# A7.0 Coastal processes

## A7.1 Methodology

This section of the EIS describes key aspects relating to the baseline coastal processes, followed by an assessment of the magnitude of the effects upon the baseline conditions resulting from the construction and operation of the proposed scheme.

This assessment process has been informed by:

- desk-based review of existing information;
- analysis of newly collected or acquired survey data; and,
- interpretation of numerical modelling results.

In particular, the MIKE21 Spectral Wave (SW) model was used to determine wave conditions within the vicinity of the proposed scheme footprint, and a three-dimensional (3D) Hydrodynamic (HD) Model of Stanley Harbour was developed using MIKE-21 HD flexible-mesh (FM) numerical modelling software. Both models were developed using metocean data and updated bathymetric data (refer to **Section A7.2.1** for further detail). The HD model was run for a baseline scenario (i.e. existing conditions, with FIPASS present) and then with the proposed scheme in place (and with FIPASS dismantled and removed) to quantify the potential effect of the proposed scheme on hydrodynamic conditions.

Further detail about the set-up and operation of the wave modelling and hydrodynamic modelling is provided in **Ref. 5** and **6** respectively.

In addition, the potential for the semi-enclosed conditions that will be created by the proposed scheme (i.e. the area in the lee of the causeway and quay) has been investigated by undertaking flushing modelling to assess the potential impact on water quality in the semi-enclosed area. This aspect is reported separately in **Section A8.0**.

It was envisaged at the environmental scoping stage that, due to the low energetic conditions in Stanley Harbour, the effect on the baseline hydrodynamic regime is likely to be localised in spatial extent and small in magnitude and, therefore, unlikely to cause an alteration in baseline sediment transport patterns. Furthermore, the magnitude of change was deemed unlikely to be sufficient to cause far-field effects on the morphological function of Stanley Harbour. Consequently, sediment transport modelling was not undertaken.

While a change to coastal processes can be predicted and described with respect to the known baseline conditions in terms of its magnitude of effect, it is not appropriate to assess this change in terms of significance. Instead the significance of any changes in coastal processes is assessed upon those environmental receptors that could subsequently be affected by the change in coastal processes, such as water quality and marine ecology, within the relevant sections of the EIS.

It should be noted that the modelling and assessment reported in this section of the EIS has been undertaken on a quay structure which is both longer and wider than that currently proposed. It is therefore concluded that the potential effects on coastal processes arising from the smaller quay would be within the bounds of the assessment undertaken for the larger quay. For this reason, the modelling and assessment undertaken on the larger quay (which is illustrated on figures throughout this section of the EIS) has not been repeated for the smaller sized quay.

## A7.2 Baseline conditions

### A7.2.1Bathymetry

The Falkland Islands are situated on a projection of the Patagonian continental shelf, which is bounded to the north by a steep slope (the Falklands Escarpment), separating it from the Argentine Basin. A gently north-eastward sloping area between the Falkland Islands and the Falklands Escarpment, at water depths of between 150 and 1,500m, is known as the North Falklands Basin (Otley *et al.*, 2008).

Based on freely accessible bathymetric information available online (https://webapp.navionics.com/) and the numerical model bathymetry data (presented in **Figure 7.1**), it can be seen that the main body of Stanley Harbour has a maximum water depth of approximately 10m, with a depth of up to approximately 13m in the Narrows (the narrow entrance to Stanley Harbour from the north). Over the majority of the area of Stanley Harbour, depth typically ranges between approximately 5m and 9m.

Bathymetric and topographic survey data was collected in September 2020 in the immediate vicinity of the proposed scheme footprint (**Figure 7.2**), showing that FIPASS, and consequently the proposed scheme, is typically within water depths of around 3 - 5m. At the shore, the seabed shelves steeply, reducing by around 5m in water depth (from +1m to -4m) over a length of around 175m (**Figure 7.3**).

A layer of surficial silts (formed from sewage sludge) has accumulated on the bed of the harbour. In places within the footprint of the proposed scheme, the thickness of this layer can locally be up to 2m.

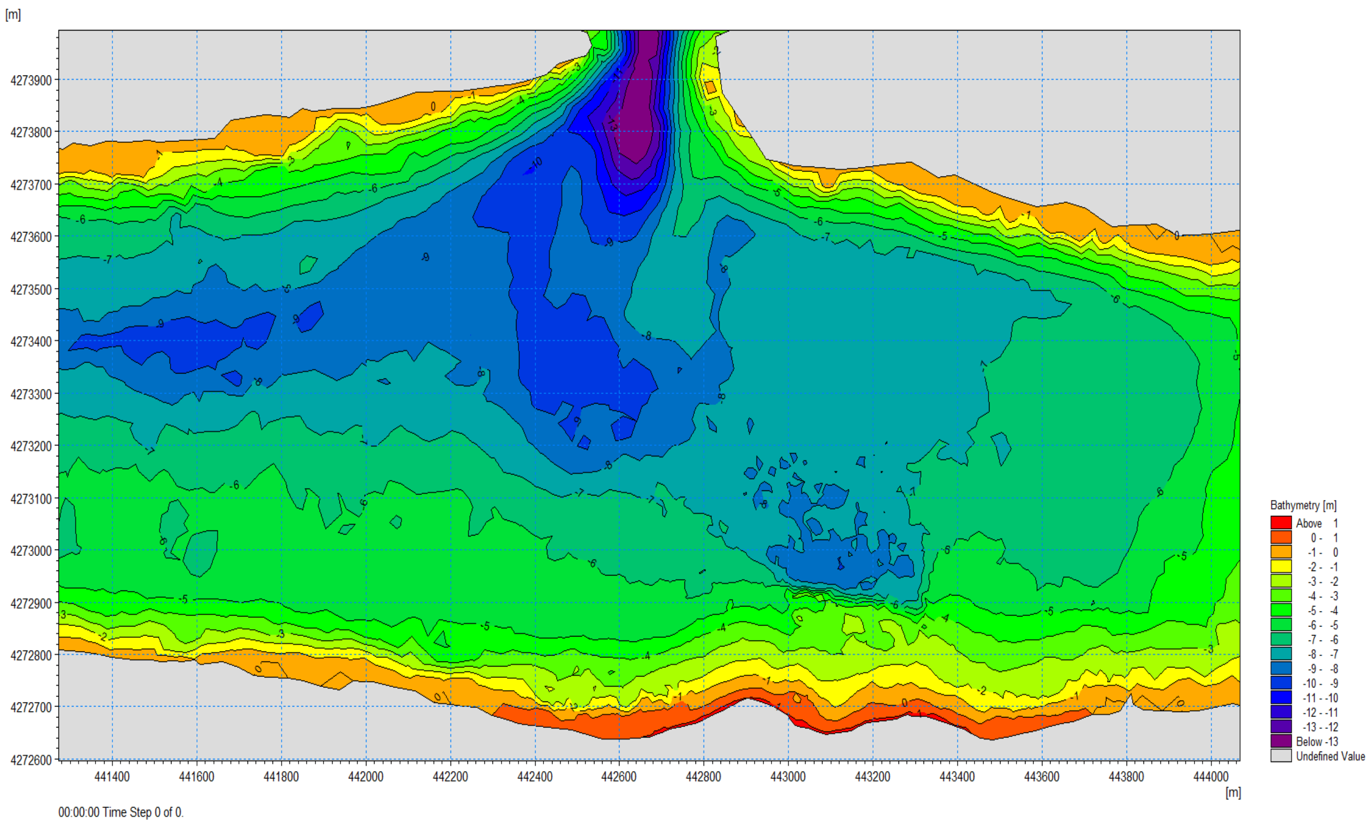


**Figure 7.1** **Bathymetry of Stanley Harbour**

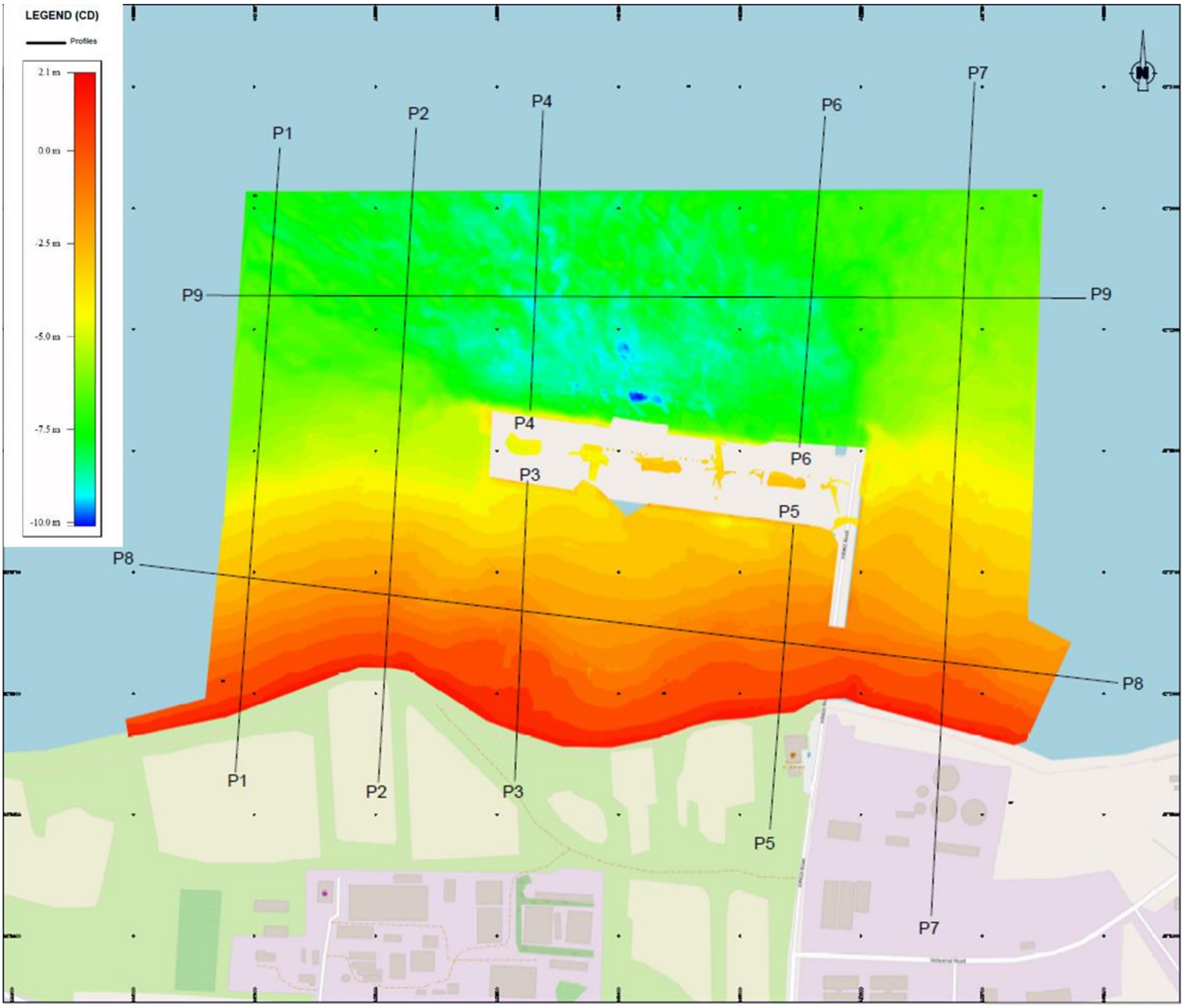


**Figure 7.2** Bathymetric contours in the vicinity of FIPASS and the proposed scheme


**Figure 7.3** Bathymetric cross section in the vicinity of FIPASS and the proposed scheme (cross section 3 shown on Figure 7.2)

### A7.2.2Local oceanographic conditions

**Winds**

There is no significant seasonal variation in wind direction and strong winds are frequent throughout the year; the Falkland Islands are located in one of the world's most energetic wind climates (Regnauld *et al.*, 2008). As detailed in the State of the Environment Report (Falkland Islands Government Environment Unit, 2020), monthly average wind speed is generally in the order of 15 knots.

Manually recorded hourly time-series wind data was obtained from Stanley Airport covering periods when the airport was in operation between 2006 and 2020. This showed a dominant wind direction from the west (270°N).

Further wind data (frequency tables for Mount Pleasant Airport) was purchased from the UK Meteorological Office covering the period 2010 and 2019. This also shows a dominant wind direction from the west (270°N) with 25.2% of winds coming from this directional sector. However, the greatest wind speeds (up to 24 m/s) are from the north (0°N) and south-west (210°N) sectors (**Figure 7.4**).

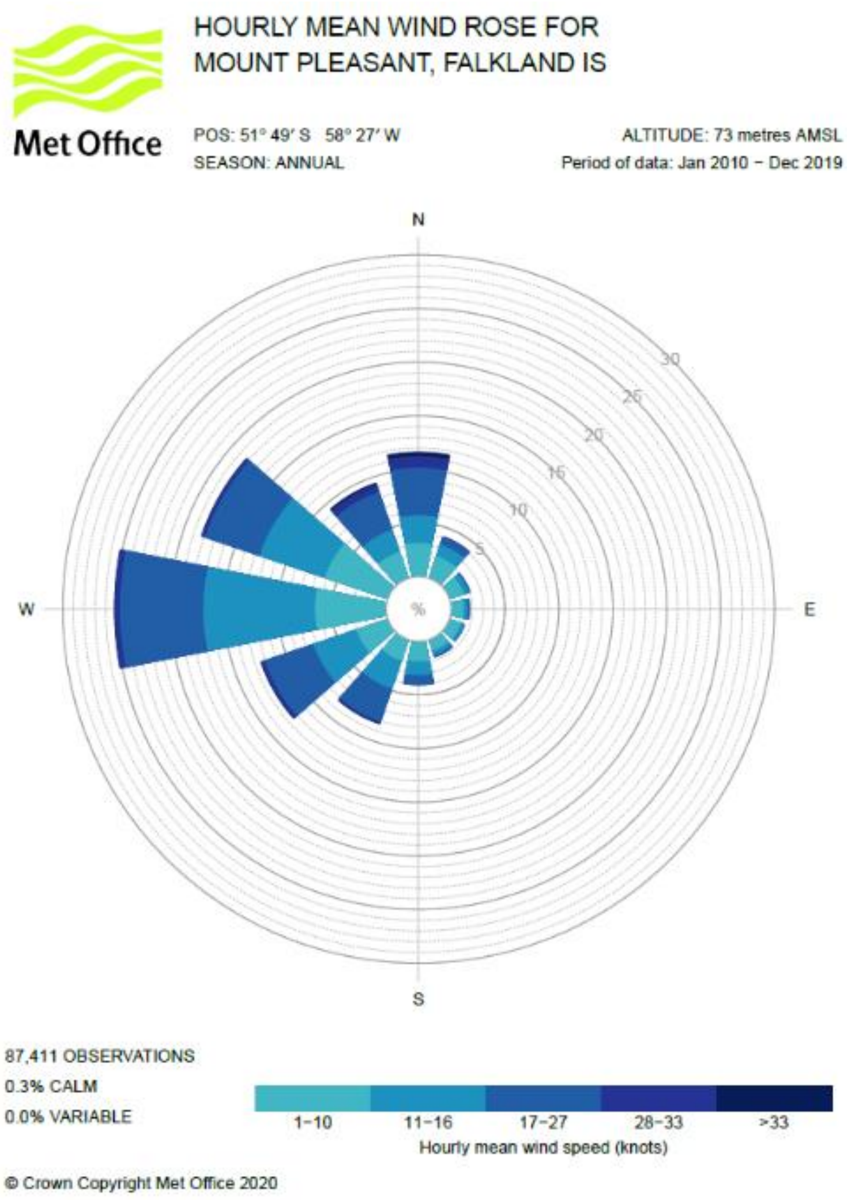


**Figure 7.4** **Annual wind rose at Mount Pleasant Airport (2010-2019)**

### Waves

Given the predominance of westerlies and the constrained entrance into Stanley Harbour, swell waves are not a significant issue at the location of the proposed scheme. The wave climate is dominated by locally-generated wind waves that will occur across the approximate 8km fetch of Stanley Harbour (noting that the maximum fetch for waves occurring at the location of the proposed scheme is approximately 6.5km).

Numerical modelling, using the MIKE21 SW Model, was undertaken to hindcast waves at the proposed scheme footprint. Four wind directions (0°N, 60°N, 210°N and 270°N) and two return periods (1 in 1 year and 1 in 100 years) were considered. Wave modelling was undertaken at a fixed water level of Mean High Water Springs (MHWS), with sensitivity tests also performed at a level of MHWS + 1m for the 1 in 100 year return period to determine worst case wave conditions.

For the 1 in 1 year event, significant wave heights (Hm0) and peak wave periods (Tp) at the proposed scheme footprint are worst under winds from the north, reaching up to 1m in height and with 3.2s in period (**Figure 7.5**). These values increase under a 1 in 100 year event to 1.85m in height and 3.9s in period, again with winds from the north producing the greatest wave conditions at the proposed scheme footprint (**Figure 7.6**). It should be noted that the existing structures within the harbour (including FIPASS) were excluded from the baseline wave modelling (as the wave model does not accurately simulate the effects of such structures).

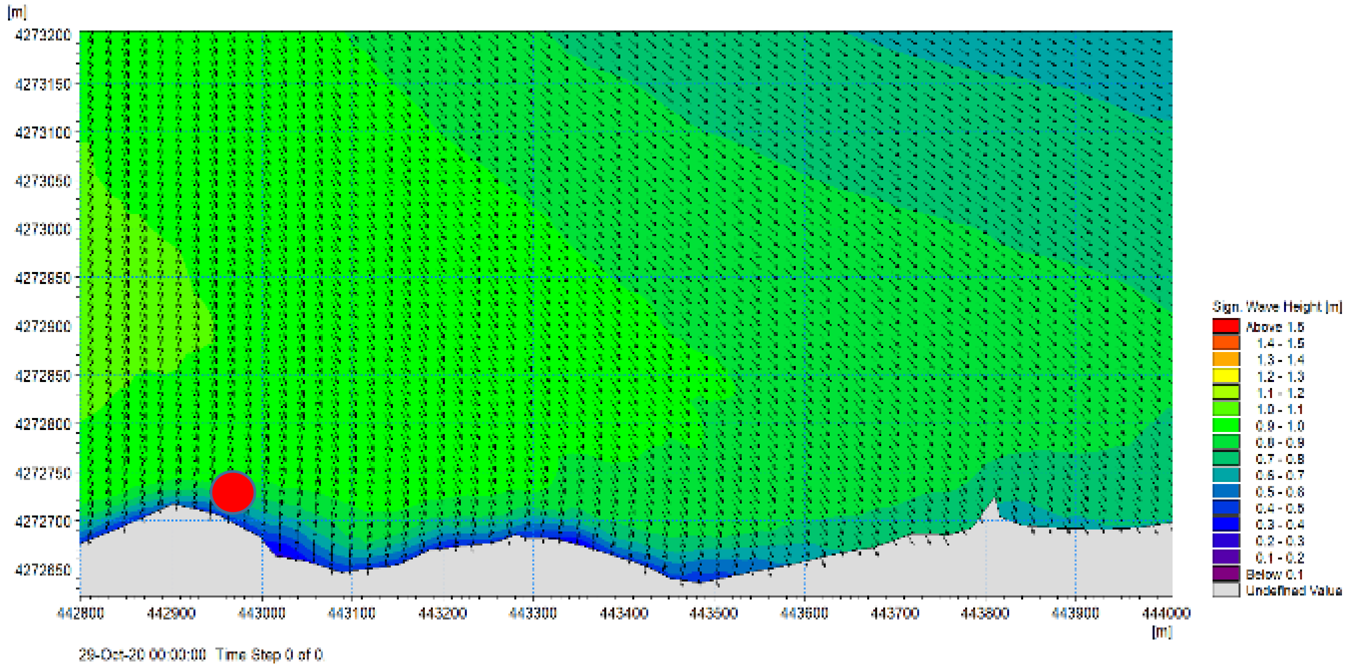


**Figure 7.5** **Baseline wave conditions under a 1 in 1 year event with winds from 0°N (indicative scheme location shown by the red circle)**

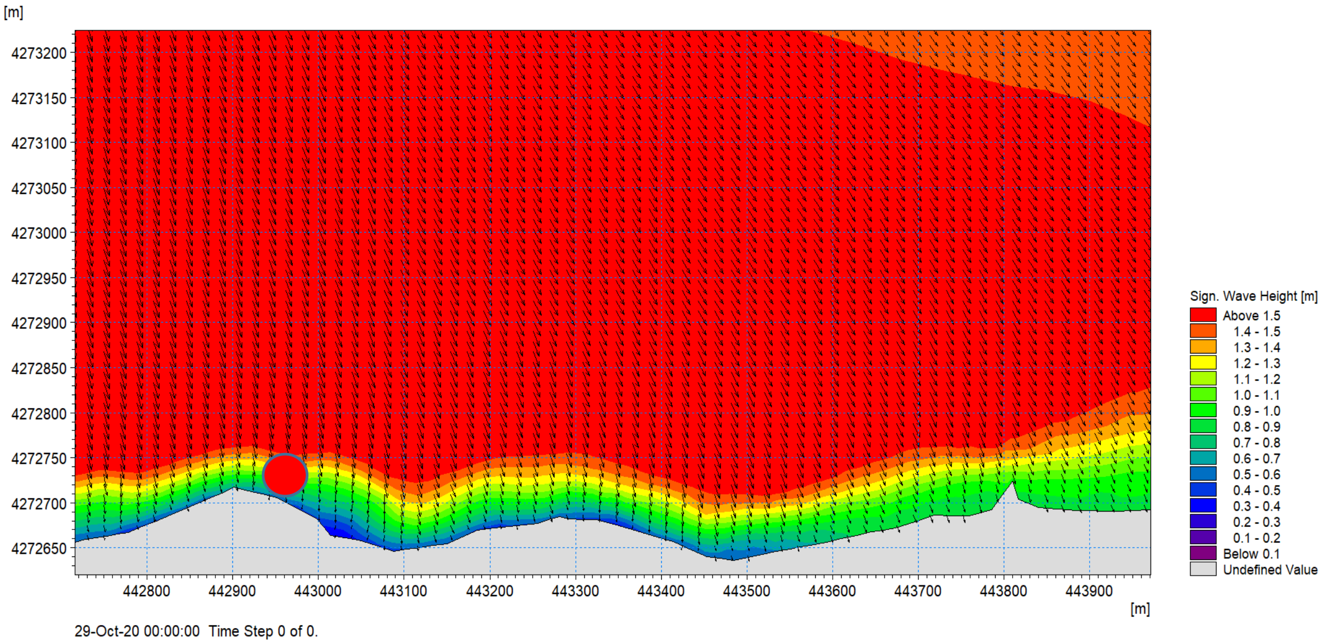


**Figure 7.6** **Baseline wave conditions under a 1 in 100 year event with winds from 0°N (indicative scheme location shown by the red circle)**

## Tidal levels

The UK Hydrographic Office publishes predictions of astronomical tidal levels at Port Stanley on an annual basis. The maximum high tide level (Highest Astronomical Tide (HAT)) recorded in the tide tables for Stanley Harbour is 2m CD, with the minimum level (Lowest Astronomical Tide (LAT)) recorded as 0m CD. The Mean Sea Level is 1m CD, with Mean Low Water Springs (MLWS) at 0.128 m CD and MHWS at 1.5m CD. The site can be described as a micro-tidal environment.

**Figure 7.7** shows the tidal levels derived from the MIKE21 hydrodynamic model over the course of one year (in this case the year 2020), whilst **Figure 7.8** shows the tidal levels for a typical monthly cycle to more distinctly demonstrate the daily variations (by way of example the month of February 2020 is shown).

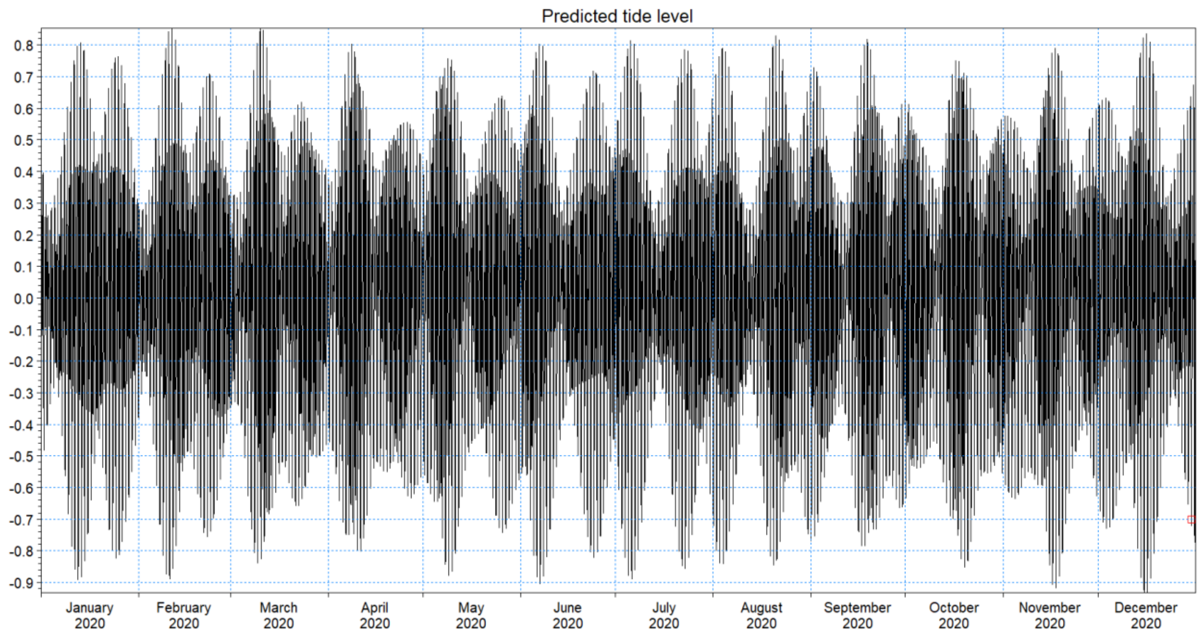


**Figure 7.7** **Predicted tide levels in 2020 (relative to mean sea level)**

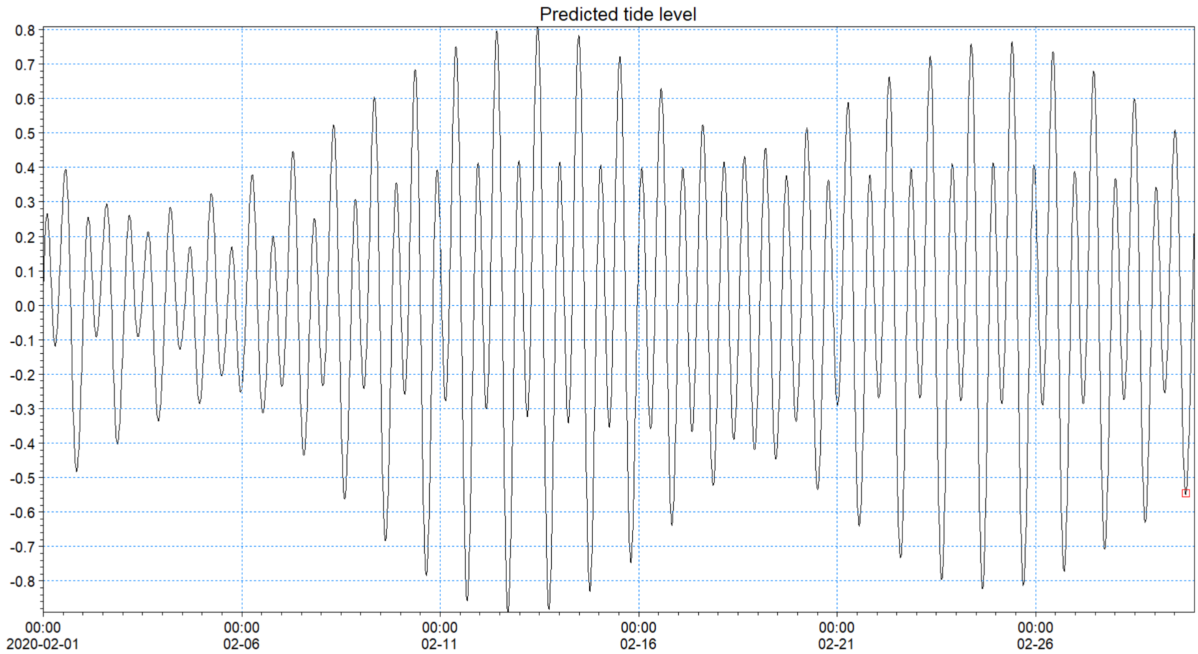


**Figure 7.8** **Predicted tide levels in February 2020 (relative to mean sea level)**

### Tidal currents

The baseline tidal currents are influenced by the presence of FIPASS, which consists of six floating barges, six dolphins and six sets of causeway piers. These elements have therefore been included in the baseline hydrodynamic modelling.

**Figure 7.9** presents an example plot from the baseline modelling, showing tidal current velocities at mid flood during a neap tide. It can be seen that the baseline currents are of the order of 0.01 to 0.02m/s in the vicinity of FIPASS and increase only to around 0.05m/s around 600m north of the shore.

**Figure 7.10** presents an example plot from the baseline modelling for the corresponding phase of a spring tide, showing that baseline spring tidal currents are greater than those observed during the neap tide, but remain at low values. In the vicinity of FIPASS, currents are up to around 0.08m/s, increasing to around 1.0m/s within around 400m of the shore.

Overall, because the site is a micro-tidal environment, the baseline current speeds are extremely low at all stages of the tidal cycle and are not significantly influenced by FIPASS due to the relatively open nature of its construction.

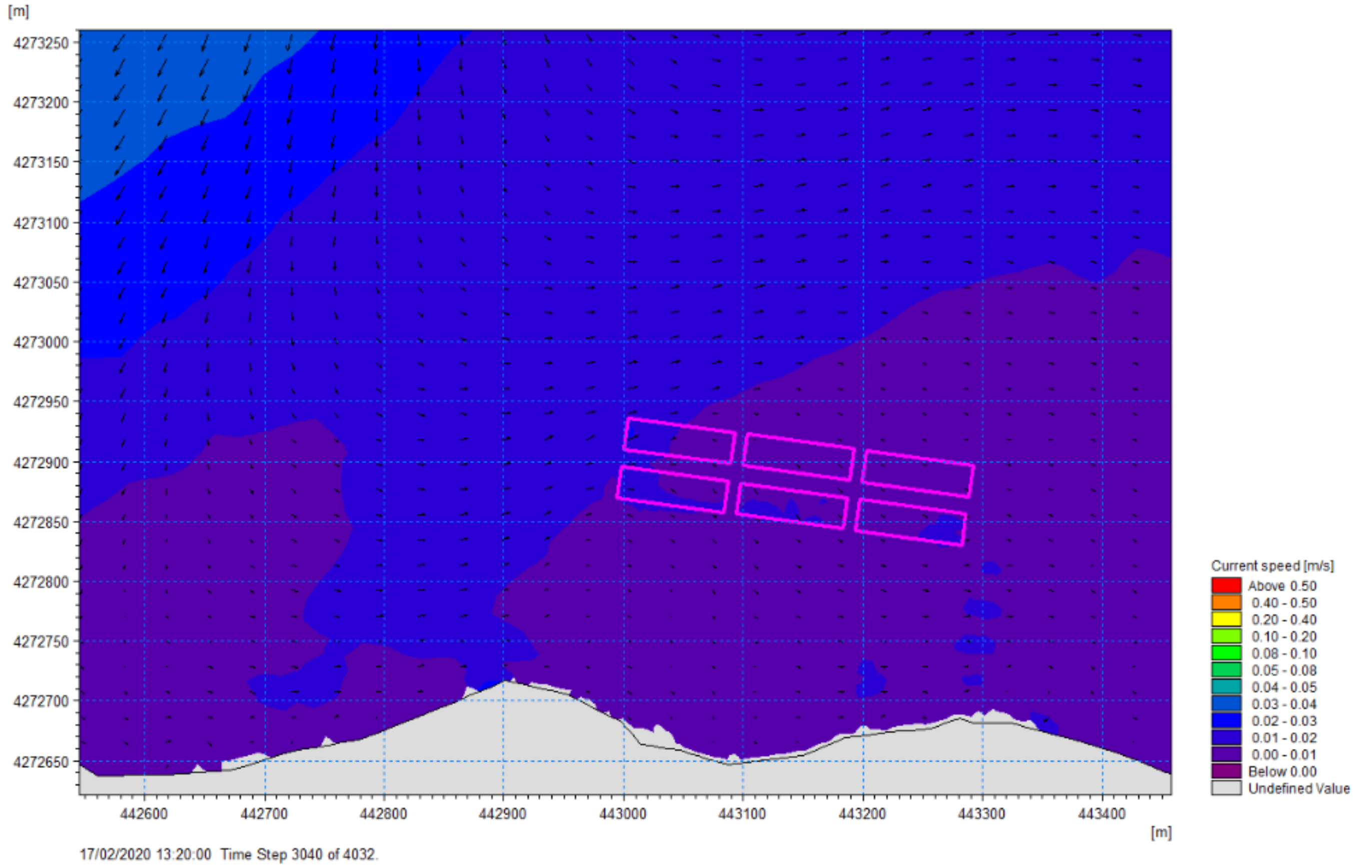


**Figure 7.9** Modelled baseline tidal currents during neap tides at mid flood

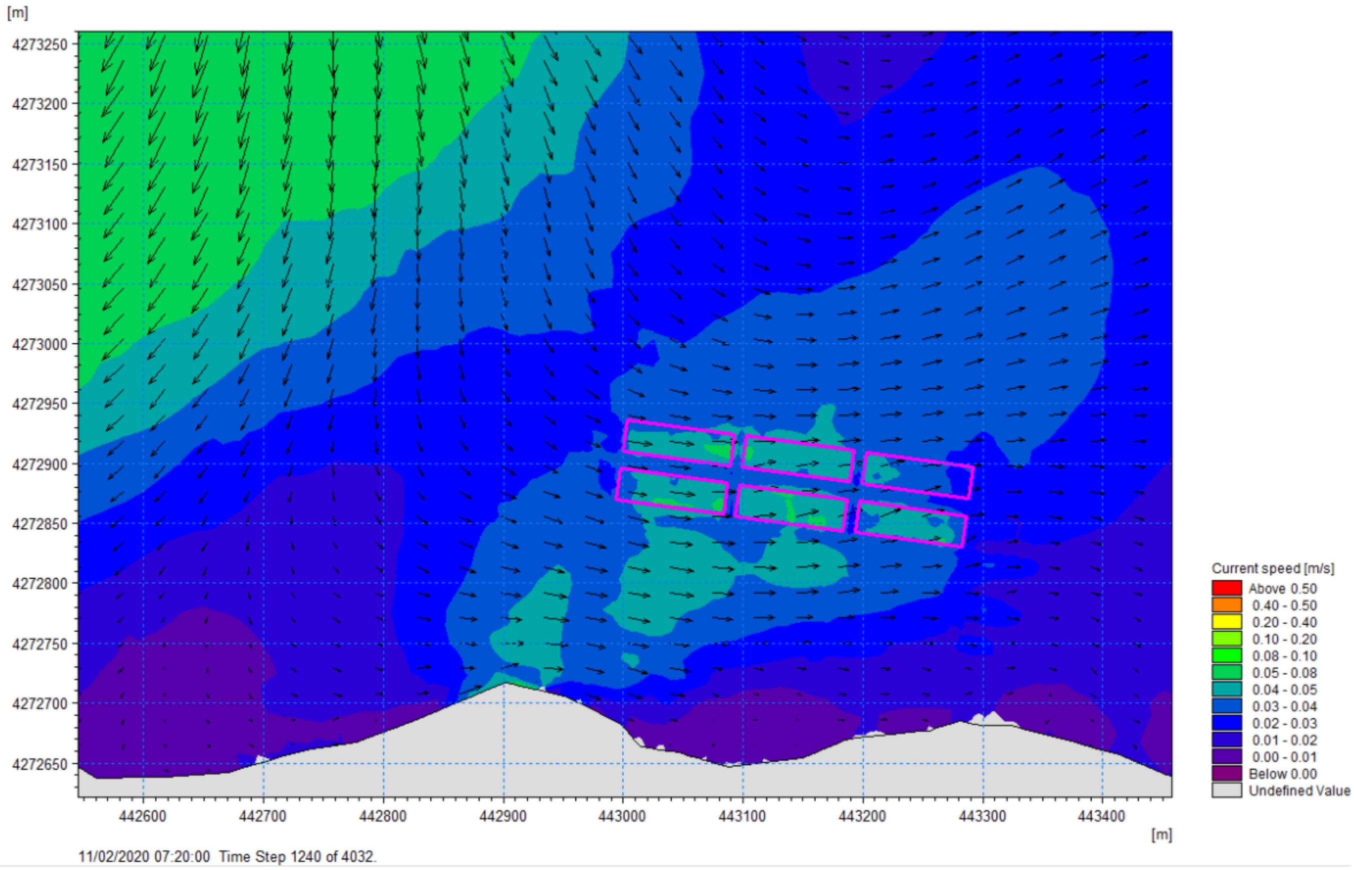


**Figure 7.10** Modelled baseline tidal currents during spring tides at mid flood

### A7.2.3 Sea level rise

The IPCC recommends various allowances for sea level rise depending on the effectiveness of efforts to control global warming. The project assumes the RCP8.5 scenario (Representative Concentration Pathways 8.5 is the most pessimistic 'greenhouse gas emissions scenario') for the proposed design life of 50 years. The 50 percentile value yields a sea level rise of 400mm. This has been factored into the design for the proposed scheme.

### A7.2.4 Local morphological and sedimentological conditions

Stanley Harbour is a large natural harbour connected to open water by The Narrows which is approximately 150m in width. The superficial geology around Stanley predominantly comprises Holocene deposits of Marine Clay overlying Solifluction Deposits and stone runs of Pleistocene age. The Marine Clay is described as *"firm, slightly over-consolidated, fissured, green grey sandy CLAY" (*Aldiss and Edwards, 1999*)*, and the Solifluction Deposits are described as *"Pale grey unsorted stony sandy silty clays (diamictons) and stony sandy silts, and often contain subangular quartzite boulders" (*Aldiss and Edwards, 1999*).*

There is no published information on the seabed sediments in Stanley Harbour, although it is observed to primarily comprise a soft sedimentary shoreline with large rocks and areas of rocky outcrops (SMSG, 2011). From previous studies undertaken in the area, the surface of the sediment within the harbour is understood to be dominated by homogeneous soft silts with a relative lack of habitat variability (Royal HaskoningDHV, 2013).

As reported in **Section A9.1**, a site-specific benthic ecological survey was undertaken within the eastern section of Stanley Harbour, including the recovery of 24 grab samples from across a seabed grid for particle size analysis (PSA). This shows the majority of sediments between The Narrows and FIPASS to be slightly gravelly muddy sand (11 samples) or gravelly muddy sand (eight samples) (refer to **Figure 9.6**). There was one sample of slightly gravelly sand and towards The Narrows, the bed is characterised by slightly coarser sediment texture in the form of muddy sandy gravel (three samples) or muddy gravel (one sample). One further sample of muddy sandy gravel was also noted immediately seaward of FIPASS.

There is a long history of raw sewage disposal into Stanley Harbour which creates a slurry of low-strength fine-grained surficial silts layered on top of the natural bed deposits. In places within the footprint of the proposed scheme, the thickness of this layer can locally be up to 2m (however it should be noted that these silts are likely to be widespread across the rest of the harbour). Under baseline conditions, the soft surficial sediments are mobile, particularly under propeller action, and are suspended in the water column and become deposited beneath the FIPASS structures.

### A7.2.5 Future evolution of baseline in the absence of the proposed scheme

The baseline coastal processes cause relatively little effect on the seabed or shoreline morphology in the vicinity of the proposed scheme. The only notable change in the absence of the proposed scheme will be a predicted increase in water levels by around 400mm due to sea level rise over the next 50 years.

## A7.3 Potential effects during construction

### A7.3.1 Effect on hydrodynamics, sediment transport and morphology

To assist with the removal of FIPASS, a slipway will be built during the construction phase to hoist the barges from the water onto land for dismantling. This will require the construction of a new slipway in the immediate lee of FIPASS (shown on **Figure 4.1**). The slipway will have **negligible** effect on existing hydrodynamics, sediment transport and morphology (during either the construction phase or, if left in place, the operational phase) since the baseline currents in the harbour are so low and the footprint of the structure is small.

For construction of the proposed scheme, works are proposed to be undertaken predominantly using land-based plant. Due to this, the potential effects during construction upon the baseline hydrodynamics, sediment transport and morphology will be insignificant.

### A7.3.2 Disturbance and dispersion of bed material

During the construction phase, potential effects relating to the disturbance and dispersion of bed material may arise from: (i) the placement of fill material and positioning of rock armour; and (ii) increased turbidity during the progressive removal of surficial silts from the harbour bed.

As the proposed placement of rock on the bed of the harbour is to be undertaken using land-based plant, sediment disturbance is expected to be minimal, with only temporary and localised dispersion of any disturbed sediment due to the low energetic conditions at the location of the proposed causeway and quay. Broadly speaking, temporary in this context can be classified as the duration of the disrupting activity plus the order of minutes (rather than hours or days) after its cessation. Similarly, 'localised' in this context can be classified as the footprint of the disrupting activity plus the order of a few metres (rather than tens or hundreds of metres) beyond its footprint.

For the removal of surficial silts from the harbour bed within the footprint of the proposed quay, a 'heavy water' slurry (comprising approximately 90% water and 10% silt) will be removed progressively from the bed using a suction device and pumped into geotubes on land. The proposed suction technique is predicted to create less silt disturbance compared to other techniques which were considered. Silt management will be undertaken using flocculants within the geotubes and settlement tanks for the water draining from the geotubes before this water is returned to the harbour. Good industry practice measures will be adopted through all surficial silt removal activities and therefore any increases in turbidity are envisaged to be temporary, localised and small in magnitude. As described in **Section A7.1**, the implication of this predicted change is assessed (in terms of its significance) in the relevant receptor-specific chapters.

## A7.4 Potential effects during operation

### A7.4.1 Effect on hydrodynamics

**Waves**

During operation, there will be some wave reflection off the solid faces of the proposed quay wall and causeway, and some wave energy absorption from the proposed rock armour structures. To investigate the changes from baseline wave climate with the proposed scheme present, the MIKE-21 SW Model was run for a 'with scheme' scenario, for the same range of wind directions and return periods that were used for the baseline scenario modelling. The differences in wave climate are shown for the 1 in 1 year event (**Figure 7.11**) and the 1 in 100 year event (**Figure 7.12**) with winds from the north in both cases (with the wind from the north being the strongest). **.**

These results show that with the proposed scheme in place, there will be a considerable reduction in the baseline wave climate in the lee of the new quay, but that the effect is relatively localised and baseline conditions are unaffected seaward of the quay or beyond the proposed scheme along shore in either direction under this wind approach direction.

The zone of sheltering influence provided by the proposed scheme does alter along shore depending on the wind conditions assessed, such that if the wind is coming from the west (270°N) (as is the prevailing condition), then under a 1 in 1 year event the shore to the east of the proposed scheme has a reduced wave climate over a length of around 500m alongshore.

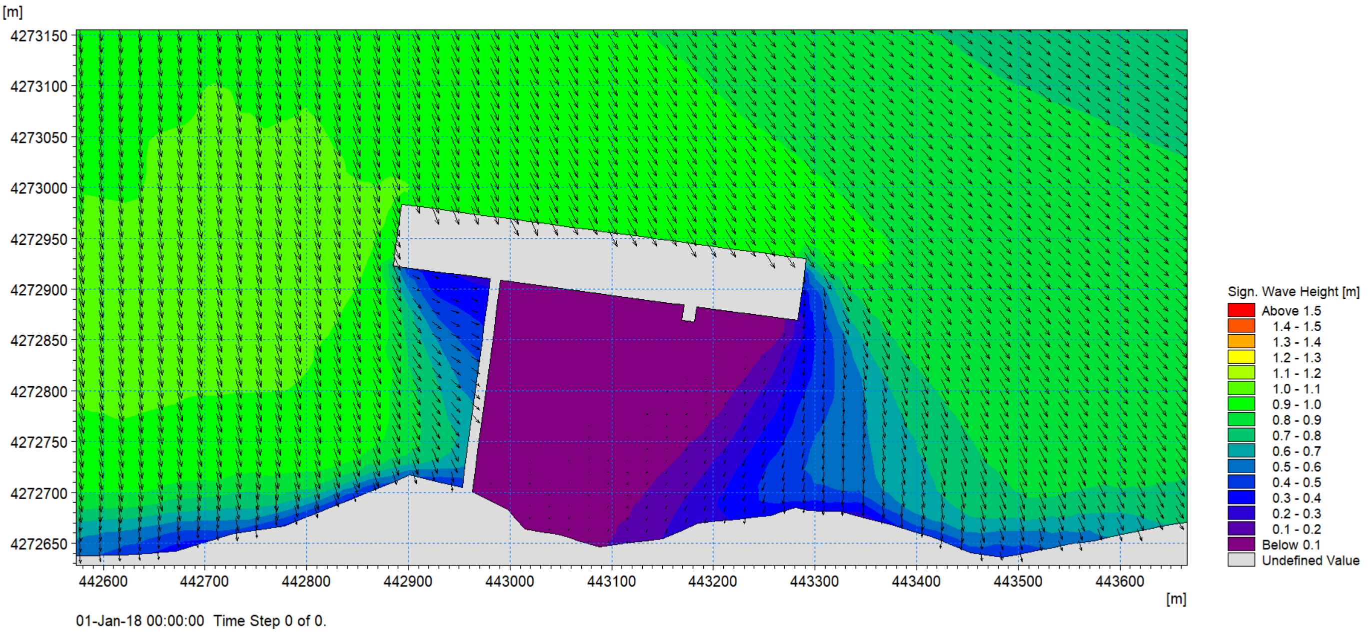


**Figure 7.11** **'With scheme' wave conditions under a 1 in 1 year event with winds from 0°N**

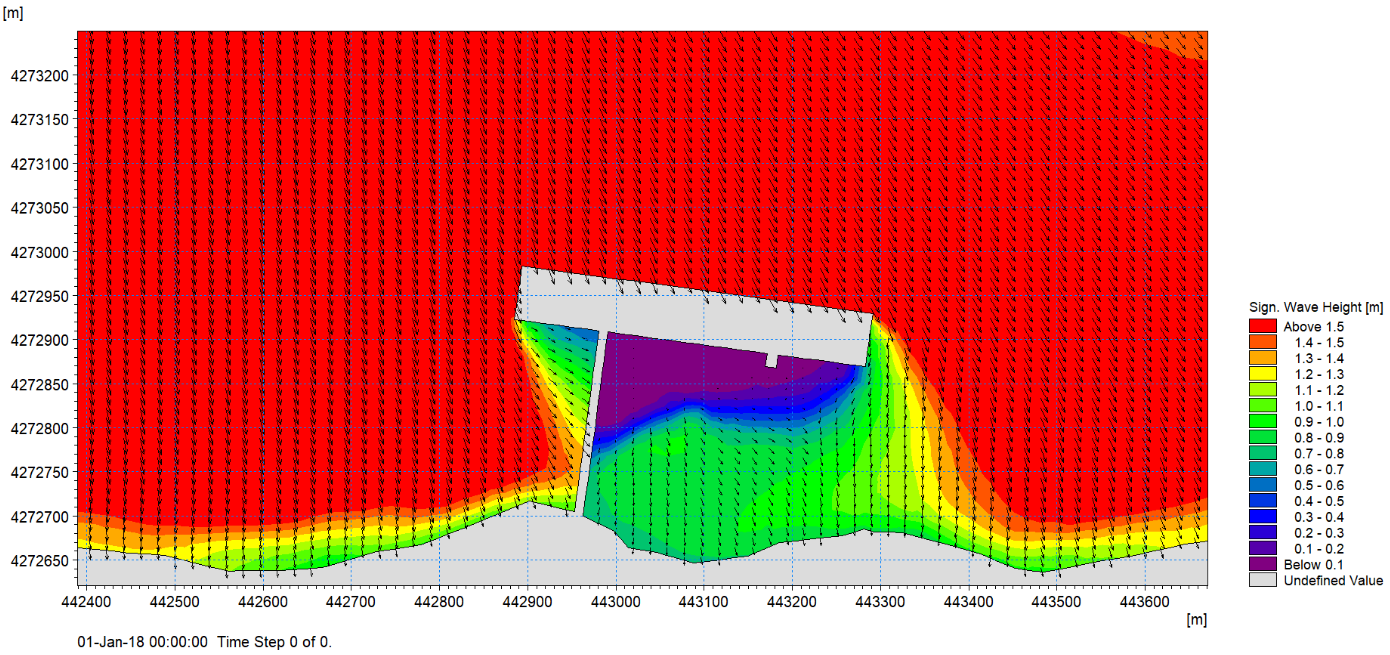


**Figure 7. 12** **'With scheme' wave conditions under a 1 in 100 year event with winds from 0°N**

## Tides

During operation, there could potentially be changes in tidal flow velocities (speed and direction) associated with the new structures in the marine environment (and the absence of FIPASS, which will have been dismantled). In particular, the proposed causeway and quay will create a semi-enclosed area of water, restricting tidal currents in this area. The magnitude of these changes has been assessed using the MIKE21-HD model, with the proposed scheme represented and FIPASS removed.

**Figure 7.13** presents an example modelled output showing tidal current velocities at mid flood during a neap tide. A similar example model output is presented in **Figure 7.14** for the spring tide. It can be seen that the tidal current direction is influenced locally by the presence of the new quay in particular, with the solid structure pushing the currents along its seaward face. However, the magnitude of the current speeds remains very low, with mostly the current direction being affected (locally).

To further investigate the magnitude of change, a series of 'difference plots' have been produced showing the changes in magnitude in current speed between the baseline and 'with scheme' conditions. These difference plots are presented in **Figures 7.15 (a-d)** and **7.16 (a-d)** for neap and spring tides respectively, with the same phases of each tidal cycle being represented, namely low water, mid flood, high water and mid ebb. In these plots any changes ±0.2m/s have been blanked as being beyond the range of model accuracy. It can be seen that during neap tides, the changes in baseline conditions are **negligible**. During spring tides, there are more widespread changes, albeit remaining local to the immediate vicinity of the proposed quay and causeway. In particular, currents off the eastern end of the proposed quay increase locally by up to around 0.05m/s and currents within the shoreward lee of the proposed new quay reduce through much of the tidal cycle by up to 0.05m/s (locally with a reduction of up to 0.1m/s at the landward end of the causeway at high tide).

These changes are small in magnitude and local to the proposed quay and causeway in spatial extent, although they do represent a relatively large percentage change in these areas compared to baseline conditions.

**Figures 7.17** (wider view) and **7.18** (proposed scheme view) show the absolute maximum difference in current speed that has been modelled between the baseline conditions and the 'with scheme' conditions at any point in the overall model run. This confirms that effects on tidal currents are confined to the immediate vicinity of the proposed scheme footprint and that increases in flow occur around the edges of the proposed new quay and rock armour, with decreases in the shoreward lee of the quay.

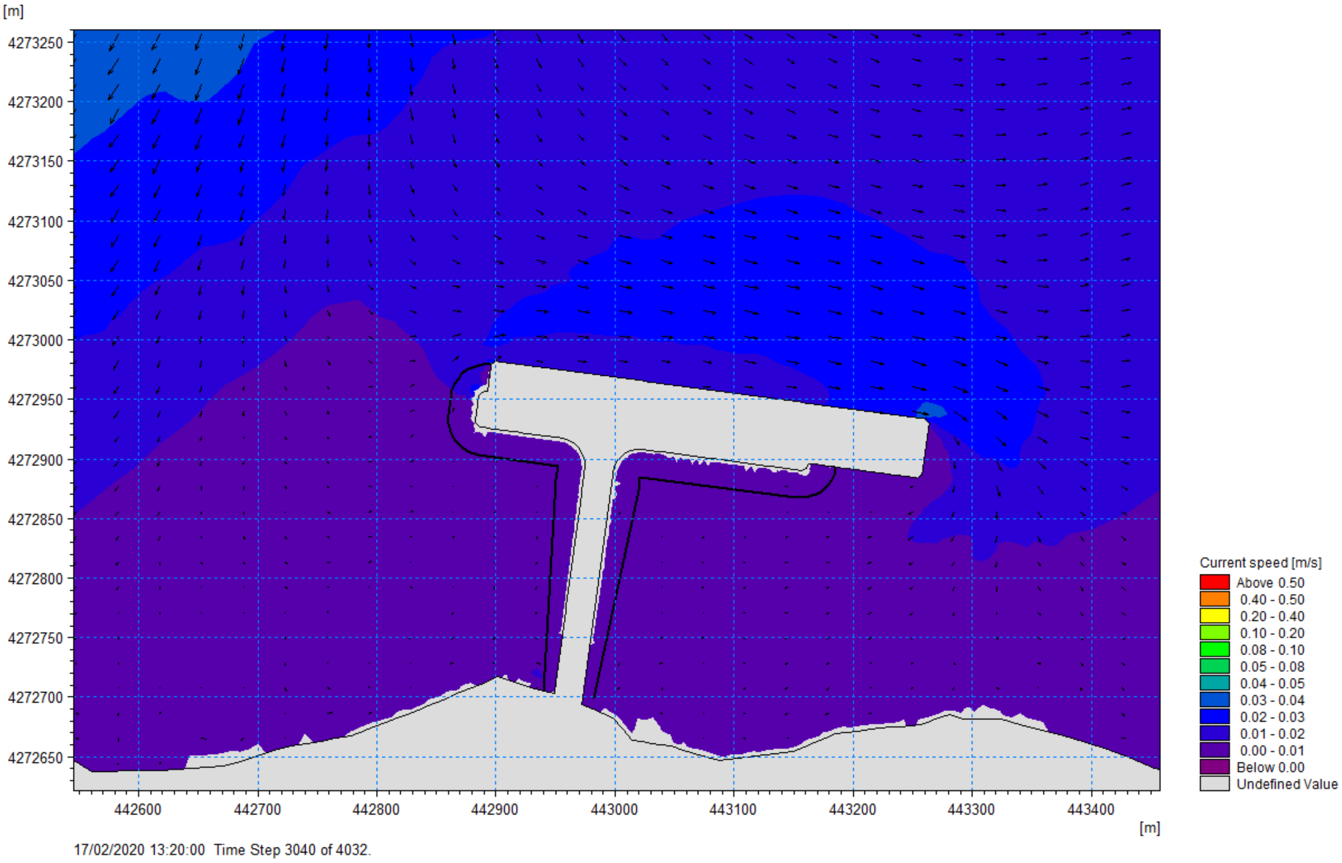


**Figure 7.13** Modelled 'with scheme' tidal currents during neap tides

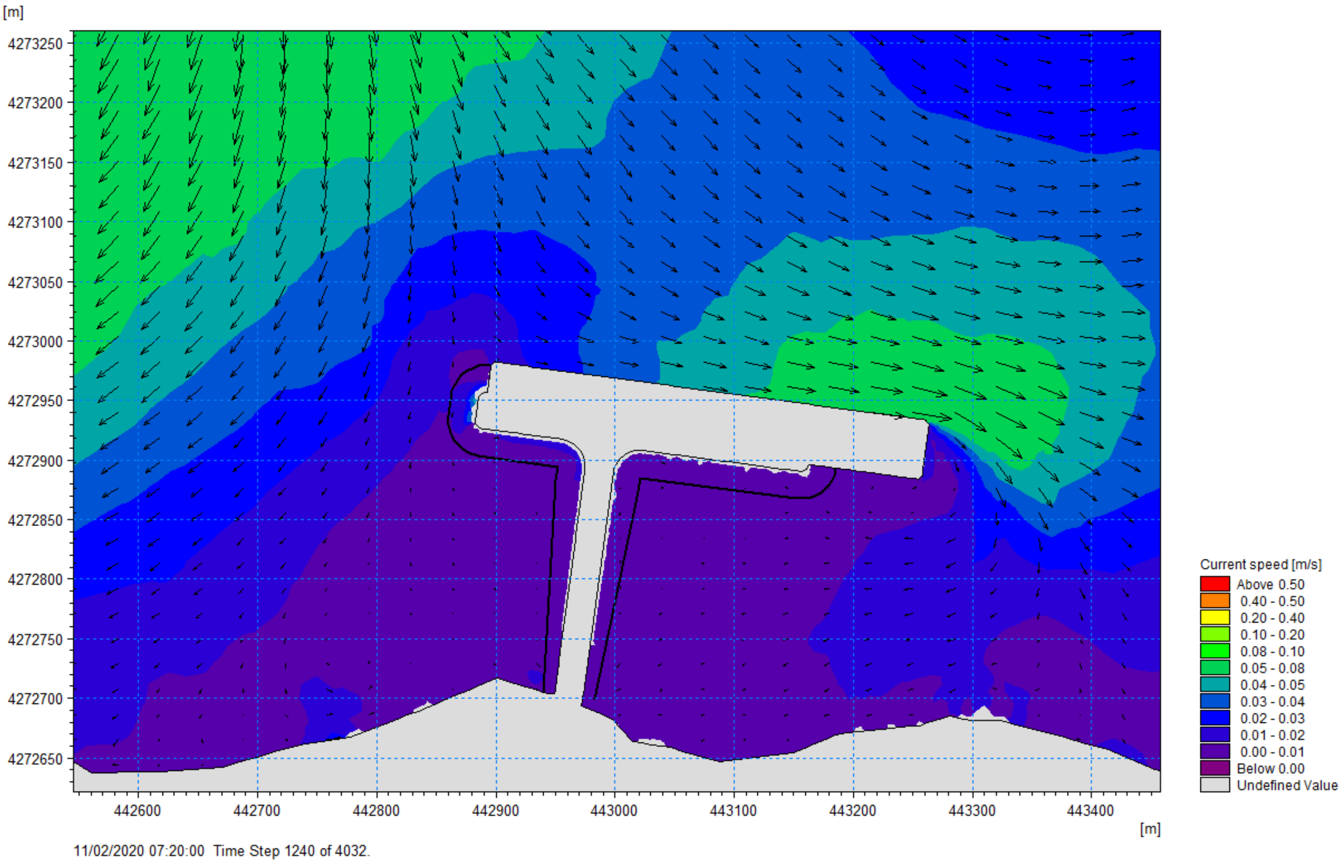


**Figure 7.14** **Modelled 'with scheme' tidal currents during spring tides**

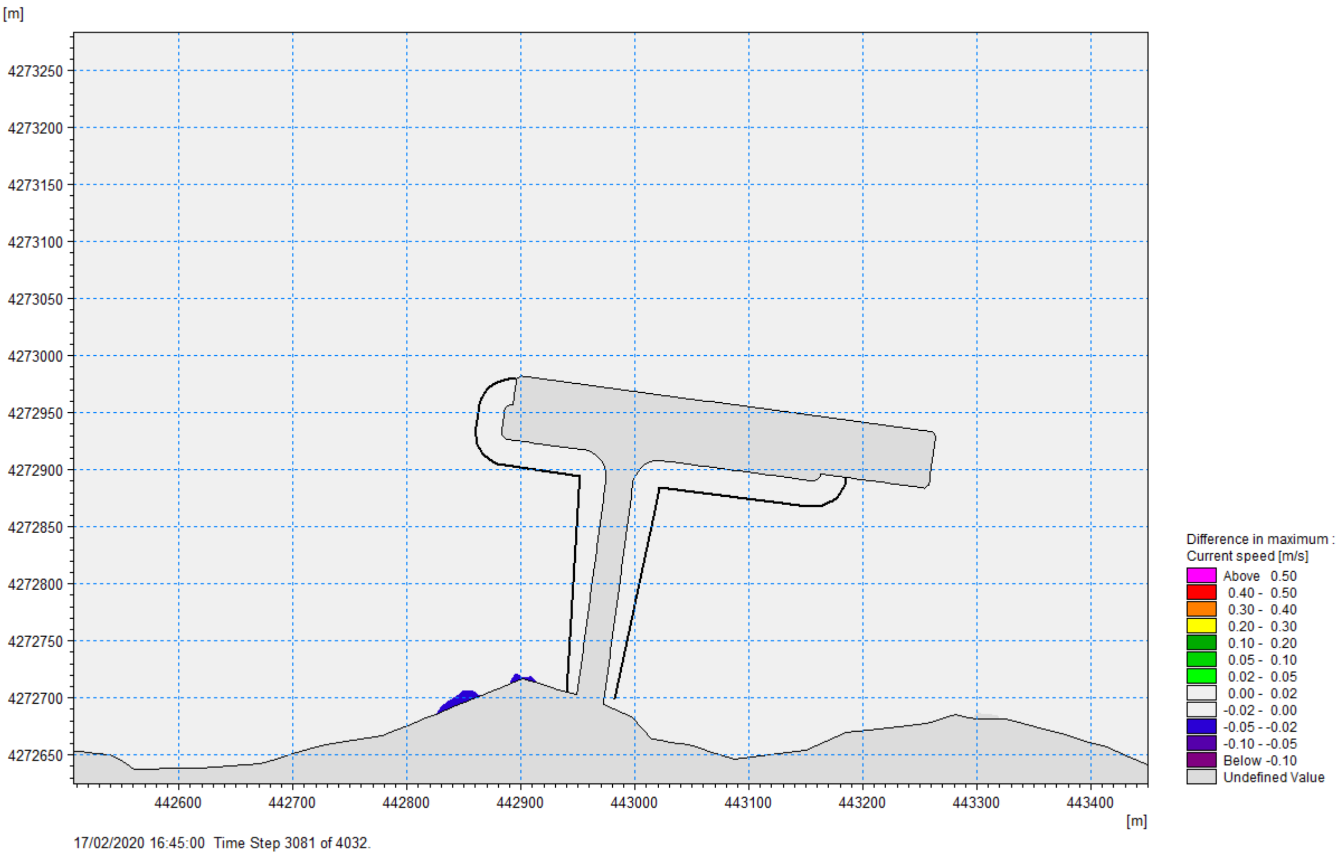


**Figure 7.15a** **Difference plot showing changes in tidal currents during neap tides at high water**

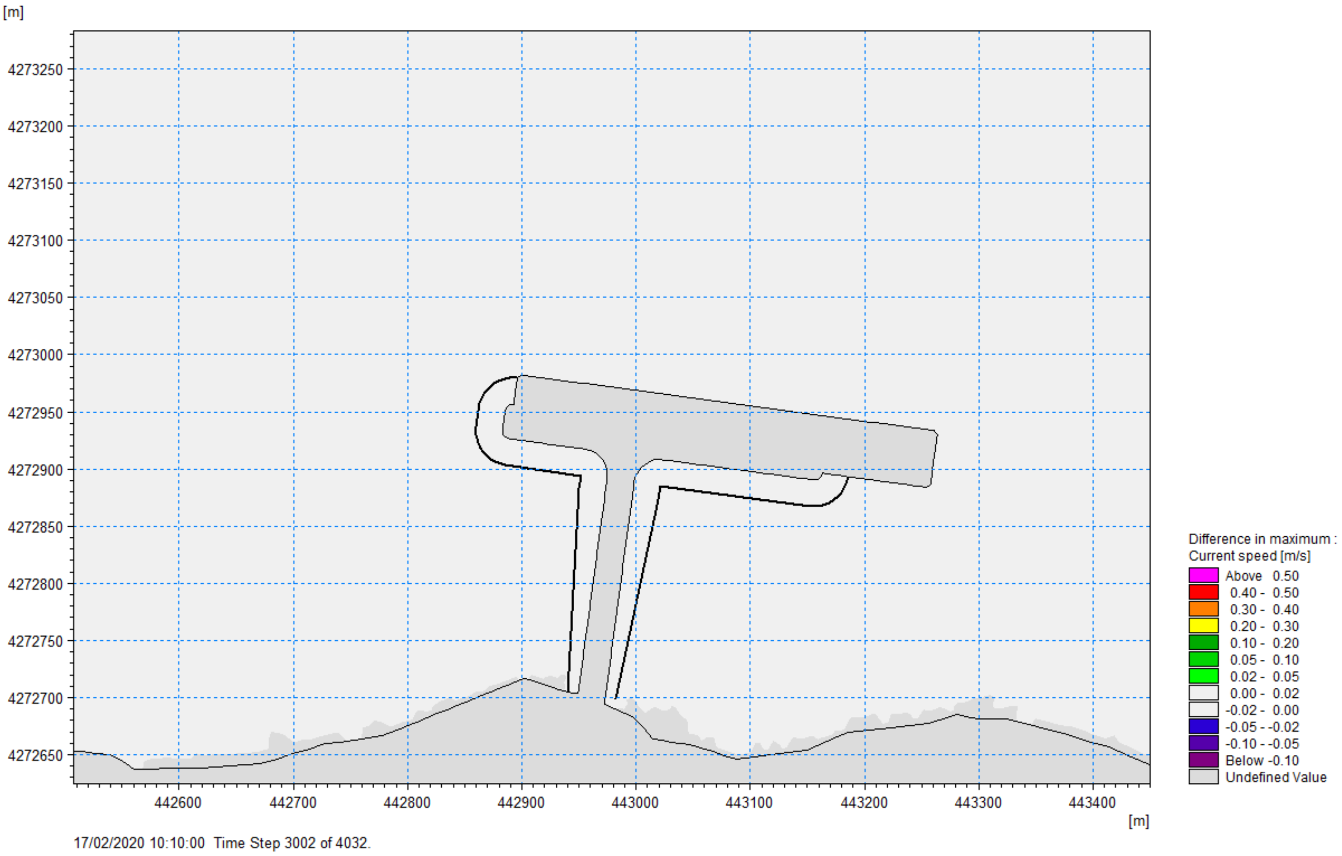


**Figure 7.15b** **Difference plot showing changes in tidal currents during neap tides at low water**

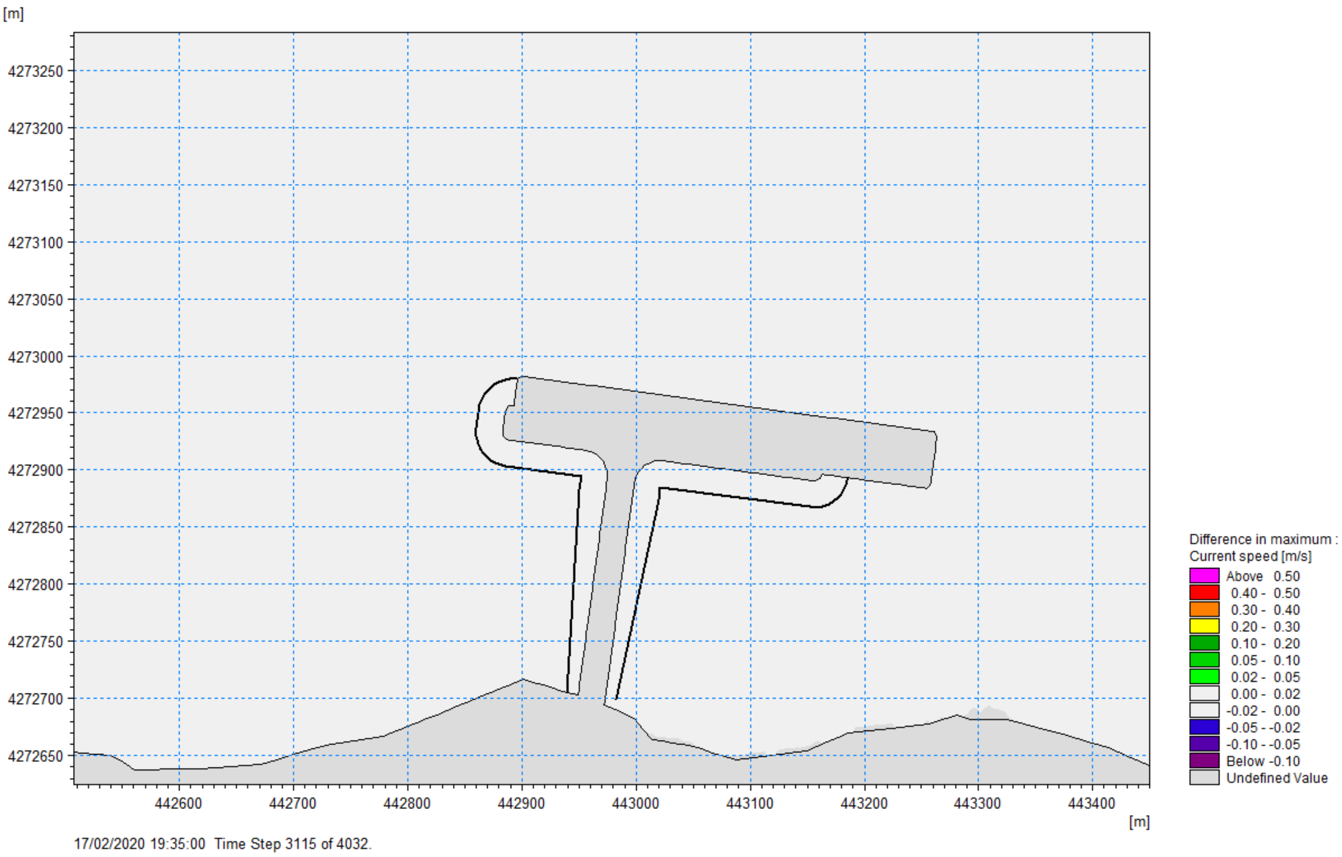


**Figure 7.15c** **Difference plot showing changes in tidal currents during neap tides at mid ebb**

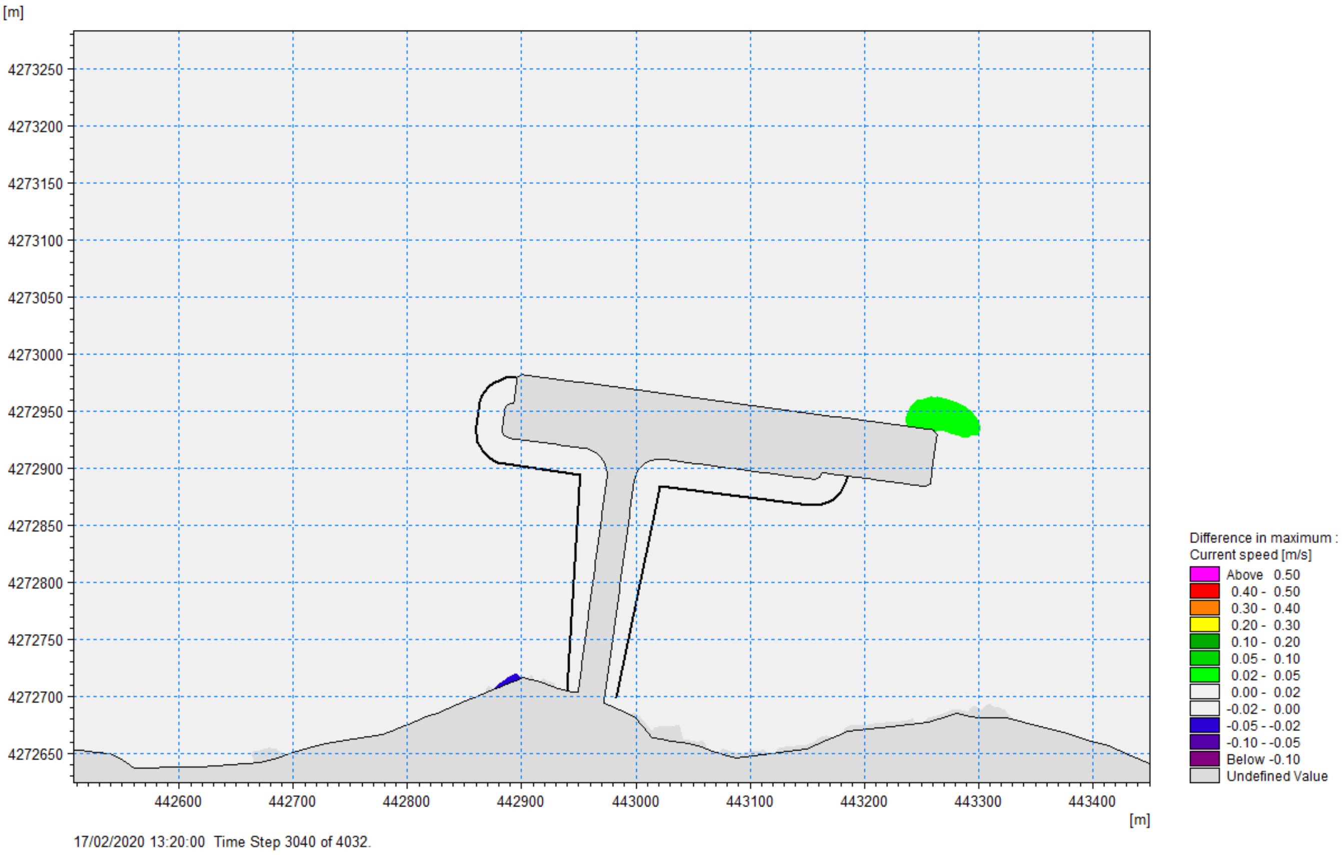


**Figure 7.15d** Difference plot showing changes in tidal currents during neap tides at mid flood

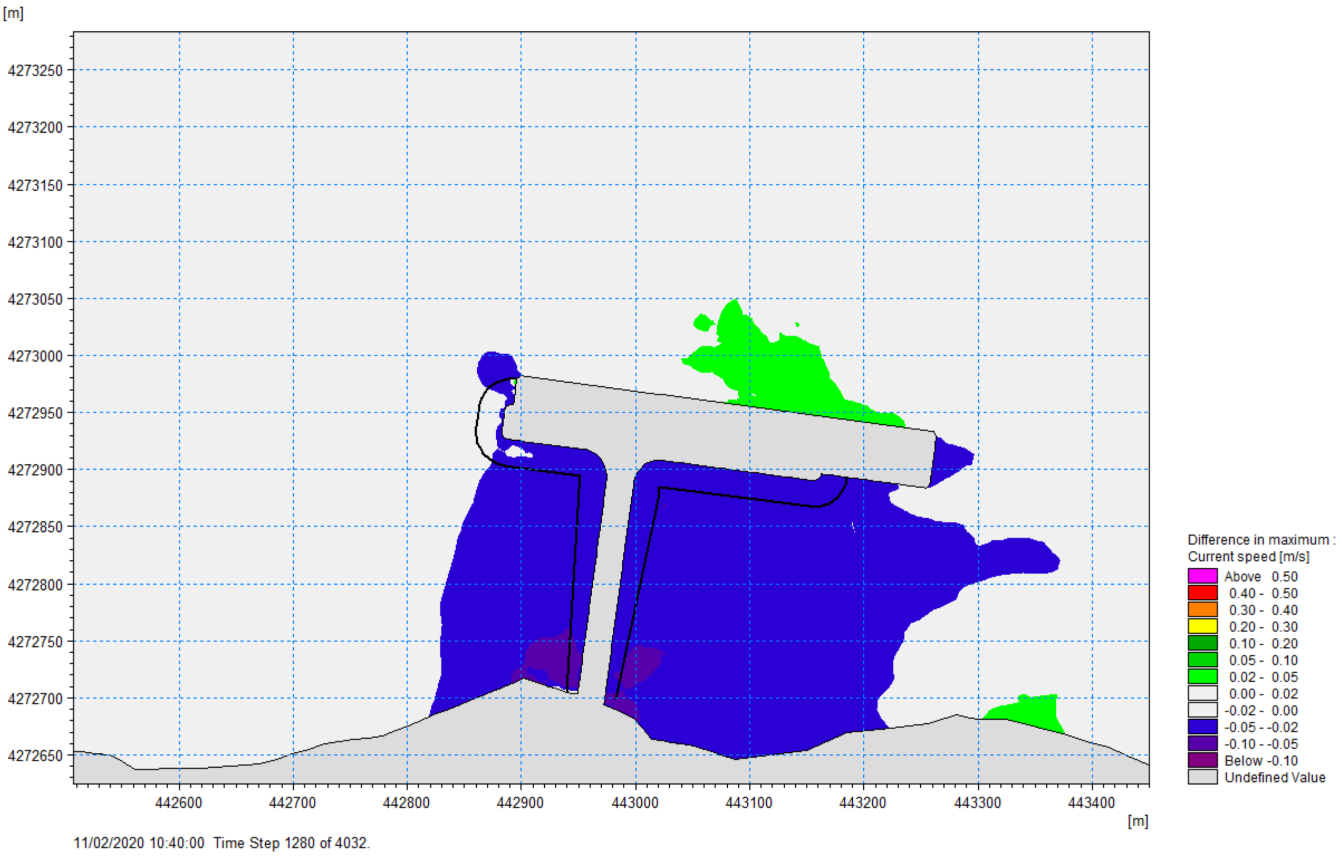


**Figure 7.16a** Difference plot showing changes in tidal currents during spring tides at high water

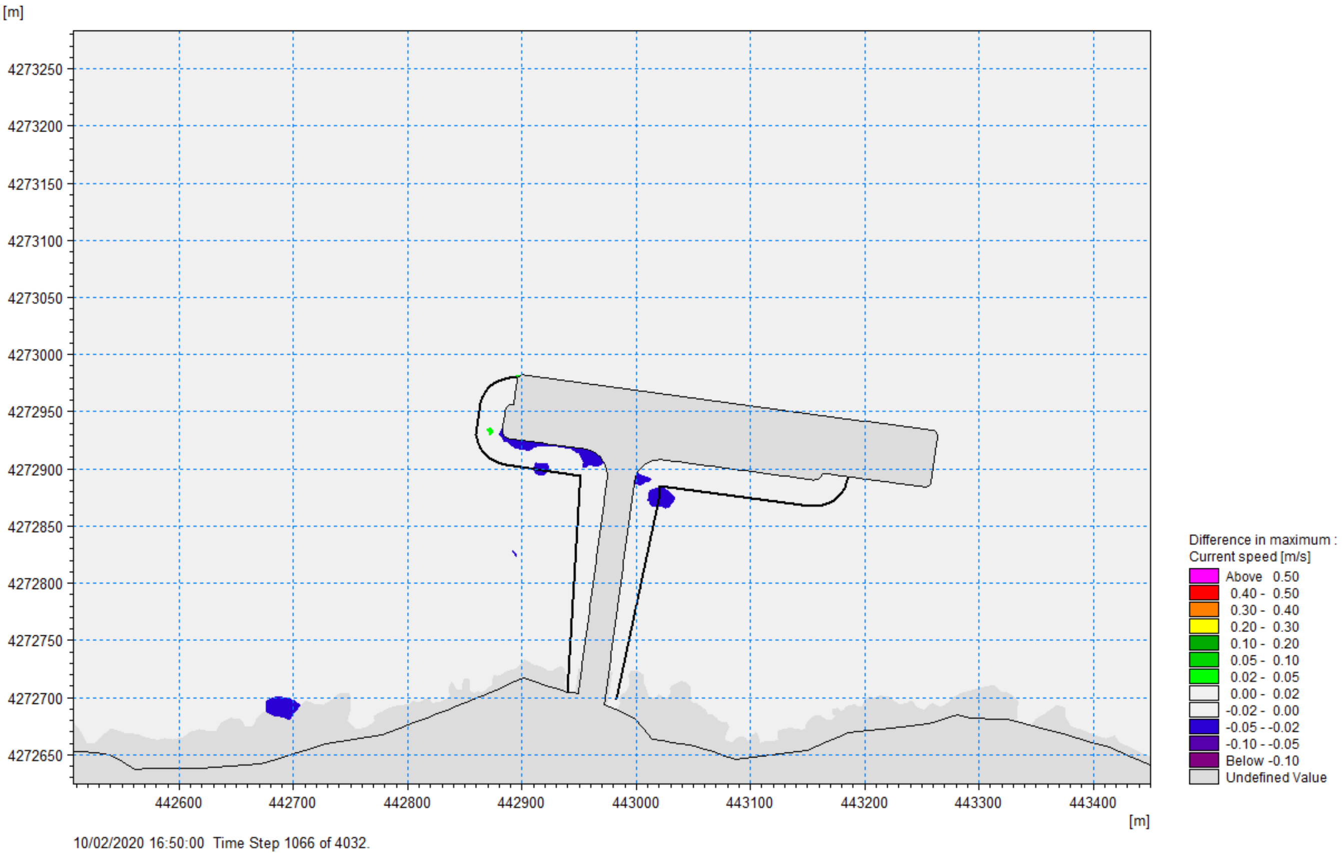


**Figure 7.16b** Difference plot showing changes in tidal currents during spring tides at low water

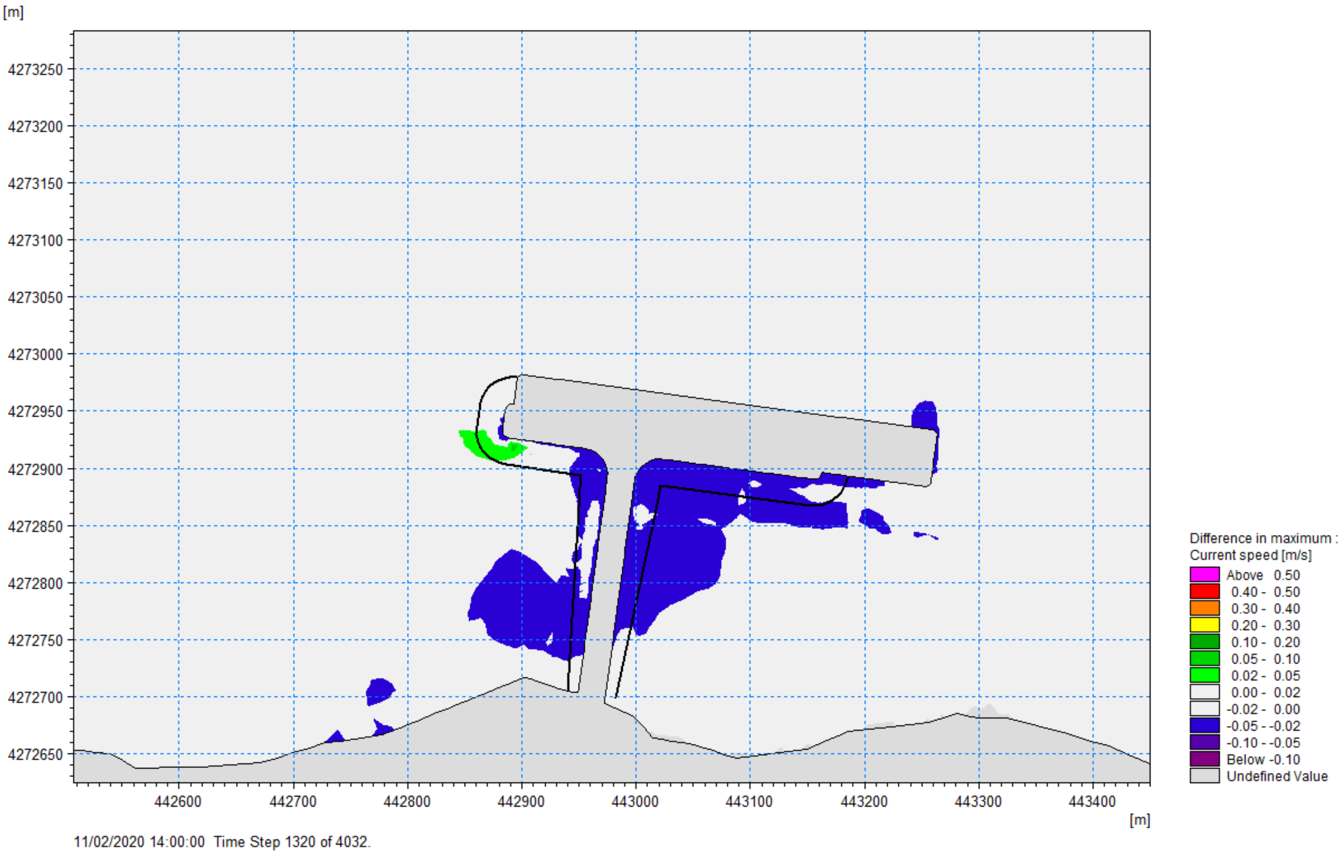


**Figure 7.16c** Difference plot showing changes in tidal currents during spring tides at mid ebb

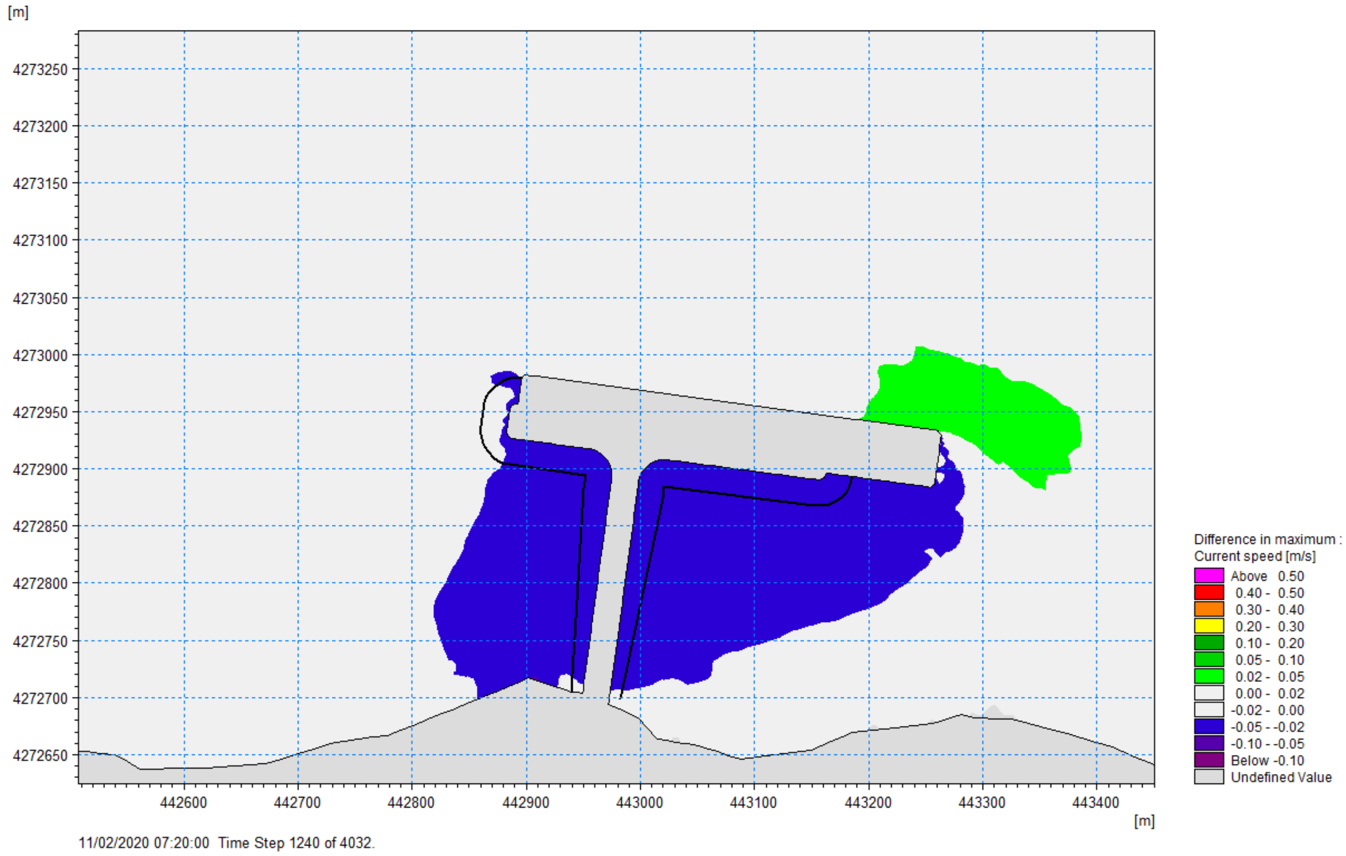


**Figure 7.16d** **Difference plot showing changes in tidal currents during spring tides at mid flood**

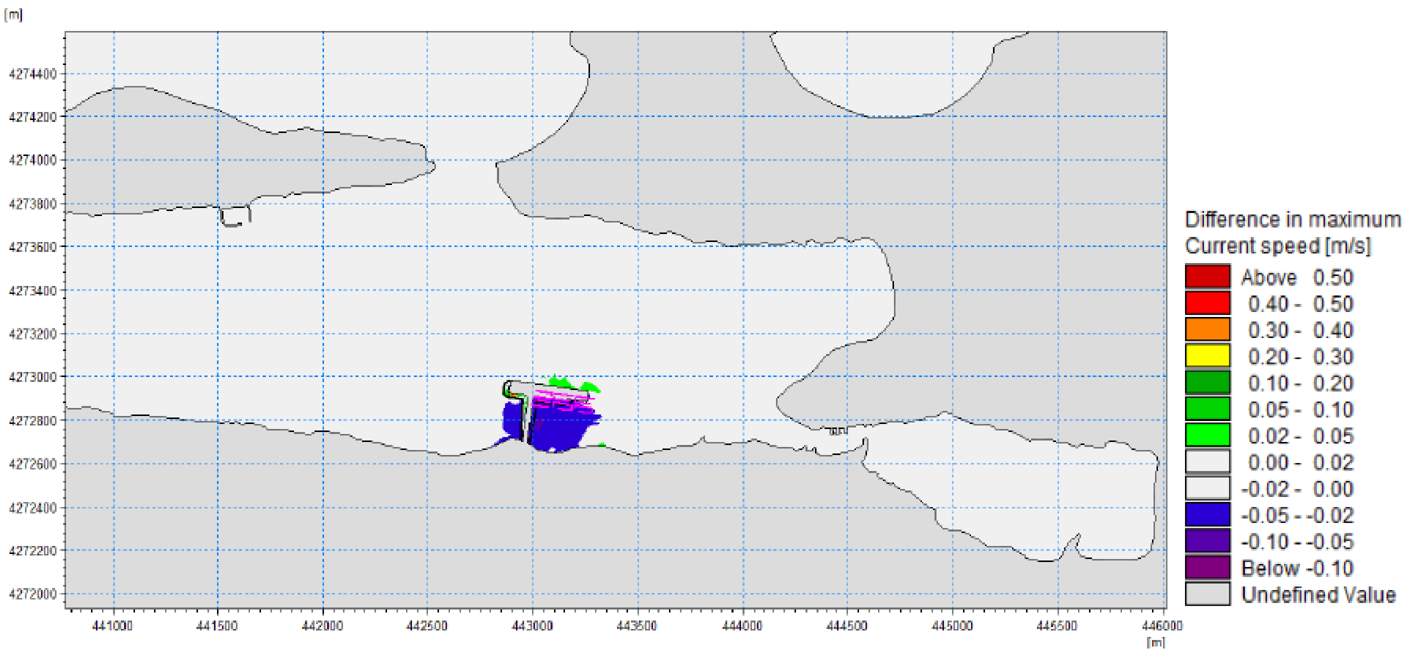


**Figure 7.17** **Difference in maximum current speed – wider view**

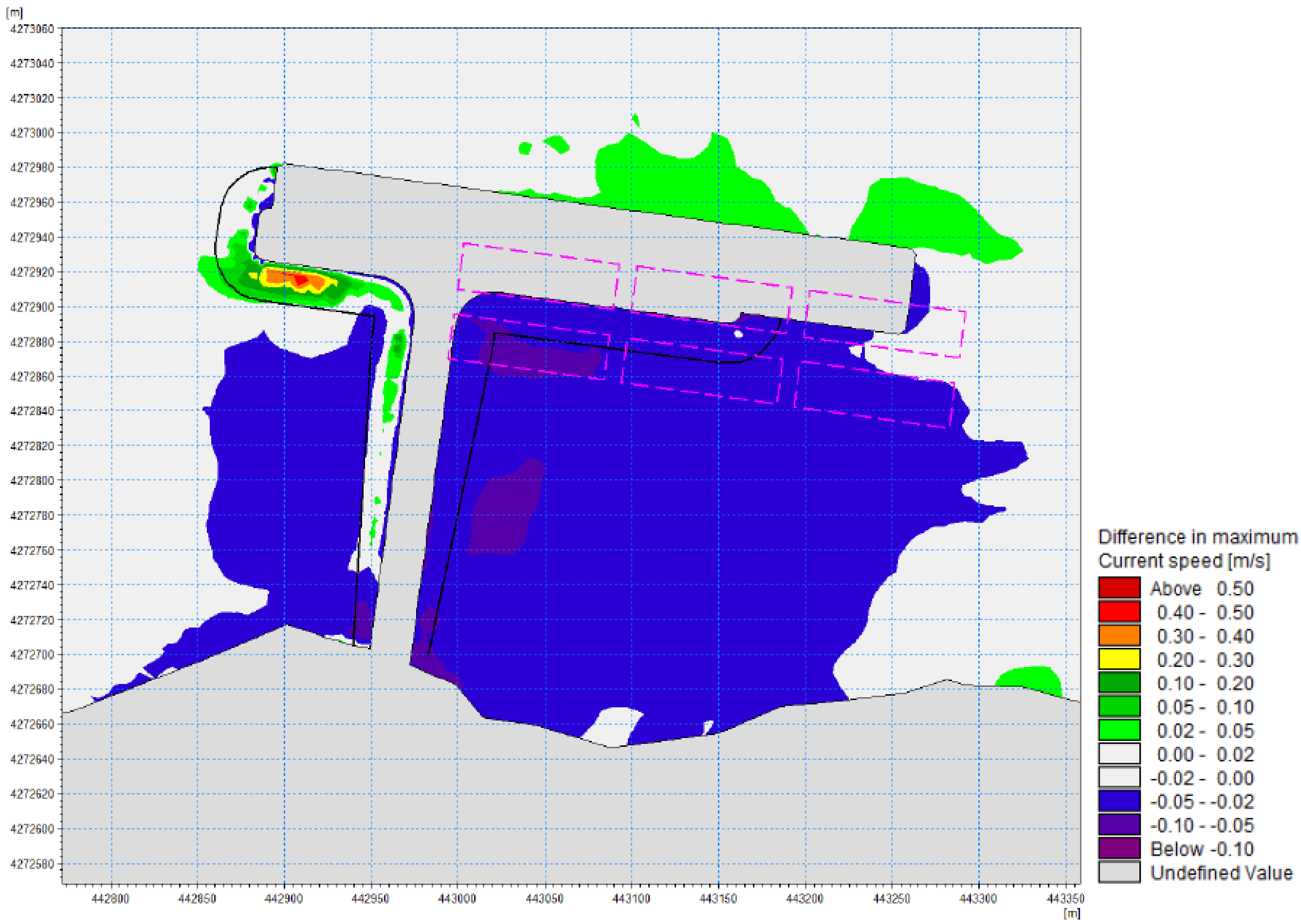


**Figure 7.18** **Difference in maximum current speed – focussed around the proposed scheme footprint**

In summary, the modelled reduction in the baseline locally-generated wind wave climate in the lee of the new quay is an unavoidable, and indeed intended, consequence of the proposed scheme on baseline wave conditions, caused by the construction of a solid quay structure. Baseline wave conditions are predicted to be unaffected seaward of the proposed quay or to any significant distance along shore beyond the proposed scheme footprint in either direction. Similarly, the modelled changes in the baseline tidal currents are locally confined to the vicinity of the proposed scheme, and especially in terms of a reduction in baseline currents within the shoreward lee of the proposed new quay.

Due to the localised nature of the changes on the baseline hydrodynamic regime, there will be no far-field effect on the hydrodynamics of Stanley Harbour as a result of the proposed scheme. The potential for the semi-enclosed conditions that will be created by the causeway and the quay to impact on water quality is reported separately in **Section A8.0**.

### A7.4.2Effect on sediment transport

Changes to the hydrodynamic conditions described in **Section A7.4.1** have the potential to alter baseline patterns of sediment erosion, transportation and deposition, depending on the nature of the sediments in the areas of hydrodynamic change. In particular, the modelled reductions in wave climate and tidal currents shoreward of the proposed quay may lead to increased tendency for deposition of any sediment that is carried in suspension in the water column (if present). However, because the baseline wave climate is modest and the baseline tidal currents are so low, there are unlikely to be considerable quantities of suspended sediment available for deposition and so the magnitude of this highly localised effect is envisaged to be small. In addition, the proposed berthing of vessels on the rear face of the proposed quay and on the pontoon is intended to minimise the risk of sediment accumulation in the sheltered lee of the proposed quay (due to propellor action).

Furthermore, due to the potential changes on baseline sediment transport being so small and localised, there will be no far-field effect on the sediment regime of the wider Stanley Harbour.

### A7.4.3 Effect on morphology

Changes to the sediment regime described in **Section A7.4.2** could affect the local seabed morphology. In particular, the potential for deposition of sediments in the lee of the proposed quay could lead to local shoaling of the seabed, but because these changes are predicted to be locally confined to the vicinity of the proposed scheme, there will be no far-field effects on the morphology of Stanley Harbour. In addition, as noted above the proposed berthing of vessels on the rear face of the proposed quay (including the Concordia Bay vessel) and on the pontoon is intended to minimise the risk of sediment accumulation/shoaling in the sheltered lee of the proposed quay.