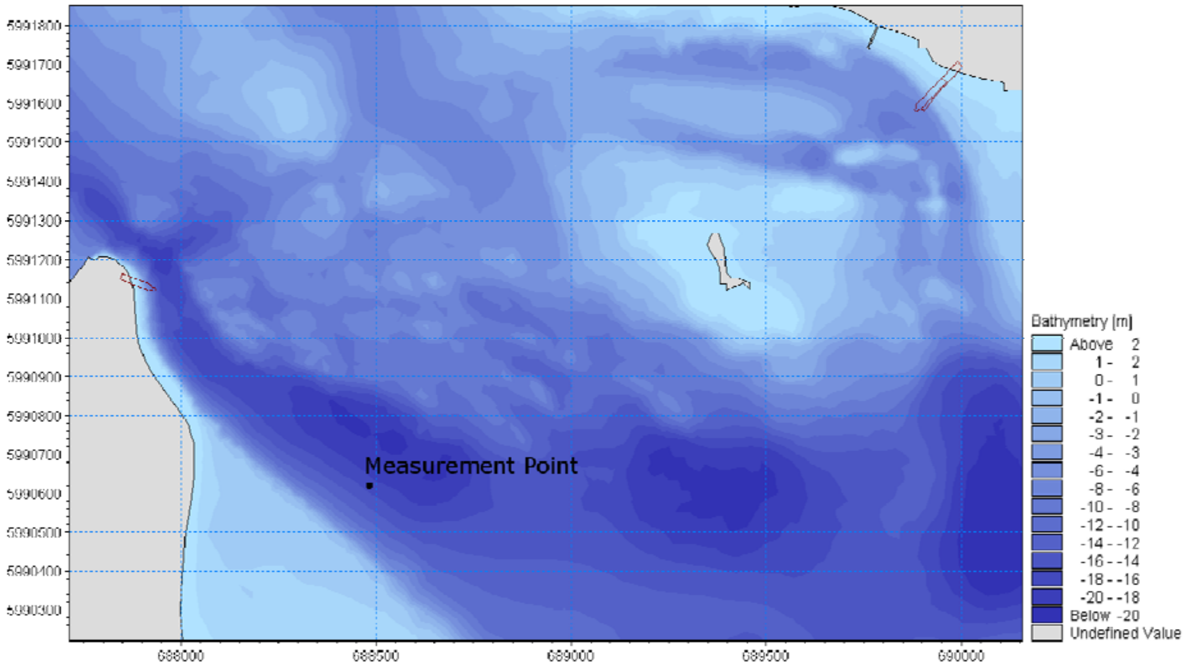

Figure 9.2: Detailed Bathymetry in Greenore and Greencastle locations and location of the measurement point

9.2.1 The Tidal Model

The tidal conditions were simulated using a MIKE 21 HD flow model. Simulations were run for one month to include both spring and neap tide cycles. The boundary conditions used for the model were tidal levels derived by using harmonic constants published in the Admiralty Tide Tables and modified through the calibration process. The one month period was chosen to coincide with available field data from a previous study in the Lough; this data was then directly used to calibrate the model results.

9.2.2 Wave modelling

The impact of the changes were investigated under gale winds (Force 8) approaching the site from the SE, N and W directions. These are the types of conditions which would be experienced at the site from time to time and therefore give an indication of the wave climate under reasonably severe conditions. Wind waves were generated within the model along the entire fetch. Each of the directions was investigated under a range of water levels from mean high water springs (MHWS) to mean low water springs (MLWS) and included mean sea level (MSL). The bathymetry for the model studies was taken from the same sources as those used for the tidal study.

Any potential changes to littoral currents and their implied impact on sediment transport were investigated. The tidal model was re-run with the inclusion of the radiation stresses generated during the SE, W and N gales over the course of several tidal cycles (to illustrate the worst case scenario). Comparisons were made between the resulting littoral currents before and after the proposed development in order that an assessment may be made in terms of the impact on sediment transport.

9.3 Tidal Flow Regime

9.3.1 Tidal Model Calibration

The tidal model was calibrated against the predicted tidal heights given in the Admiralty Tide tables for Warrenpoint and verified using current metering data collected by Hydrographic Surveys Ltd. This survey consisted of vertical current profiles taken at two locations of which one location is shown in Figure 9.2. The closest location to the Greenore site was chosen for the calibration. In addition, monitoring of tidal height was carried out from the Quay for the duration of the current monitoring period.

Figure 9.3 shows the comparison between the tidal elevations recorded at the Quay site (blue marks) and the respective values from the numerical model (black trace) during the neap tide. Similarly Figure 9.4 shows these values for the spring tide. It should be noted that the numerical model is driven by tidal flows alone and discrepancies may arise due to climatic conditions present during the monitoring programme. In both cases the numerical model gives a good level of correlation in tidal range.

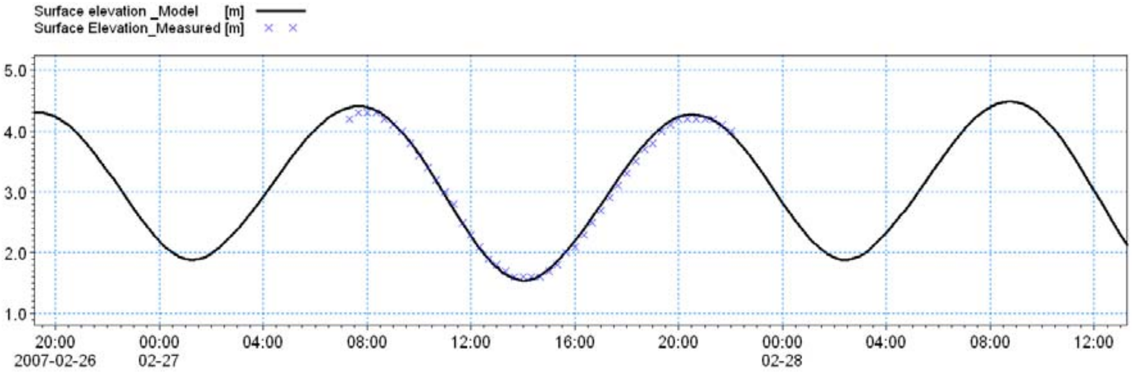

Figure 9.3: Simulated & measured tidal elevations (m) for neap tide

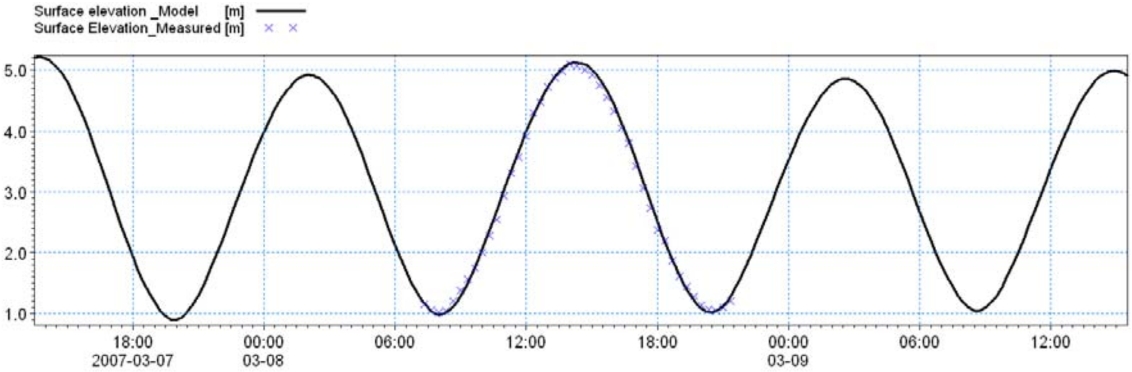

Figure 9.4: Simulated & Measured Tidal Elevations (m) for Spring Tide

The following pairs of figures show the comparison of measured and simulated values at the monitoring point; the upper plot shows the current velocity while current direction is shown in the lower plot of each pair. Figure 9.5 shows current speed and direction for the spring tide, while Figure 9.6 shows the neap tide values. In each case the measured data is displayed as a series of points (coloured according to measurement depth) as each was a discrete measurement. The modelled values correlated with the field monitoring indicating that the model simulated the tidal regime accurately.

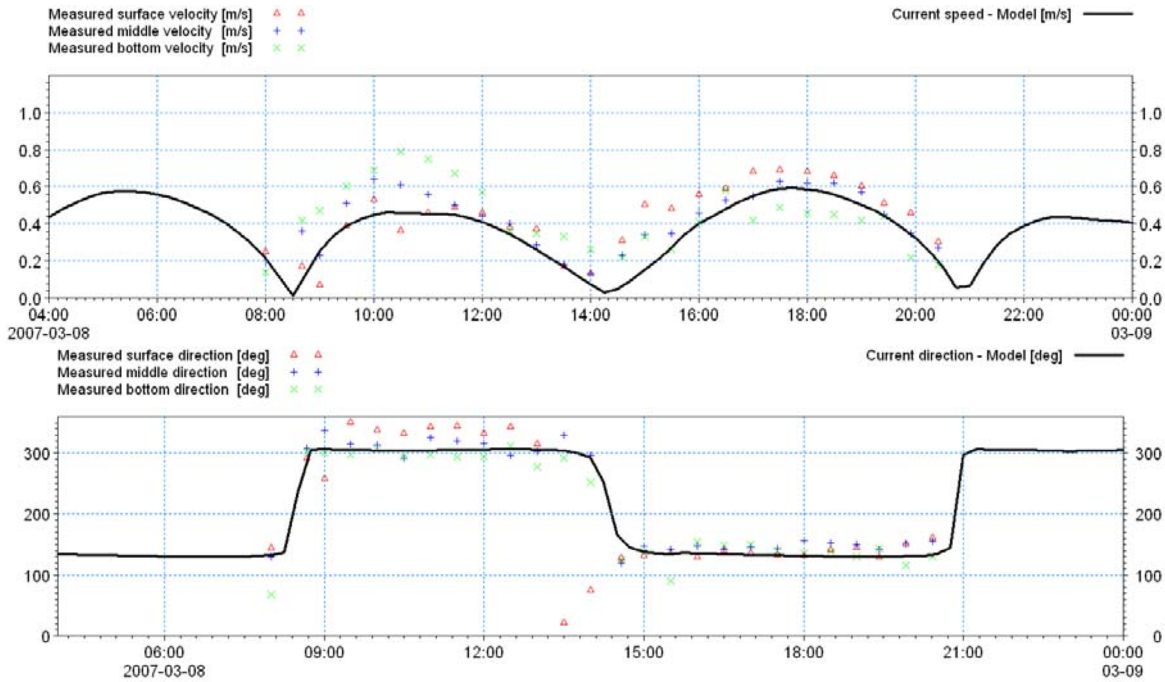

Figure 9.5 a & b: Current direction (top) and velocity (bottom) at Spring Tide

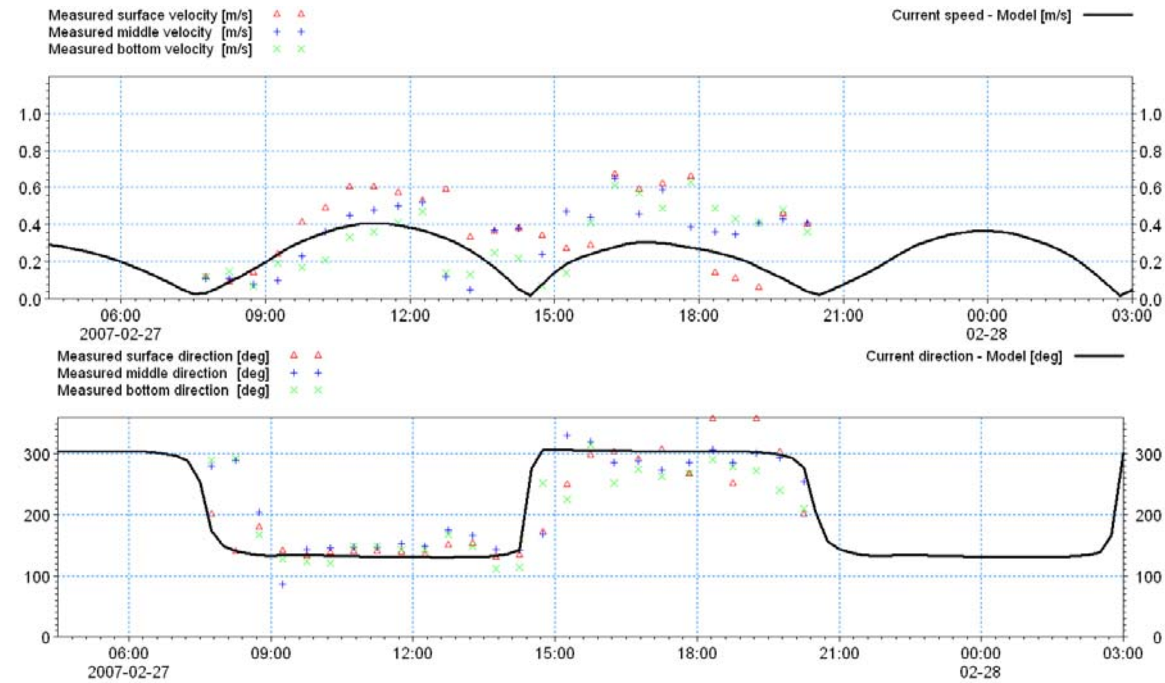

Figure 9.6 a & b: Current velocity (top) and direction (bottom) at Neap Tide

9.3.2 The Tidal Regime

Tidal flows are strongly bi-directional in the proposed construction areas, with flood flows occurring in the north-westerly direction with the largest current speeds being experienced north of Greenore Point. The flows within the Lough are also quite turbulent due to complexity of the bed as shown in Figure 9.2; giving rise to significant variations of current speeds over relatively small areas.

Typical tidal patterns are presented in Figure 9.7 and Figure 9.8 for mid-ebb and mid-flood respectively, both during spring tide conditions. The proposed locations of the slipways structures are outlined in black on these figures.

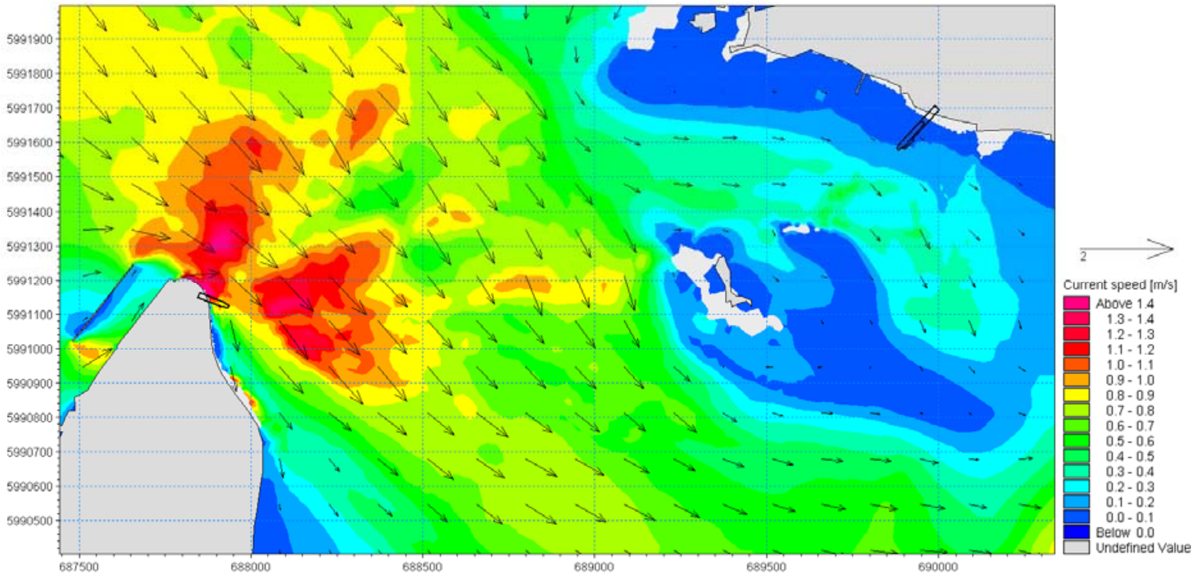

Figure 9.7: Existing current speed - mid ebb spring tide

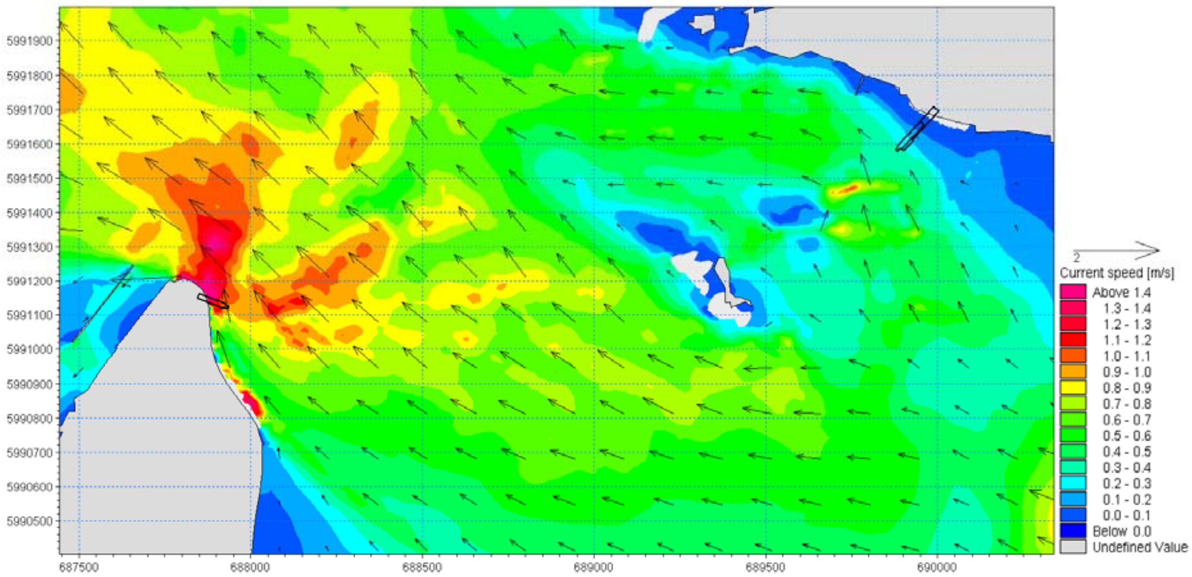

Figure 9.8: Existing current speed - mid flood spring tide

Figure 9.9 and Figure 9.10 show the maximum current speeds during ebb and flood tides for a spring tide. The residual current (being the average current over the tidal cycle) is presented in Figure 9.11. These two parameters are used to quantify potential changes due to the proposed development. It can be seen that the residual currents show a circulatory pattern on the east shore of Greenore Point, as flow is deflected around the headland on ebb tide.

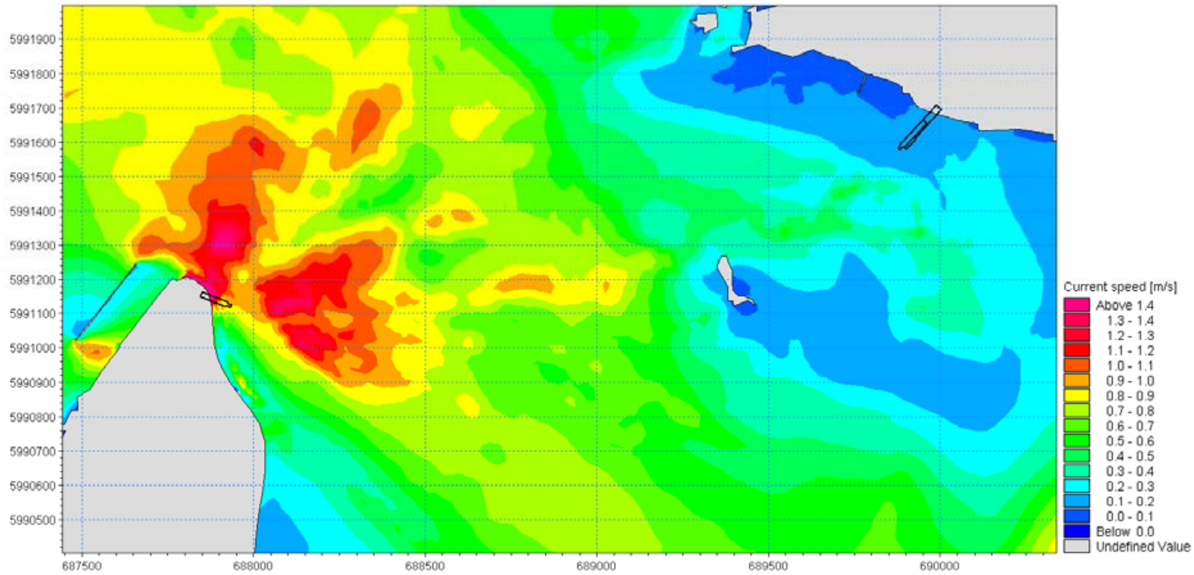

Figure 9.9: Existing peak spring tidal current – Ebb tide

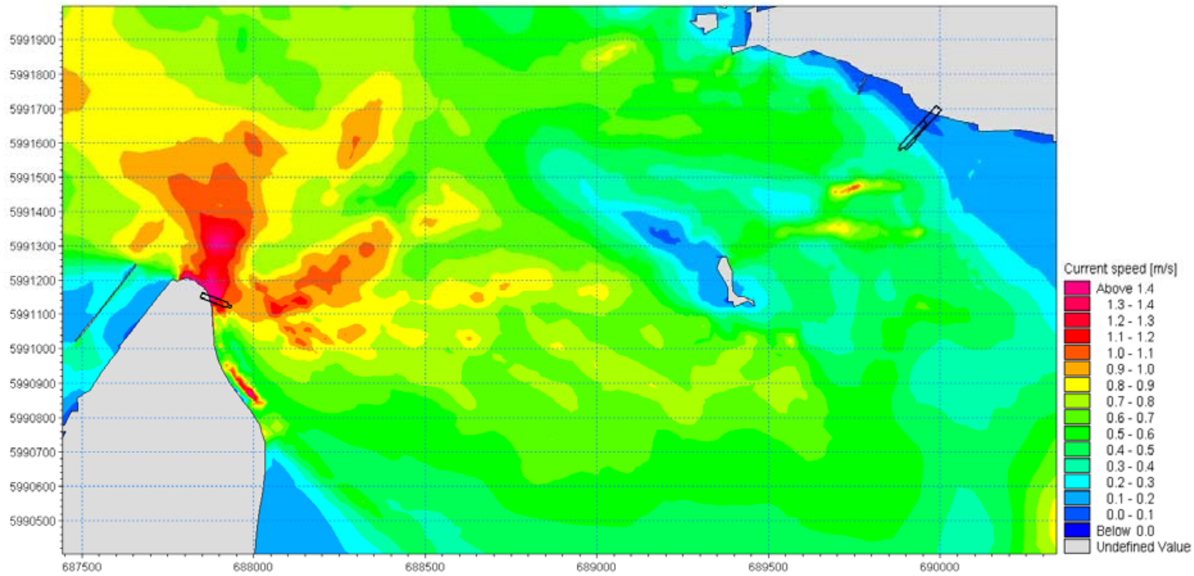

Figure 9.10: Existing peak spring tidal current – Flood tide

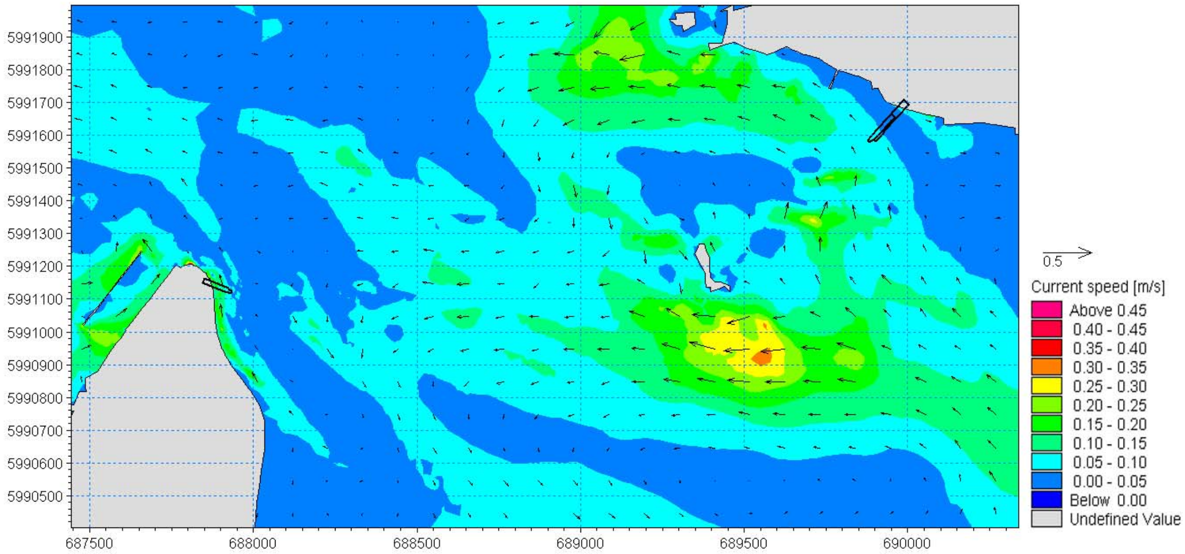

Figure 9.11: Existing residual spring tidal current

9.3.3 Impact of the Proposed Development on The Tidal Flows

The presence in the model of the proposed ferry infrastructure was simulated by altering the tidal model bathymetry according to the plan long- and cross sections. This means inclusion of the slipway structures for Greenore and Greencastle and the associated piles. Existing bathymetry and the amended bathymetry with piles in the Greenore area is presented in Figure 9.12 whereas existing bathymetry and change in the Greencastle area is presented in Figure 9.13; in each case the proposed structure is illustrated. The construction proposed at Greencastle is an open piled structure which will allow flow beneath the slipway. Although there will be no physical change in the bathymetry due to construction of the Greencastle slipway a change was made within the model in order to compensate for presence of the concrete slipway within the water column.

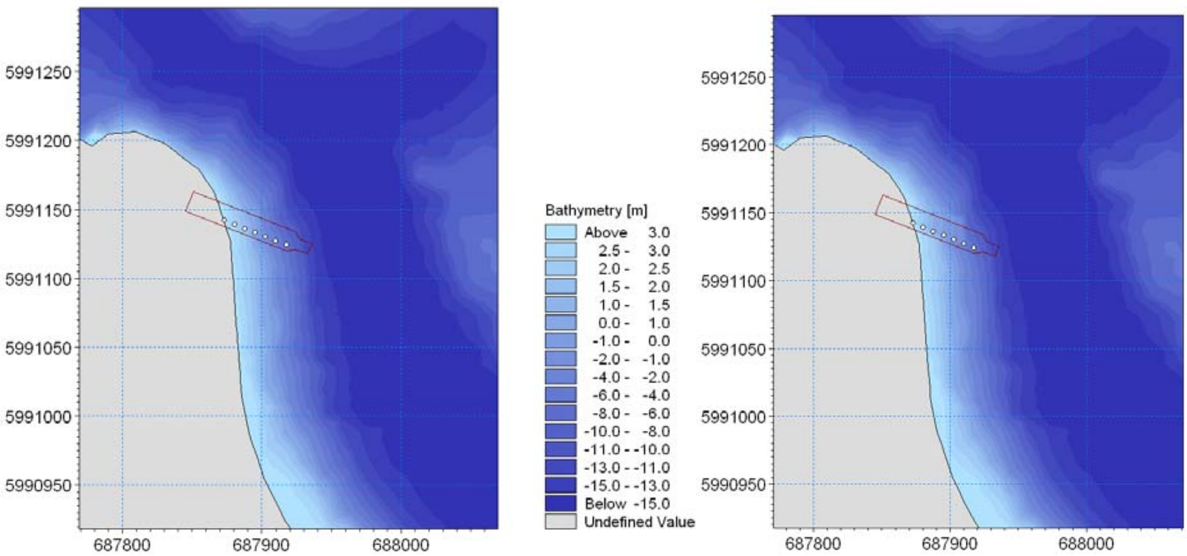

Figure 9.12: Bathymetry existing (left) and bathymetry following proposed construction (right) – Greenore

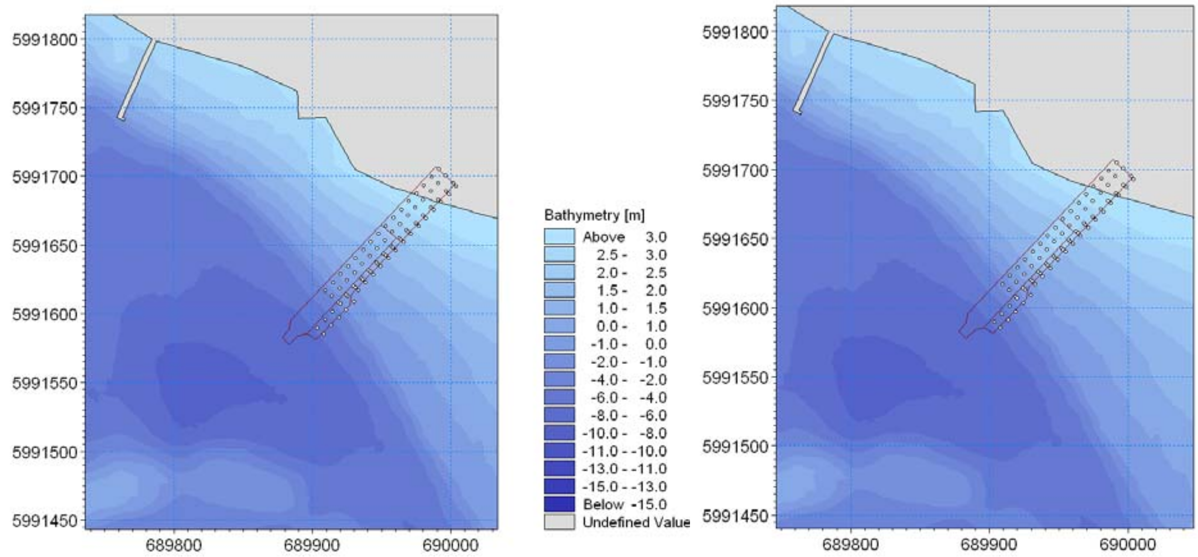

Figure 9.13: Bathymetry existing (left) and bathymetry following proposed construction (right) - Greencastle

Comparisons were made of the tidal flow conditions throughout the area to assess the impact of the new ferry infrastructure. Figure 9.14 and Figure 9.15 respectively show the difference in peak spring ebb and flood velocities between the simulation with the ferry infrastructure in place and the same simulation for the existing seabed bathymetry. From these tidal speed difference plots it can be seen that there is a small change in the local tidal velocity. Due to the presence of an eddy there is a localised increase in current speed and also an associated decrease as the flow is slightly redirected around the Greenore and Greencastle structures.

The differences are more noticeable around the proposed Greenore slipway and during the ebb tide and extend to around 400m down the eastern shore. The are areas which exhibited circulatory residual currents and indicate that the slipway causes a change in the circulation but is unlikely to cause a significant change in the overall sediment balance. The maximum differences in the peak velocities for Greenore are in the region of ±0.4m/s. For Greencastle these values reach ±0.15m/s. These differences only arise in the immediate vicinity of the construction and typical values of ±0.15m/s are experienced beyond the Greenore slipway and ±0.07m/s beyond the Greencastle slipway. These changes are more pronounced on the ebb and are lower for the flood tide. The potential change in residual current is shown in Figure 9.16; it should be noted however that the scale range for this plot has been reduced with typical values being in the order of 0.02m/s which is about 10% of the existing residual current speed.

The differences indicate that the change in flow regime in the immediate vicinity of the proposed slipways may cause some localised sedimentation.

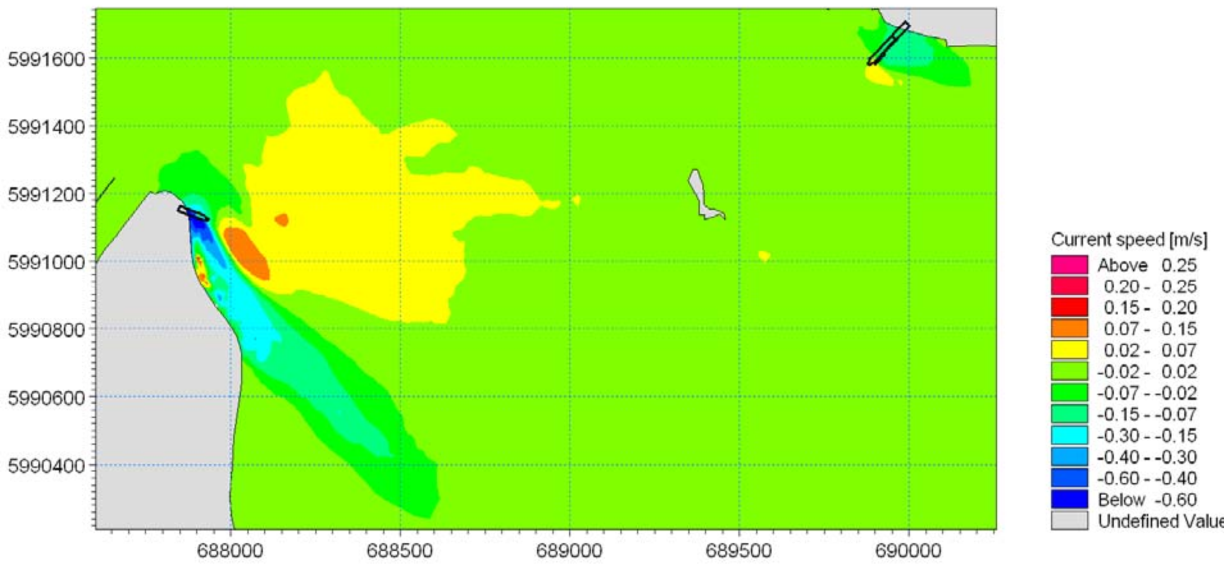

Figure 9.14: Difference in peak spring tidal current- post-construction minus existing condition- Ebb tide

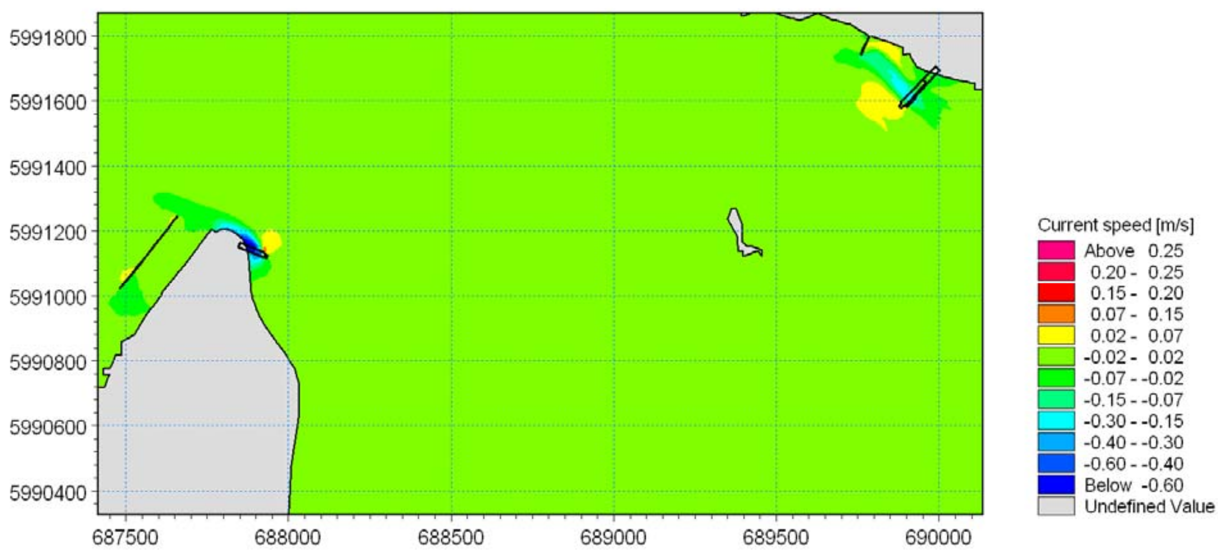

Figure 9.15: Difference in peak spring tidal current- post-construction minus existing condition- Flood tide

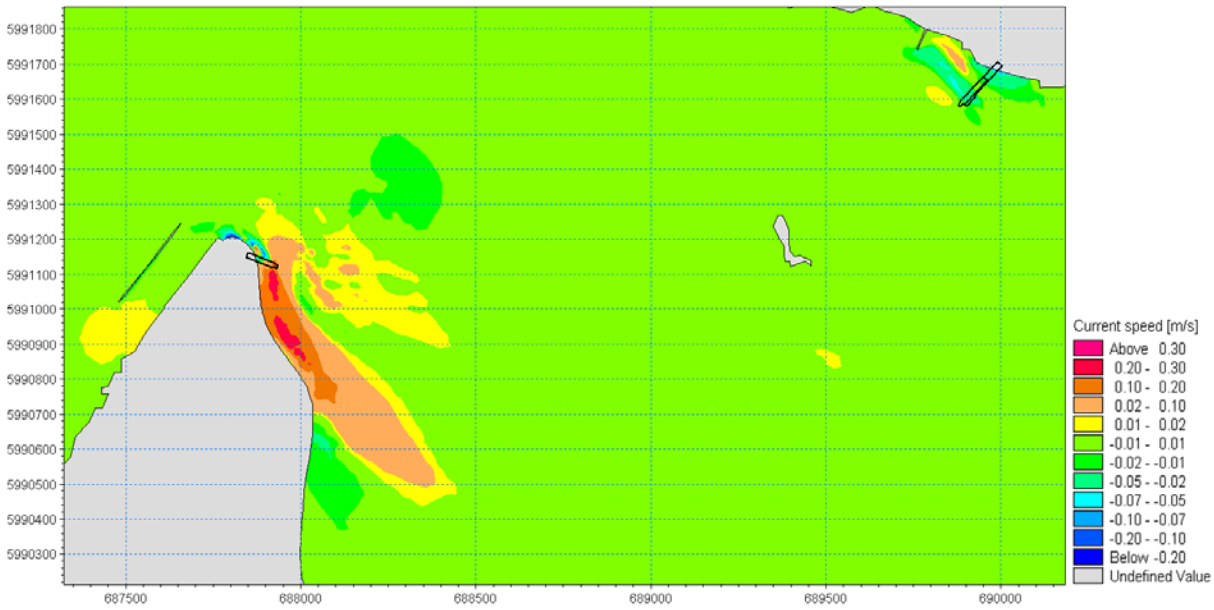

Figure 9.16: Difference in residual spring tidal current – post-construction minus existing condition

9.3.4 Modelling Wave Climate

To cover the range of waves which reach the site three directions were modelled; these had the longest fetches over which the largest waves may develop, namely north, west and south-east. The full length of each fetch was simulated; for the north and west direction this was generated wholly within the model and for the south-east the boundary wave climate was generated using a second model to develop the waves across the Irish Sea before being transformed through the Carlingford Lough model domain..

The wave climate generated due to Force 8 gales from the south-east were short period waves with maximum significant wave heights in the order of 0.6m in the vicinity of the proposed Greenore development and 0.3m at the Greencastle slipway site. From the north and west directions the significant wave height is 0.5m and 0.2m respectively for Greenore and 0.1m and 0.5m for Greencastle. The largest waves are developed during mean high water springs when the fetch is greatest and there is the largest ingress of water into the Lough. The results of the wave analysis are shown in the following figures and are presented in a set of three plots for each gale direction. The upper plot is the existing wave climate with the lower plots showing the detailed change in significant wave height at the two sites. It should be noted that the existing and difference plots are given to different scales in order to illustrate the changes. The current wave height for mean high water springs is shown in Figure 9.17, Figure 9.19 and Figure 9.21 for the south-easterly, northerly and westerly gales respectively. Similarly Figure 9.18, Figure 9.20 and Figure 9.22 correspondingly show the change in significant wave height.

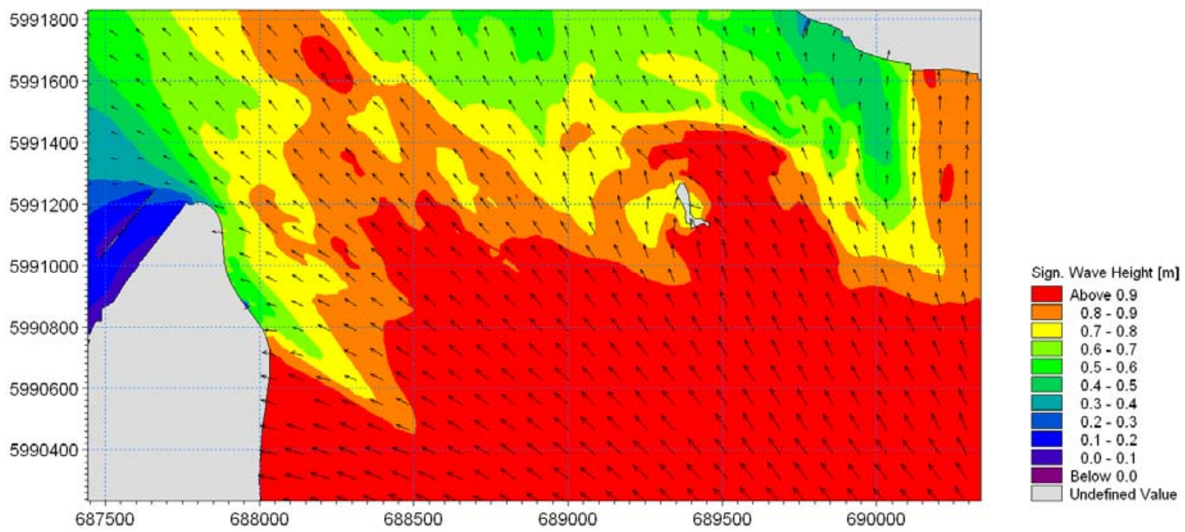

Figure 9.17: Existing significant wave height and direction for a F8 gale from the SE at MHWS

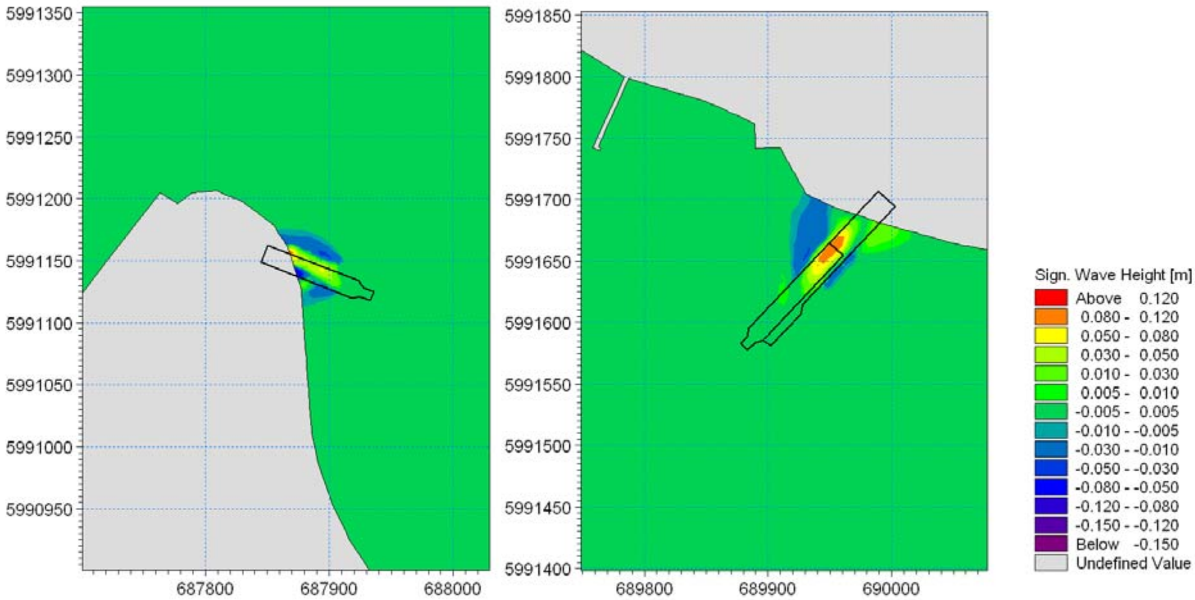

Figure 9.18: Difference in significant wave height for a F8 gale from the SE at MHWS (post-construction minus existing)

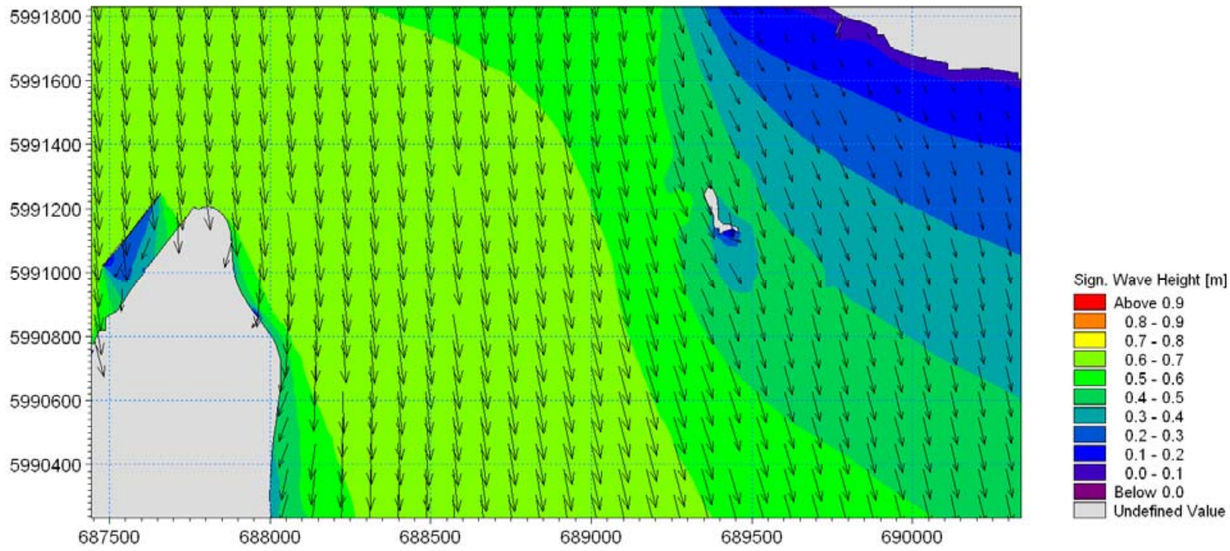

Figure 9.19: Existing significant wave height and direction for a F8 gale from the N at MHWS

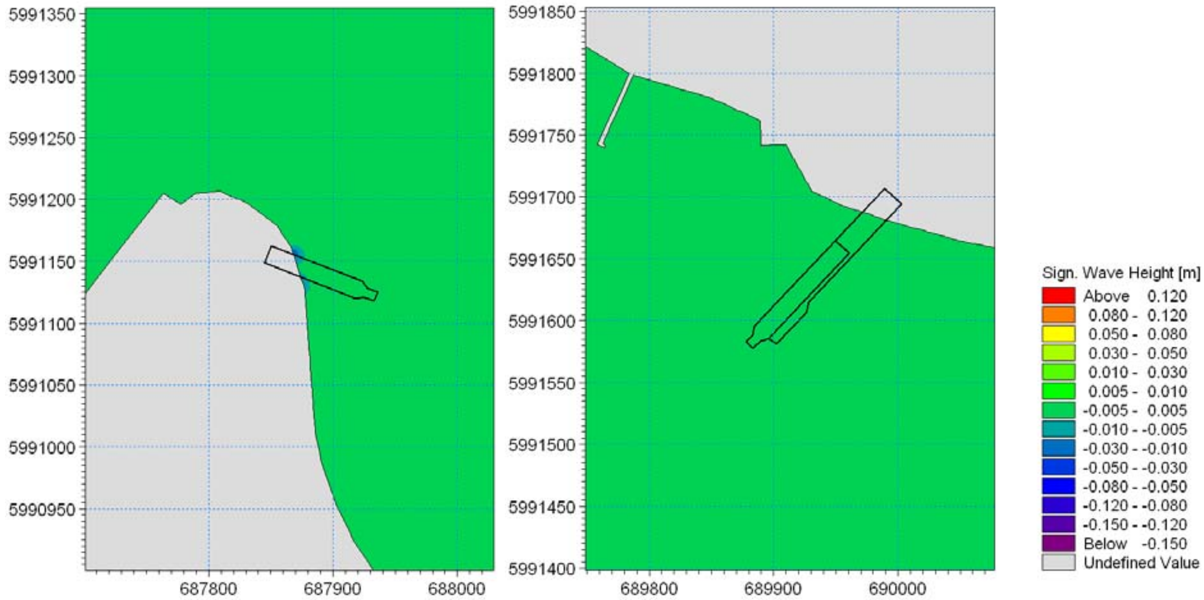

Figure 9.20: Difference in significant wave height for a F8 gale from the N at MHWS (post-construction minus existing)

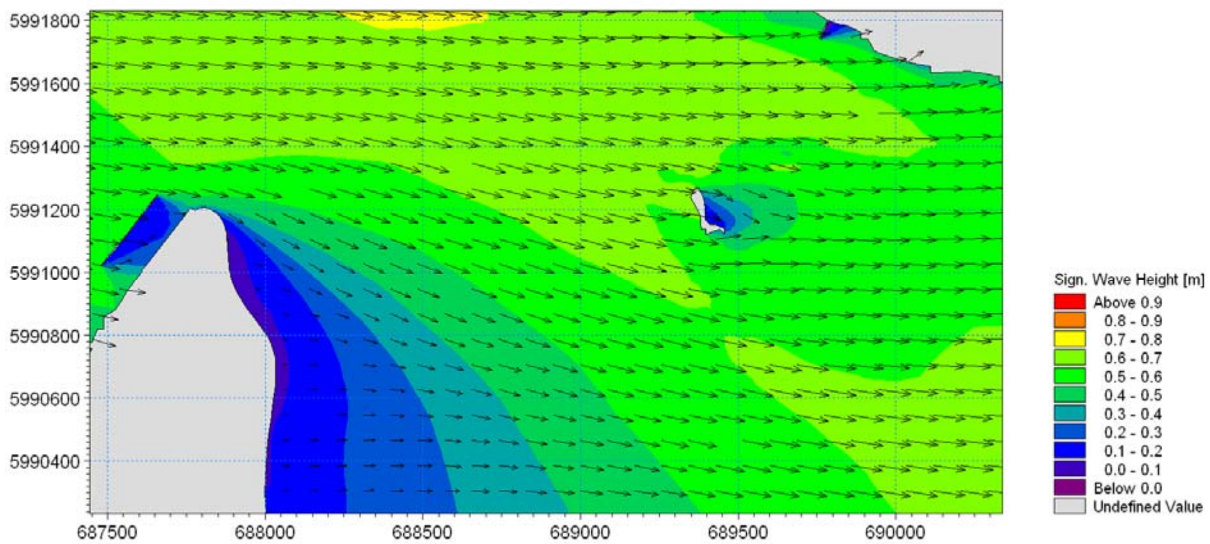

Figure 9.21: Existing significant wave height and direction for a F8 gale from the W at MHWS

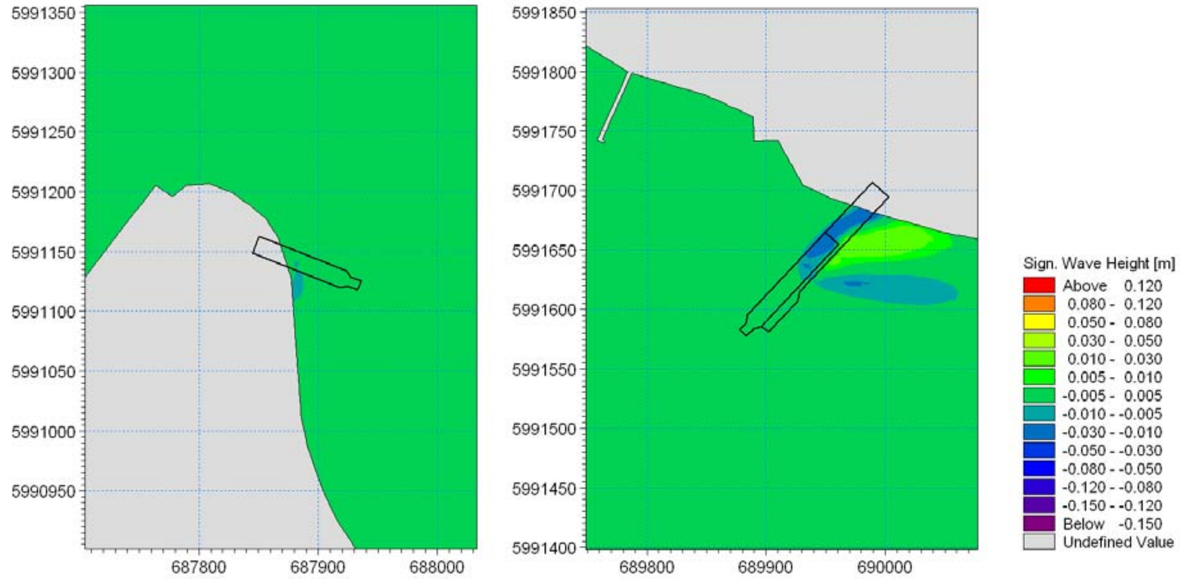

Figure 9.22: Difference in significant wave height for a F8 gale from the W at MHWS (post-construction minus existing)

Wind waves generated across Saint George's Channel into the mouth of the Lough exhibit larger wave heights due to the increased fetch although the wave heights decrease rapidly through the Lough due to the bathymetry. The presence of the proposed infrastructures shows a slight decrease, of the order of 0.03m, in significant wave height on both sides of the slipways when a SE gale is considered. However there are also small increases in significant wave height at the structures in the order of 0.08m due to the presence of piles. Both increase and decrease is localised and does not extend far beyond the slipways construction. Considering Figure 9.20 and Figure 9.22 showing north and west gale directions the difference is smaller and would be insignificant. A northerly gale gives no change in significant wave height and westerly gales only show changes on the lee side of the Greencastle slipway.

9.3.5 Modelling Littoral Currents

The sediment transport which has occurred has generally been as a result of wave action. Site investigation carried out in relation to a previous study in this area confirmed this by indicating the bed as being compact in nature and therefore not highly mobile. For this reason the littoral currents (comprising both tidal and wave constituents) were simulated for the pre- and post-construction situations during gales of Force 8 from south-easterly, northerly and westerly directions. These currents, being the driving force behind sediment transport, will allow the determination of the effect of the construction on the associated sediment transport.

The wave models discussed previously were used to simulate the Force 8 gale for a series of water levels to determine the radiation stresses throughout the course of a number of tidal cycles. The tidal model presented in Section 9.3.2 was then re-run for this period incorporating the radiation stresses; the resulting flow regime therefore included both tidal and wave induced currents. This process was carried out for both the existing bathymetry for high water, ebb tide and flood tide.

To assess the impact of the proposed construction four periods were compared through the tidal cycle. The first of these was littoral currents at high and low waters when, for all scenarios, the influence of the tide is minimal and the wave impact is more dominant. The changes at slack water were found to be minimal when compared to those mid-ebb and flood periods; therefore they have been omitted from this document. The littoral current and changes due to the proposed developments are presented in the following section.

For each gale scenario six plots are presented. The first two relate to the existing littoral current on the ebb and flood tide respectively. These are followed by detailed figures showing the changes at each of the two sites at the same point in the tide cycle. It should be noted that the contour bands differ between the existing and change plots in order to highlight the changes more clearly.

The SE gale is presented in Figure 9.23 to Figure 9.26, the northerly condition in Figure 9.27 to Figure 9.30 and the westerly gale in Figure 9.31 to Figure 9.34. In the case of the SE gale scenario during the ebb tide the tidal flows are in the opposing direction to the wind; conversely on the flood tide they are in the same direction.

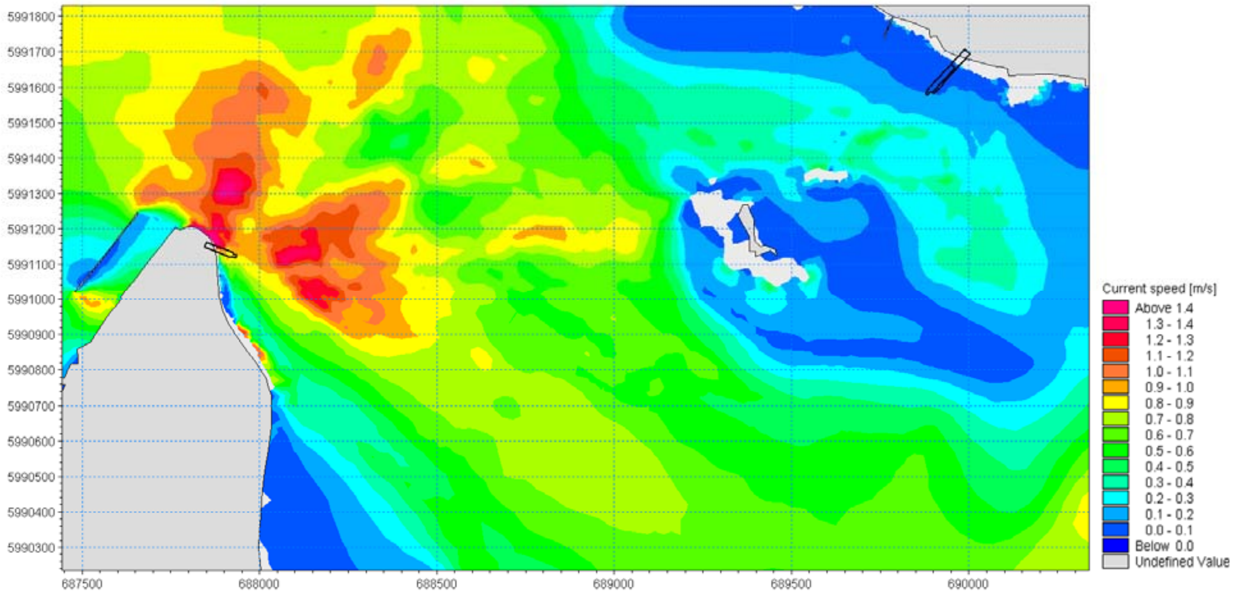

Figure 9.23: Existing littoral currents for F8 SE gale – typical ebb

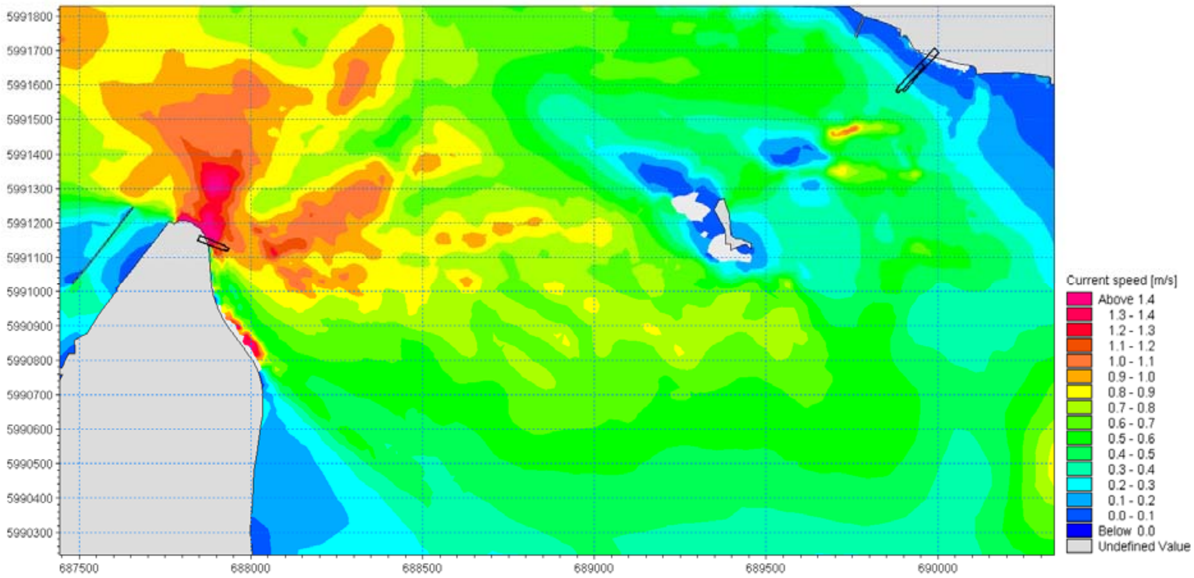

Figure 9.24: Existing littoral currents for F8 SE gale – typical flood

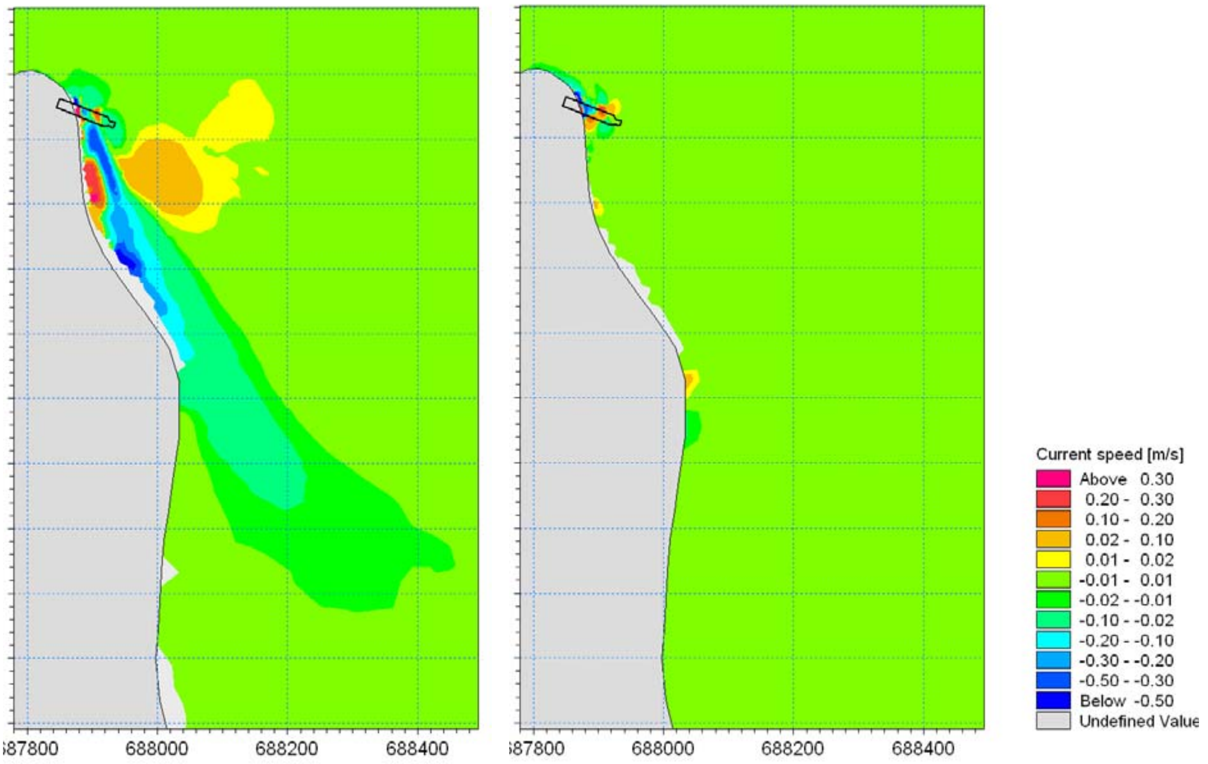

Figure 9.25: Change in littoral current for F8 SE gale Greenore – typical ebb & flood

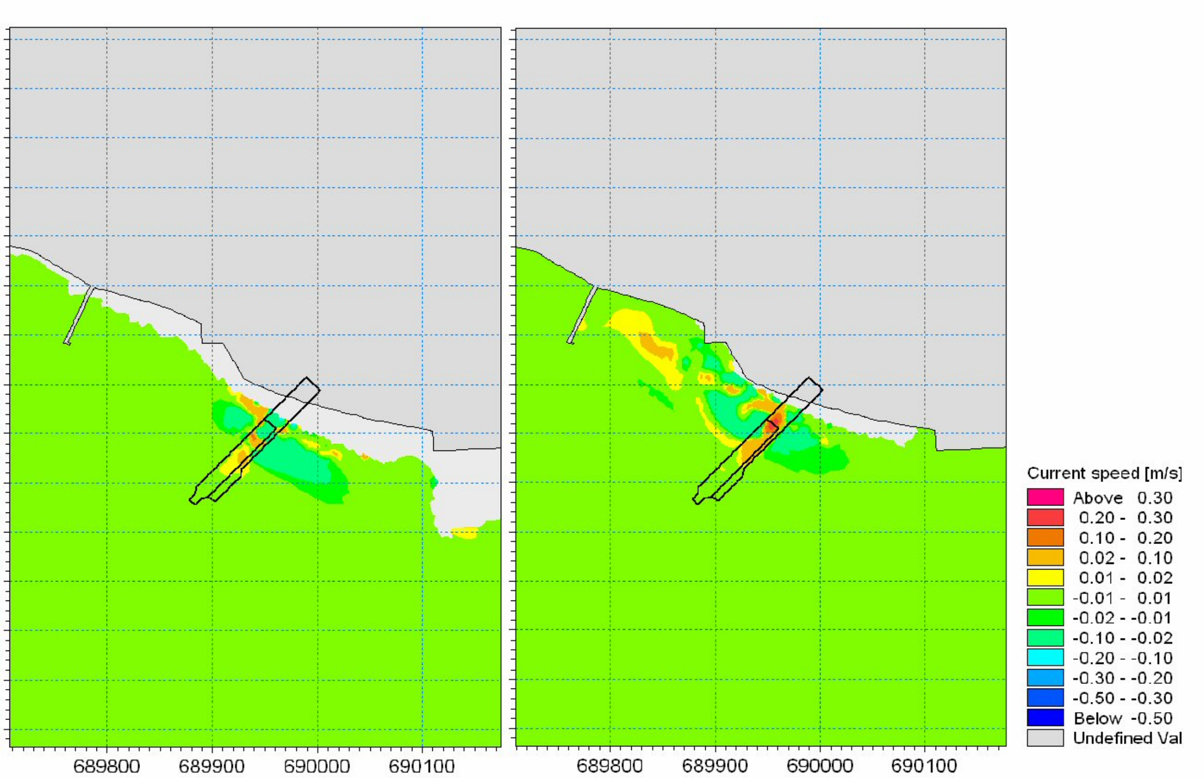

Figure 9.26: Change in littoral current for F8 SE gale Greencastle – typical ebb & flood

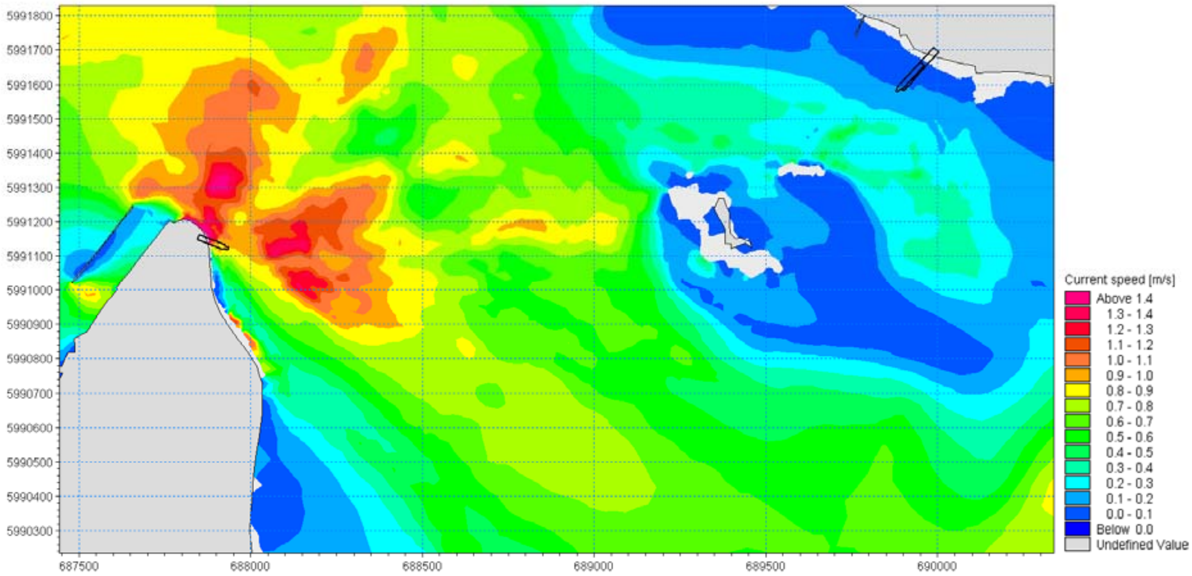

Figure 9.27: Existing littoral currents for F8 N gale – typical ebb

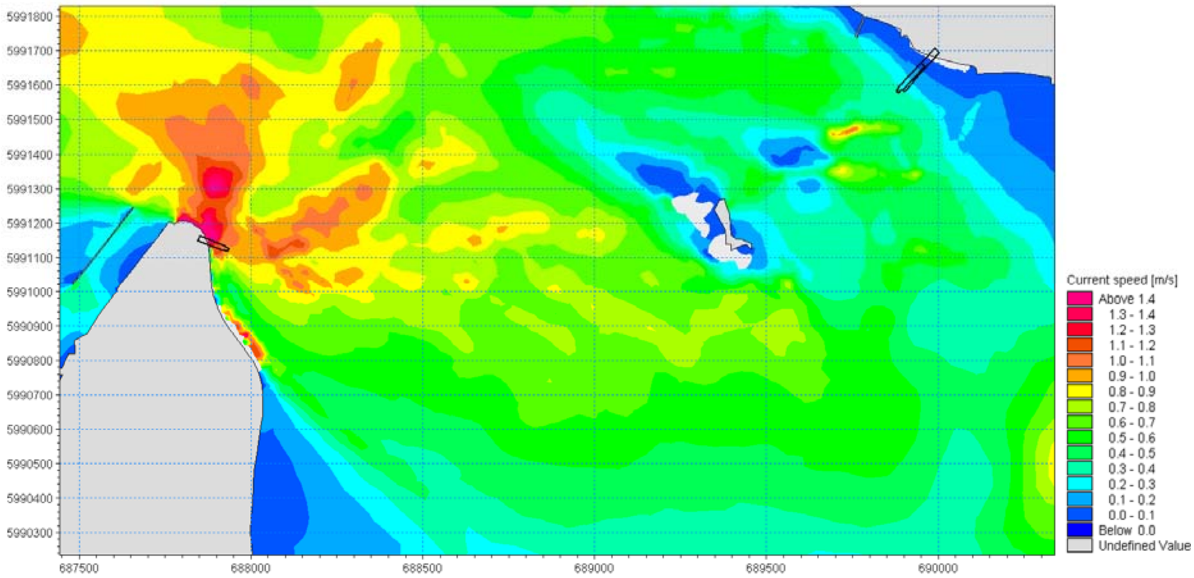

Figure 9.28: Existing littoral currents for F8 N gale – typical flood

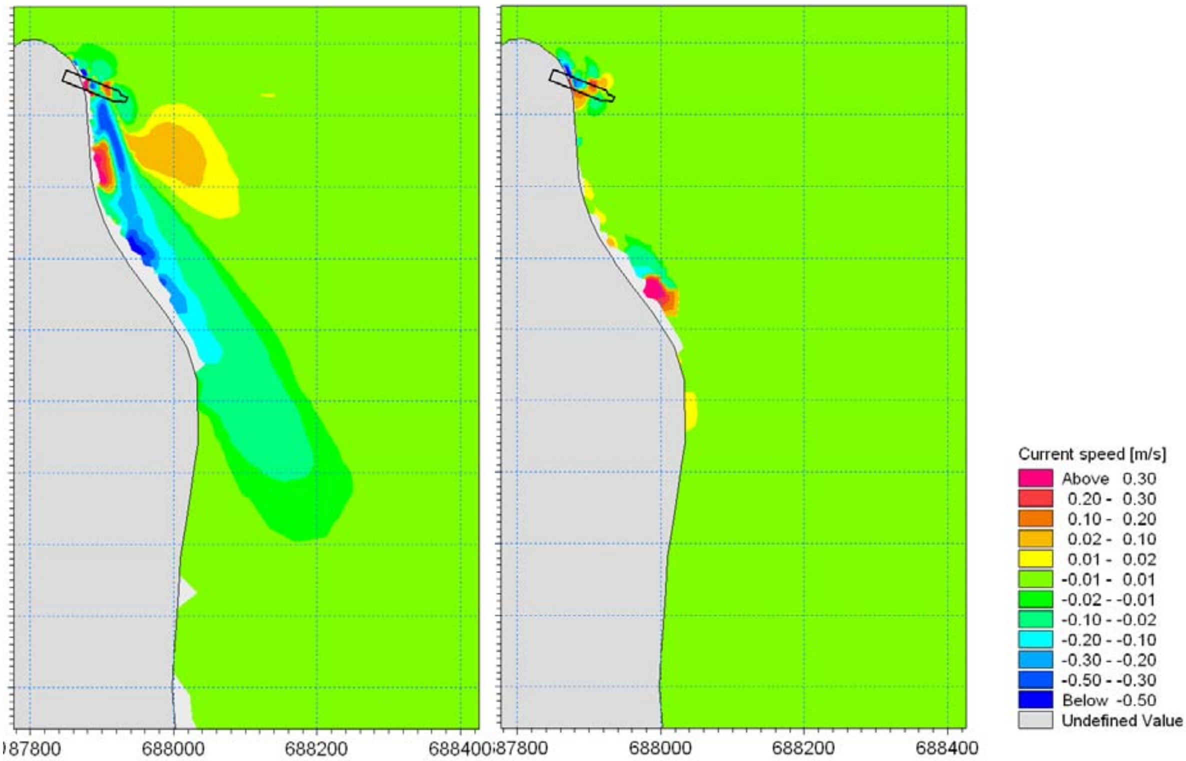

Figure 9.29: Change in littoral current for F8 N gale Greenore – typical ebb & flood

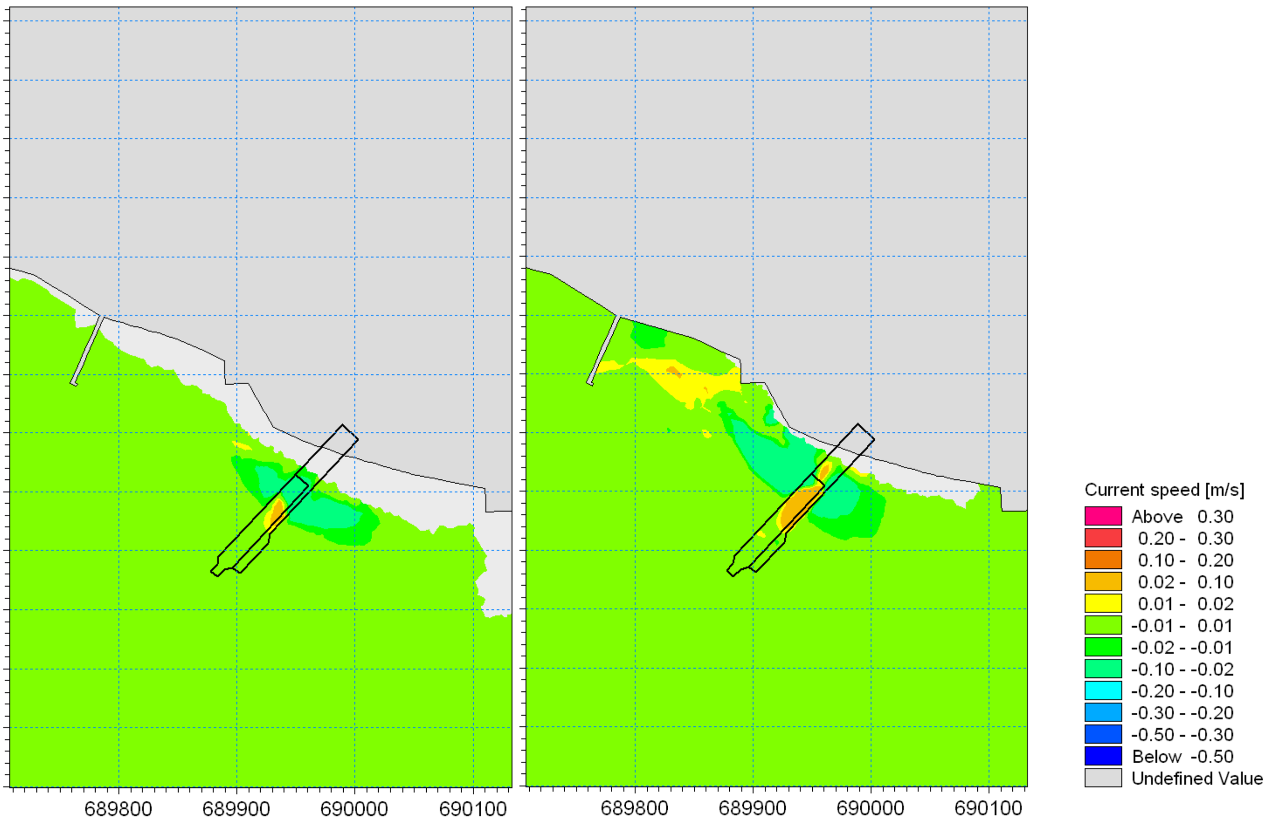

Figure 9.30: Change in littoral current for F8 N gale Greencastle – typical ebb & flood

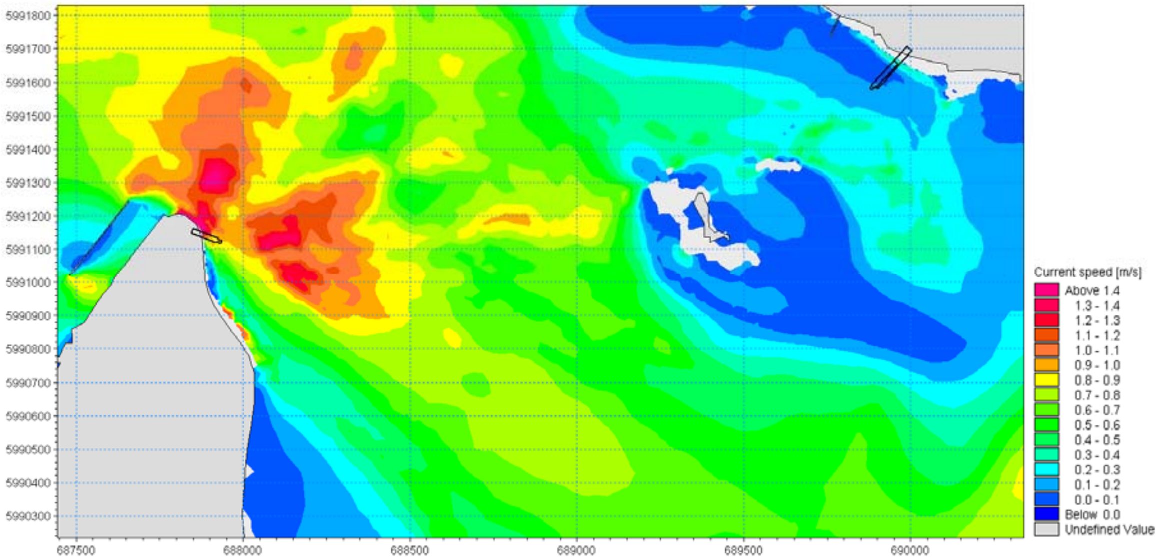

Figure 9.31: Existing littoral currents for F8 W gale – typical ebb

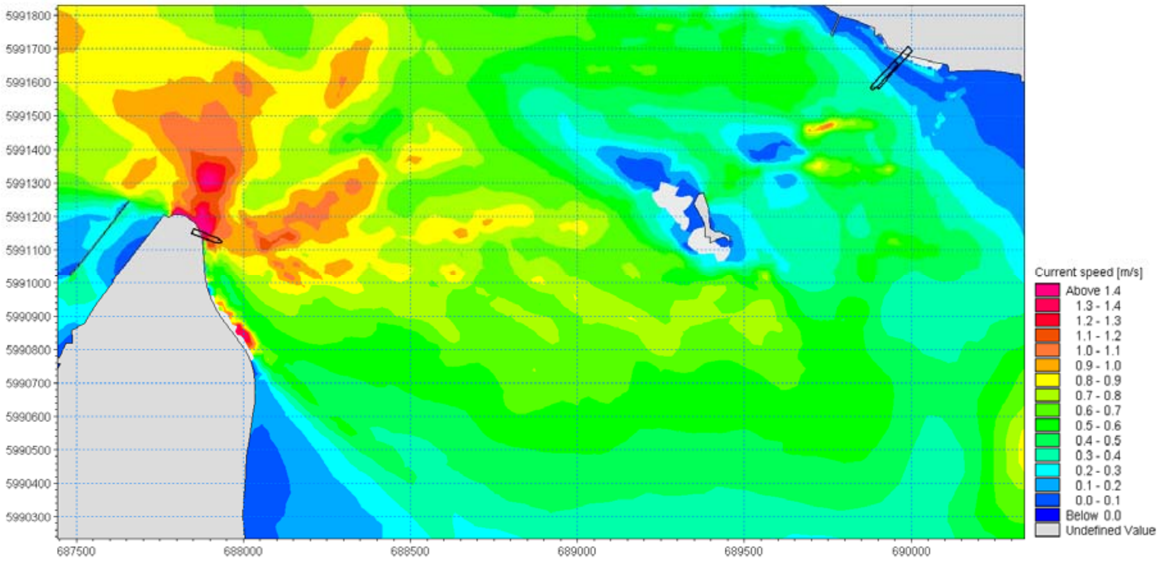

Figure 9.32: Existing littoral currents for F8 W gale – typical flood

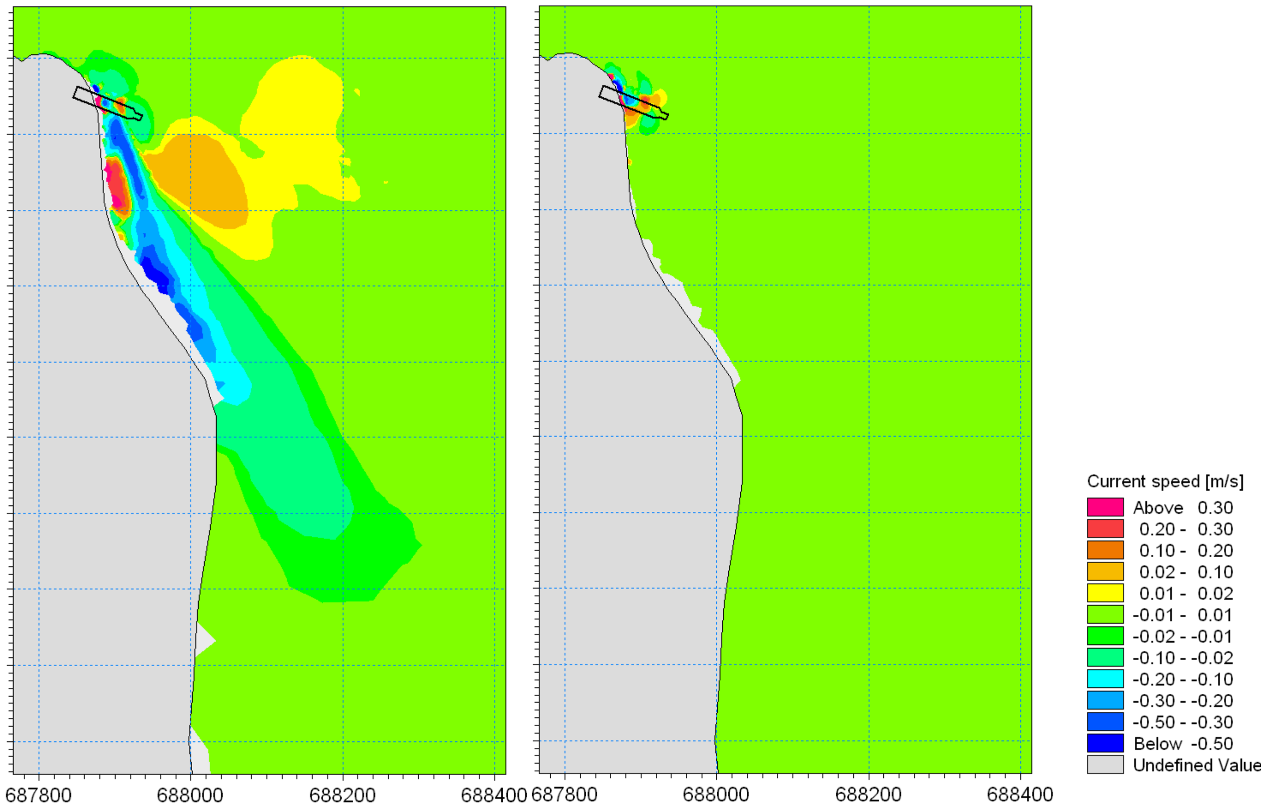

Figure 9.33: Change in littoral current for F8 W gale Greenore – typical ebb & flood

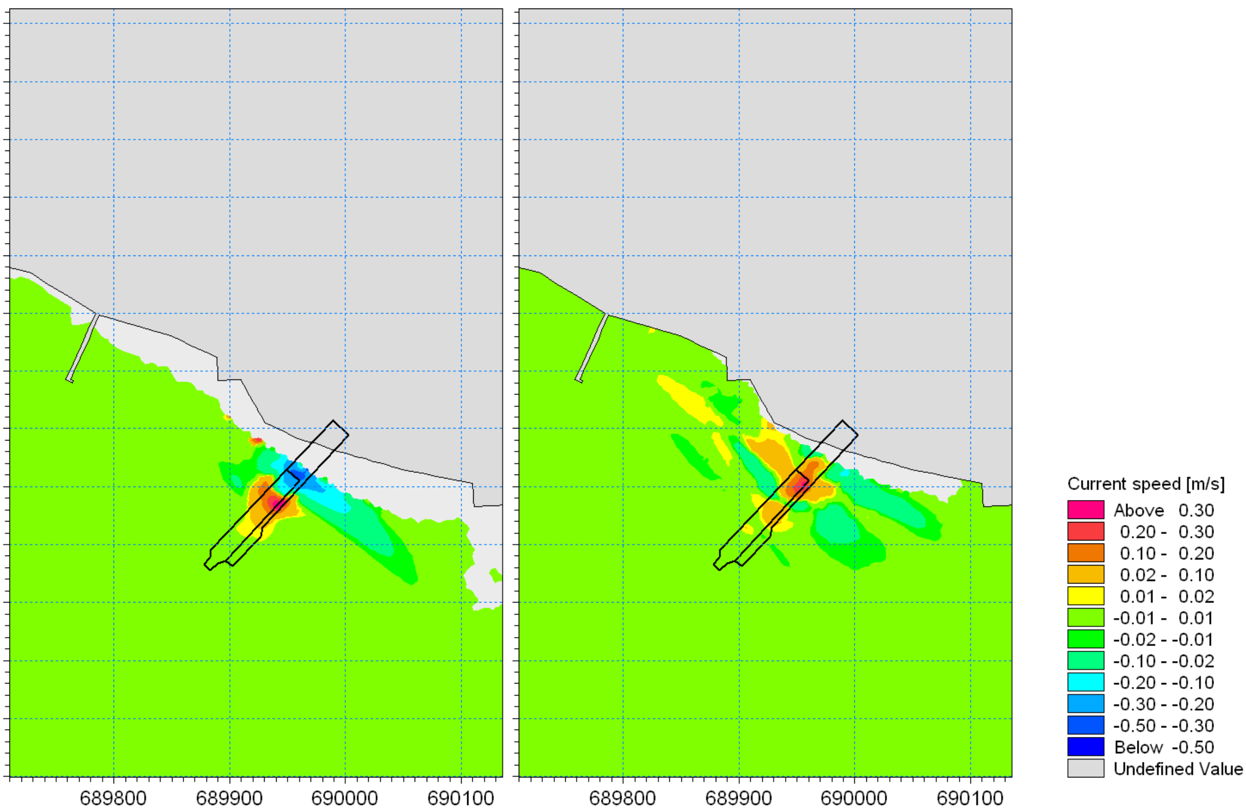

Figure 9.34: Change in littoral current for F8 W gale Greencastle – typical ebb & flood

The general form of littoral current existing at the shoreline to the east of Greenore Point is in a south to north direction due to the eddy off the headland during ebb tides. The presence of the ferry infrastructure may restrict this current and subsequent sediment transport under these conditions, however the open nature of the structure should minimise the impact on sediment transport. The strong similarities between the existing littoral currents at Greenore under all gale scenarios demonstrate that the sediment transport is dominated by tidal currents at this location. As discussed previously, the effect of the proposed construction is to slightly deflect the flow pattern around the headland altering the shape of the eddy. This is demonstrated most clearly on the ebb tide plots in Figure 9.25, Figure 9.29 and Figure 9.33.

Change in littoral current is most dominant during ebb tide in Greenore for all scenarios and both decreased and increased in littoral current can be seen. A decrease of 0.5m/s is caused by the slipway structure itself along with the piles. There is also increased littoral current of 0.03m/s the end of the slipway which is caused by the deflection of the flowpath due to the structure. The effect on the littoral currents varies little between storm conditions and is very small and localised on the flood tide.

In the case of the flood tide the most dominant factor for change is the variation in tidal current with altered water depth associated with the slipways construction. Small changes, in the order of 0.1m/s, are also evident due to the slight modification of the trajectory of tidal flows around Greenore point which were also apparent in the tidal modelling discussed in Section 9.3.3.

The Greencastle site is more sheltered and the nature of this site means that there is little impact on the site during south-easterly and northerly gales with the storms from the west having the greatest impact in terms of littoral currents. The changes in currents, shown in Figure 9.26, Figure 9.30 and Figure 9.34, demonstrate that the impact on the littoral currents and therefore sediment transport are much smaller than the Greenore site. The changes due to the proposed construction and generally limited to within a 100m radius of the site and are unlikely to impact on the existing sediment transport regime.

9.4 Cumulative Impacts

The coastal impacts above have all been addressed both independently and with regards to any potential cumulative impacts resulting from potential interactions between the construction or operational phases of any ongoing developments, recently approved development and pre-application developments outlined in Chapter 3. Due to the small scale of the proposed Carlingford Ferry development and the distance from developments outlined in Chapter 3 no cumulative impacts on (coastal processes & currents) are predicted.

9.5 Ferry Operations

The Greencastle – Greenore ferry proposal includes a ferry route as illustrated in Figure 9.35. The route has a minimum depth of around 4m CD.

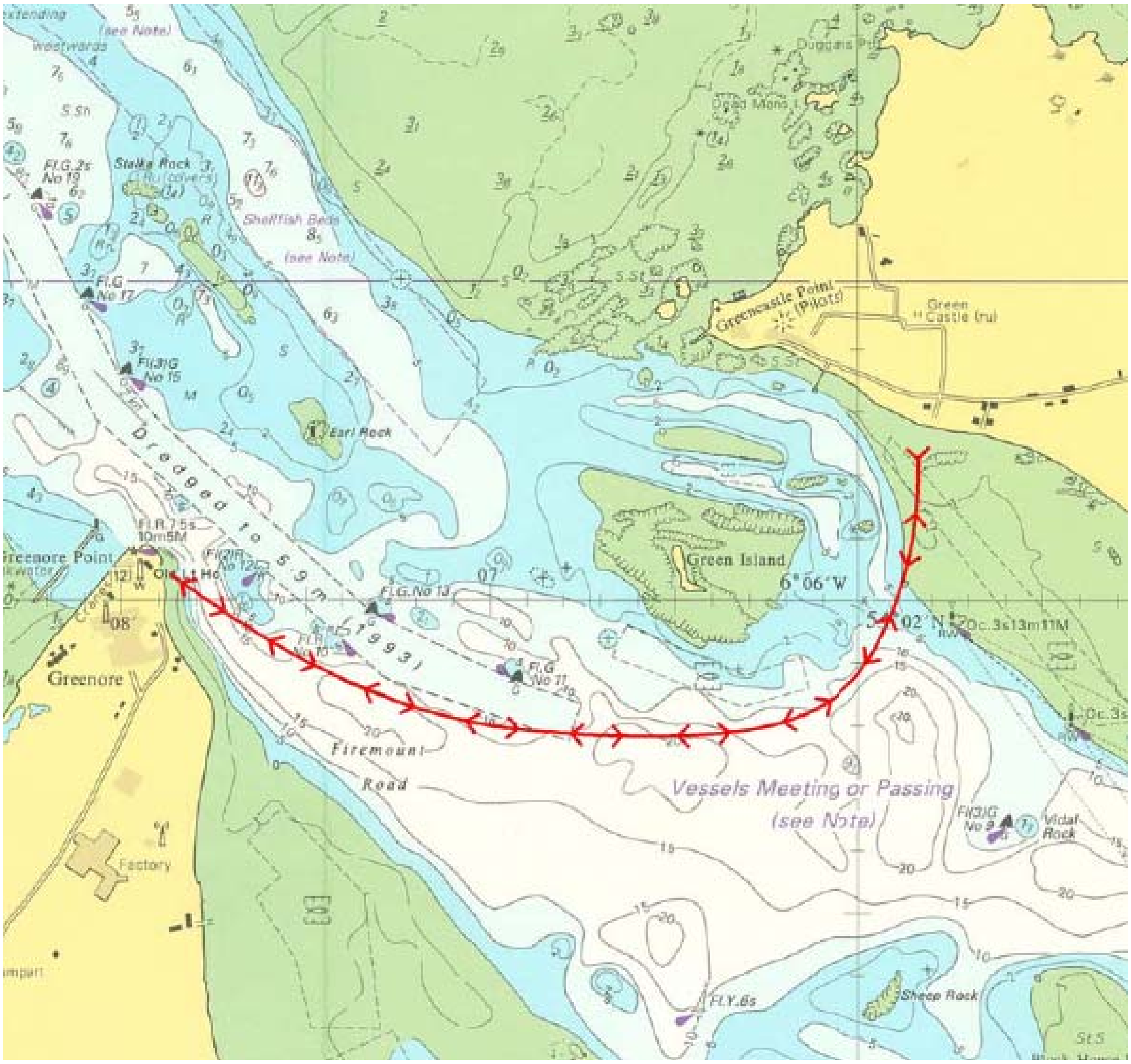

Figure 9.35: Proposed Ferry Route

The vessel is anticipated to be 40-60m in length and travel at 8-12knots. This would give rise to a critical depth in terms of ferry wash of around 3m at the highest speed. Given the draft of the vessel and available water depth the ferry should always be operating in water of a greater than critical depth and therefore resonant frequencies of waves are not likely to occur.

Across the range of operating conditions described i.e. vessel speed and tidal range, the period of the waves generated due to wash are likely to be between 2.7 and 4 seconds. These wave conditions would be similar to those experienced within the Lough due to relatively frequent meteorological conditions. Wave height will attenuate with distance from the ferry and therefore waves at Greenore Island which is at a minimum 200m from the route the wave climate would be within the norm experienced on the shoreline of the Island.

9.6 Conclusions

The potential effects of the proposed ferry and construction of the associated infrastructure on the tidal regime and sediment transport have been investigated using numerical models. A tidal model showed that changes in bathymetry had effects which were limited to the immediate vicinity of the development and did not alter the wider tidal flow pattern. The magnitude of these changes was seen to be typically ±0.07m/s in peak velocities. In the area surrounding the proposed developments very limited reduction in peak velocities could be observed. These sites continued to be flushed and the tidal patterns remained largely unaltered.

Wave modelling was undertaken to demonstrate the effect of the proposed construction under typical gale conditions from a variety of directions and stages within the tidal cycle. Typically the effect of the ferry infrastructure was in the slipways and immediately adjacent areas; with a typical change in significant wave height of ±0.05m. Gales from the three directions show no major change in wave climate surrounding the proposed ferry slipways.

Assessment of littoral currents under a relatively severe events and the presence of the ferry infrastructure show that sediment transport along the shoreline south of Greenore Point would be affected to a greater degree (by ±0.3m/s during ebb tide) and the overall area of impact extends 400m along the east shoreline. This is due to a slight change in the eddy which forms off Greenore Point on the ebb tide, which currently gives rise to a circular residual current pattern. The changes however are mainly localised on the eastern shore and as such should not have an adverse impact on sediment transport around the ferry slipways or within the 400m area of impact along the eastern shoreline due to the open nature of the proposed structures. It may be concluded that the changes to tidal currents are not significant and limited to the immediate vicinity of the development.