A.1 Introduction

Jacobs have developed a suite of numerical models covering the study area to support the design process. These models provide the following inputs:

- Wave, water level and tidal current parameters that are essential for the design of coastal protection structures.
- Information on the historical shoreline change and predicted future shoreline change if no additional coastal protection works are undertaken.
- Modelling of key options to understand their effectiveness of reducing wave and water level impacts at the railway and any changes to how sediment circulates within the study area.

A.1.1 Phase 1 Baseline Modelling Overview

Baseline modelling was undertaken by Jacobs during Phase 1 of the project. This baseline modelling also included the effect of spatial and temporal changes in water level on waves and variable sediment transport rates.

A two-dimensional wave model of the East Coast of Ireland was set up to derive wave data at nearshore points along the study area. This model uses wind and wave data recorded in the Irish Sea by the Irish Marine Data Buoy Observation Network and the UK Met Office and bathymetry information from INFOMAR and C-MAP to predict the wave heights, periods and direction close to the shoreline.

The baseline modelling of the shoreline looked at locations of interest between Dublin Bay and Wicklow Harbour to estimate the quantity of beach sediment moving along the coast and to predict the future shoreline position in 2055 and 2100. The results of this modelling highlight the areas of the railway which are most at risk of erosion. The baseline shoreline modelling does not include CCA1 as the railway is protected by a revetment and cannot erode.

A.1.2 Phase 2 Modelling Overview

Under Phase 2 of the project, a Coastal Area Model (CAM), which includes the effects of two-dimensional bathymetry variation on waves, tides, associated flows and sand transport, was set up for the whole of Dublin Bay to provide more detailed analysis for CCA1. This model was run for the present day (2025) and with an allowance for 100 years of climate change impacts. The CAM has three parts which run in parallel and provide outputs to each other: one module for waves (SW model), one for water levels (HD model) and one for sediment transport (ST model). The model extents are shown in Figure A.1-1. Figure A.1-2 indicates how the CAM modules are inter-linked. The CAM is computationally intensive and therefore it has been run for a set of representative conditions that could be expected to occur within a normal year.

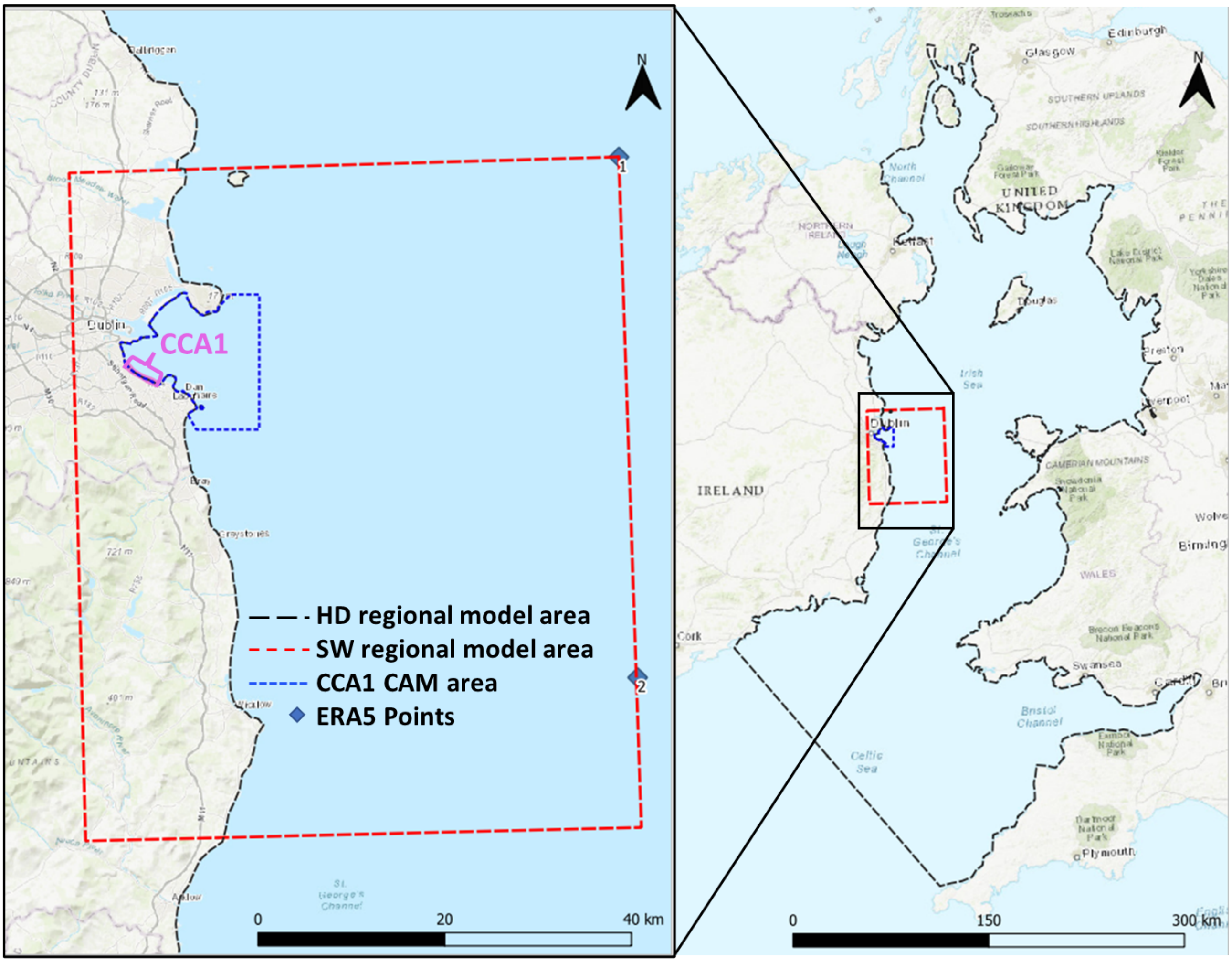


Figure A.1-1. Outlines of regional hydrodynamic model, regional wave model and local CAM.

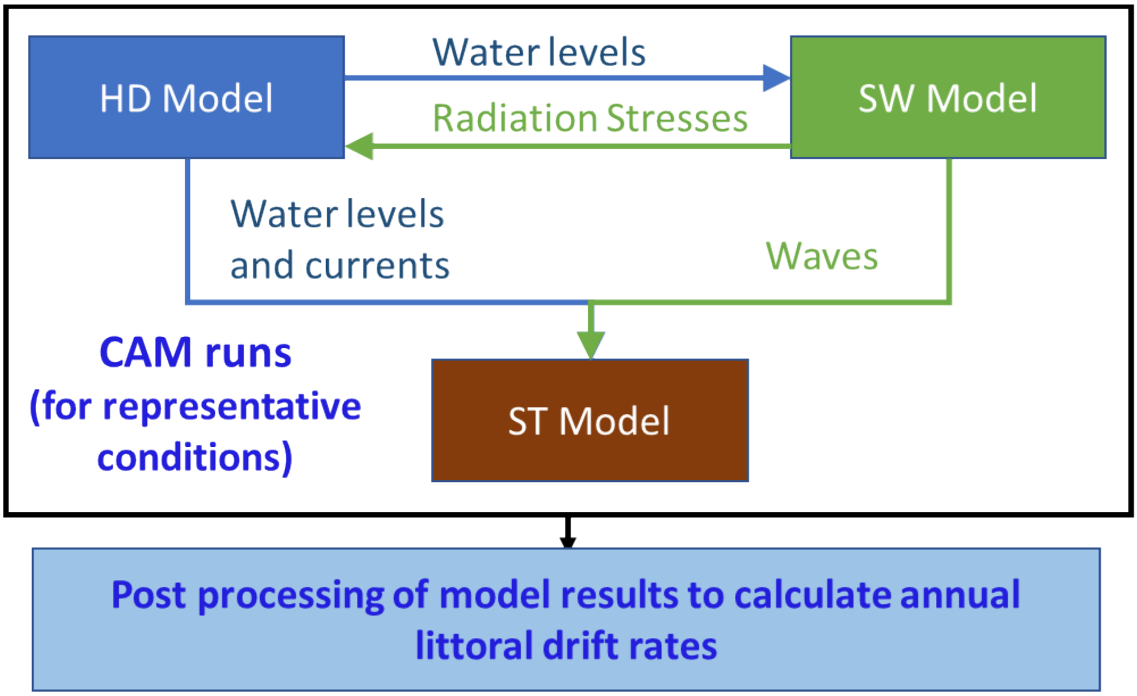


Figure A.1-2. Overview of Coastal Area Modelling (CAM) methodology

The locations of the nearshore points for CCA1 are shown in Figure A.1-3 below.

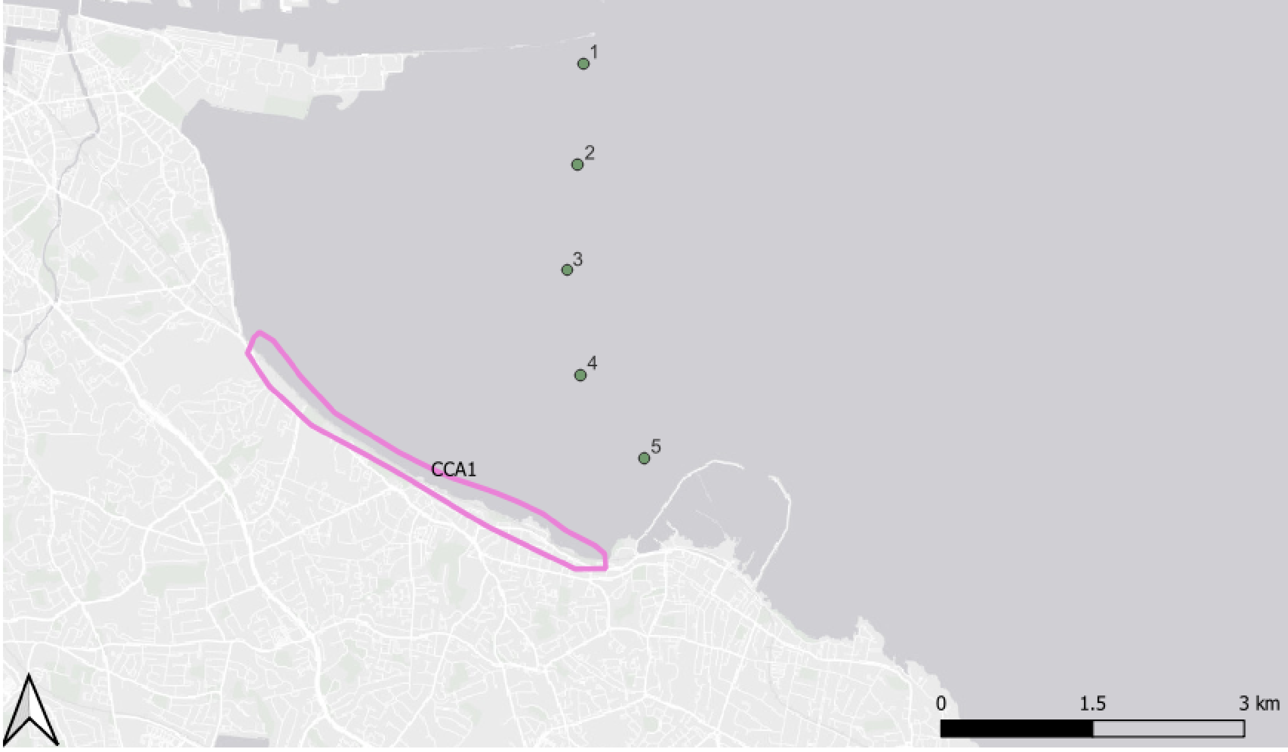


Figure A.1-3. Nearshore Points in CCA1

A.2 Waves and Water Levels

A.2.1 Waves

Figure A.2-4 provides an example output of the CAM wave module for offshore waves approaching from the northeastern sector (65°N). The wave heights are much reduced along the northern section of CCA1, with higher waves present around Seapoint beach to the east of the frontage.

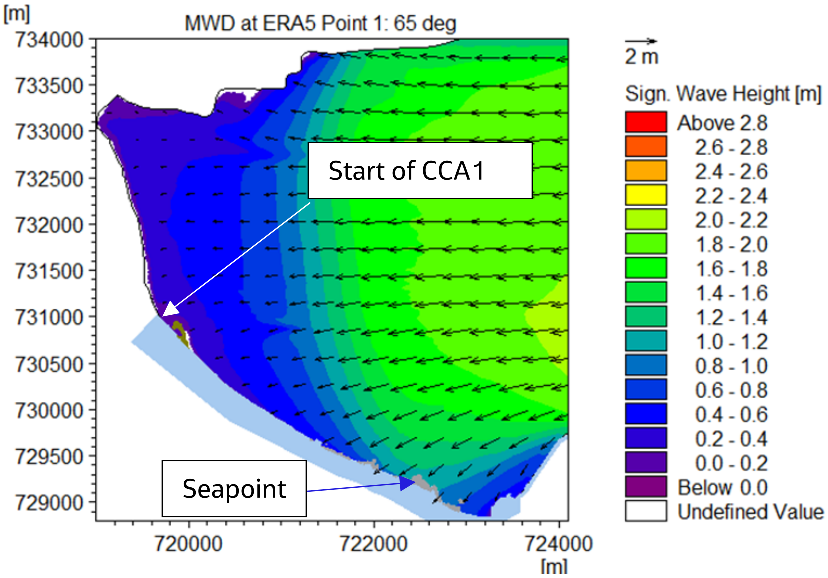


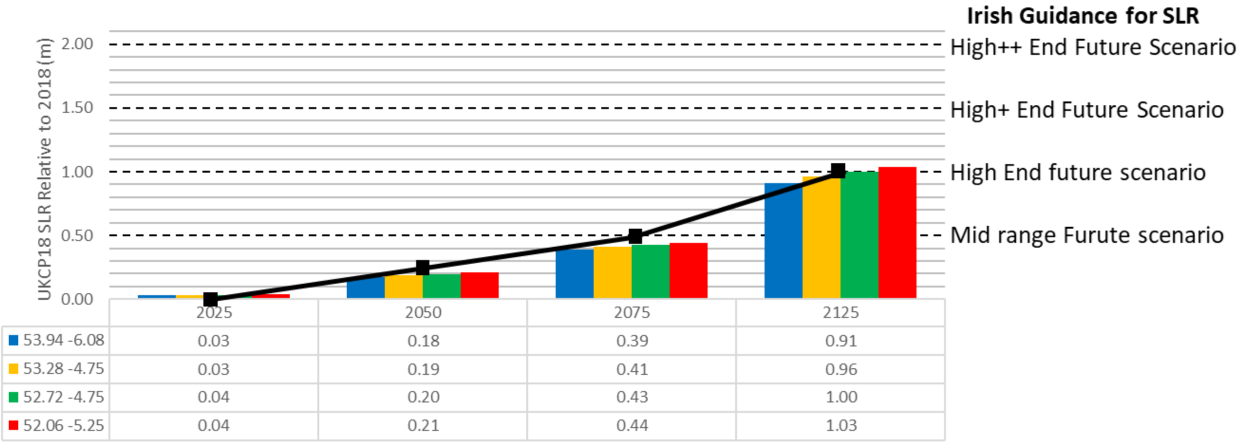
Figure A.2-4. Hm0 for selected waves from 345deg to 65deg (MWD at ERA5 Pt 1) at high tide for CCA1.

A.2.2 Water Levels

A.2.2.1 Sea Level Rise

The following sea level rises have been adopted on consideration of Irish (OPW) and UKCP18 guidance. These are plotted against the guidance in Figure A.2-5.

- Present day (2025) = +0.00 m
- Year 2055(P + 30 yrs) = +0.30 m
- Year 2075 (P + 50 yrs) = +0.50 m
- Year 2125 (P +100 yrs) = +1.0 m



	2025	2050	2075	2125
🟦 53.94 -6.08	0.03	0.18	0.39	0.91
🟨 53.28 -4.75	0.03	0.19	0.41	0.96
🟩 52.72 -4.75	0.04	0.20	0.43	1.00
🟥 52.06 -5.25	0.04	0.21	0.44	1.03

Figure A.2-5. Comparison of UKCP18 sea level rise projections and Irish Guidance. Proposed SLR curve shown with black line

A.2.2.2 Tidal Levels

Admiralty TotalTide (ATT, 2023) water levels have been extracted for the Irish Sea covering the extent of the modelled area Figure A.2-6. The levels for Dublin North Wall are summarised in Table A.2-1. Tide levels for Dublin North Wall.

Table A.2-1. Tide levels for Dublin North Wall

Tidal Level	Level (mODM)
Highest Astronomical Tide	+1.99
Mean High Water Springs	+1.59
Mean High Water Neaps	+0.89
Mean Sea Level	-0.11
Mean Low Water Neaps	-1.01
Mean Low Water Springs	-1.81
Lowest Astronomical Tide	-2.61

Figure A.2-6. Admiralty Total Tide data locations and model area

A.2.2.3 Extreme Water Levels

Extreme water levels are available along the Irish coast from the Irish Coastal Wave and Water Level Modelling Study (ICWWS, 2018), and along the Welsh coast from the Coastal Flood Boundary (CFB, 2018) dataset. Both sets of data are used to provide boundary conditions to the general ECRIPP model. Water levels at 39 locations from Dublin Bay to Wicklow Harbour have been extrapolated using these input data.

A.2.3 Joint Probability of Waves and Water Levels

Joint probability analysis combines the likelihood of two different variables occurring at the same time. In the design of coastal structures, it is common to use joint probability pairs of wave heights and water levels; this provides the design team with several different inputs which have the same chance of occurrence to fine-tune the design against. Figure A.2-7 shows the joint probability results for the 1 in 2 and 1 in 200 year return period conditions in the present day, 2055, 2100 and 2125. The left hand panel contains the conditions at nearshore point 4 and the right hand panel contains the offshore conditions.

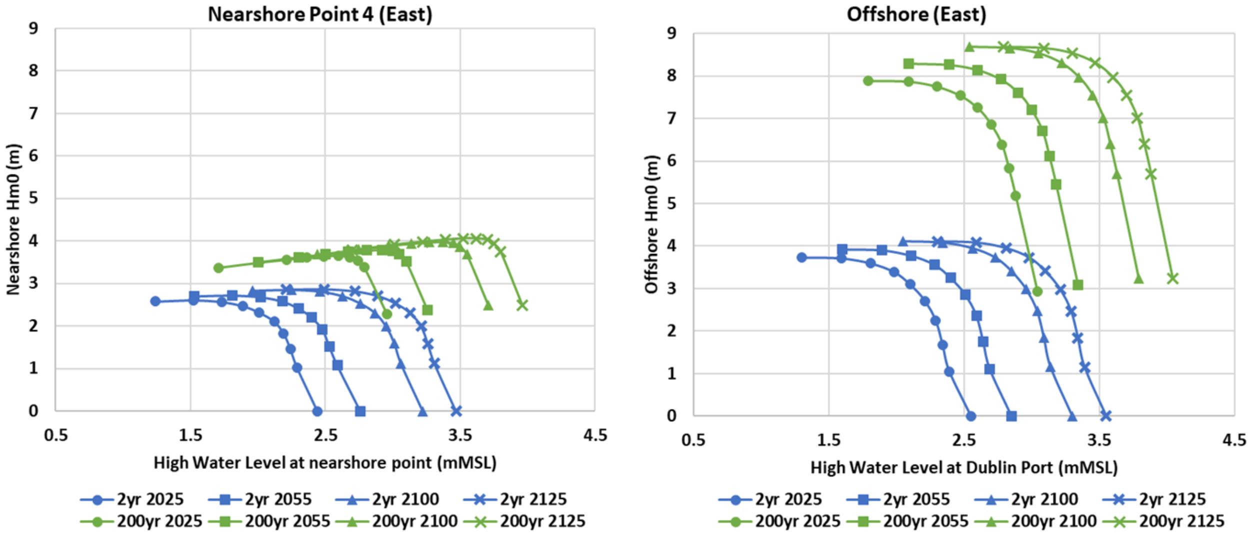


Figure A.2-7. Joint probability plots of wave height (y-axis) and water level (x-axis) at nearshore point 4 and offshore for the 1 in 2 and 1 in 200 return period conditions in the present day and with sea level rise.

A.3 Currents

Two dimensional plots of current speeds each hour from 4 hour prior to high tide to 4 hours after high tide are presented in Figure A.3-8 for the tide only case. The plots shown are limited to ± 4 hours from high tide as outside of this window the nearshore along the entire frontage of CCA1 is dry. The variations in bathymetry mean that Seapoint beach is submerged for the longest period (high tide ±4 hours), while further west the submerged window reduces to (high tide ± 2 hours). These plots show that the tidal currents along the CCA1 frontage are low (< 0.2 m/s) at all stages of the tide.

Figure A.3-9 shows how waves approaching from different directions changes the currents at high tide. For an offshore mean wave direction (MWD) of 5°N to 45°N, there is a north-westward current along CCA1 from Blackrock to Booterstown; this current close to the defences remains throughout all offshore wave directions. In addition to this, from 65°N to 165°N an anticlockwise current circulation throughout Dublin Bay can be seen. This current moves south-eastward along the CCA1 frontage and then moves north-eastward along Dun Laoghaire Harbour

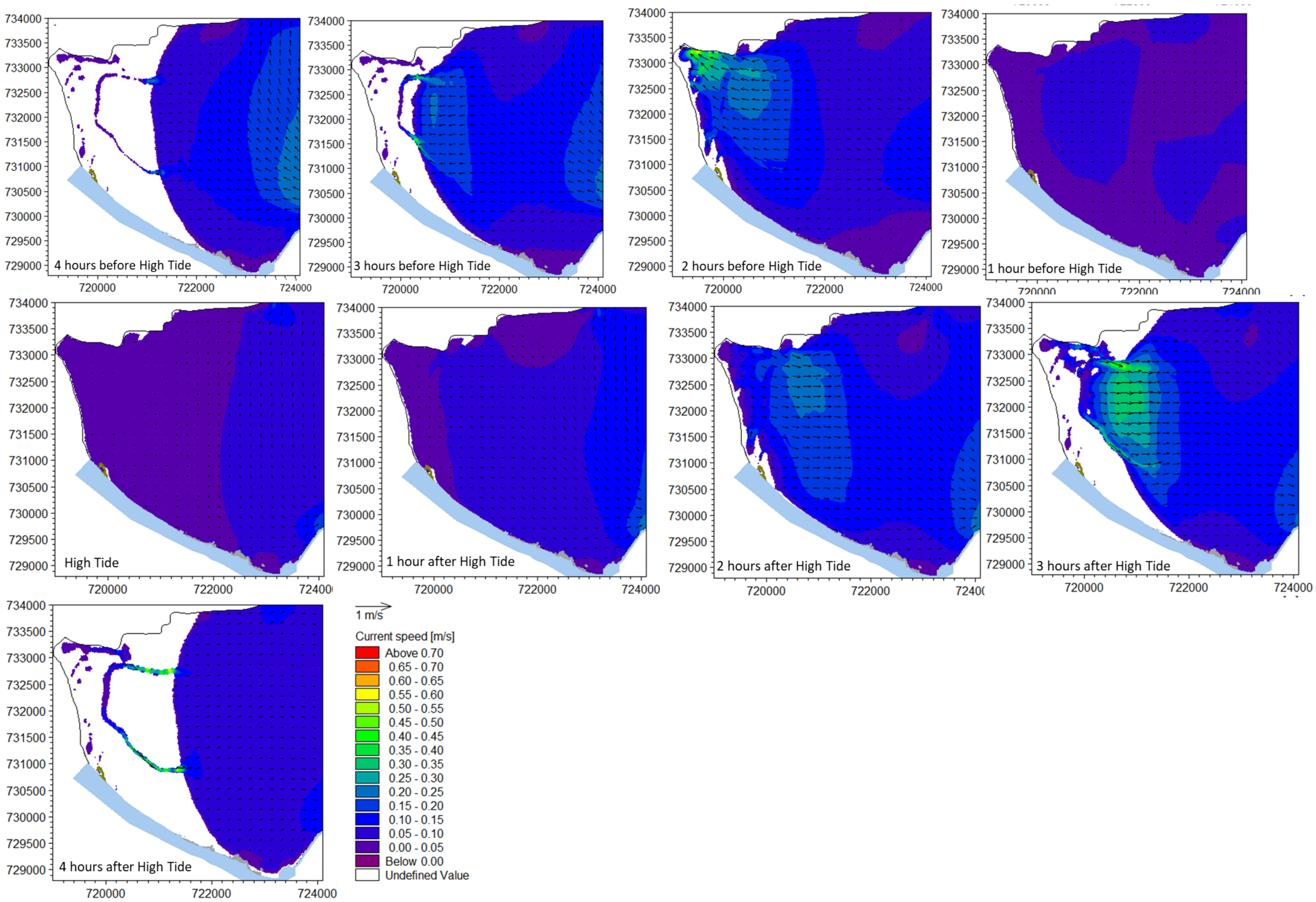


Figure A.3-8. Tidal currents across CCA1 from 4 hours before high tide to 4 hours after high tide

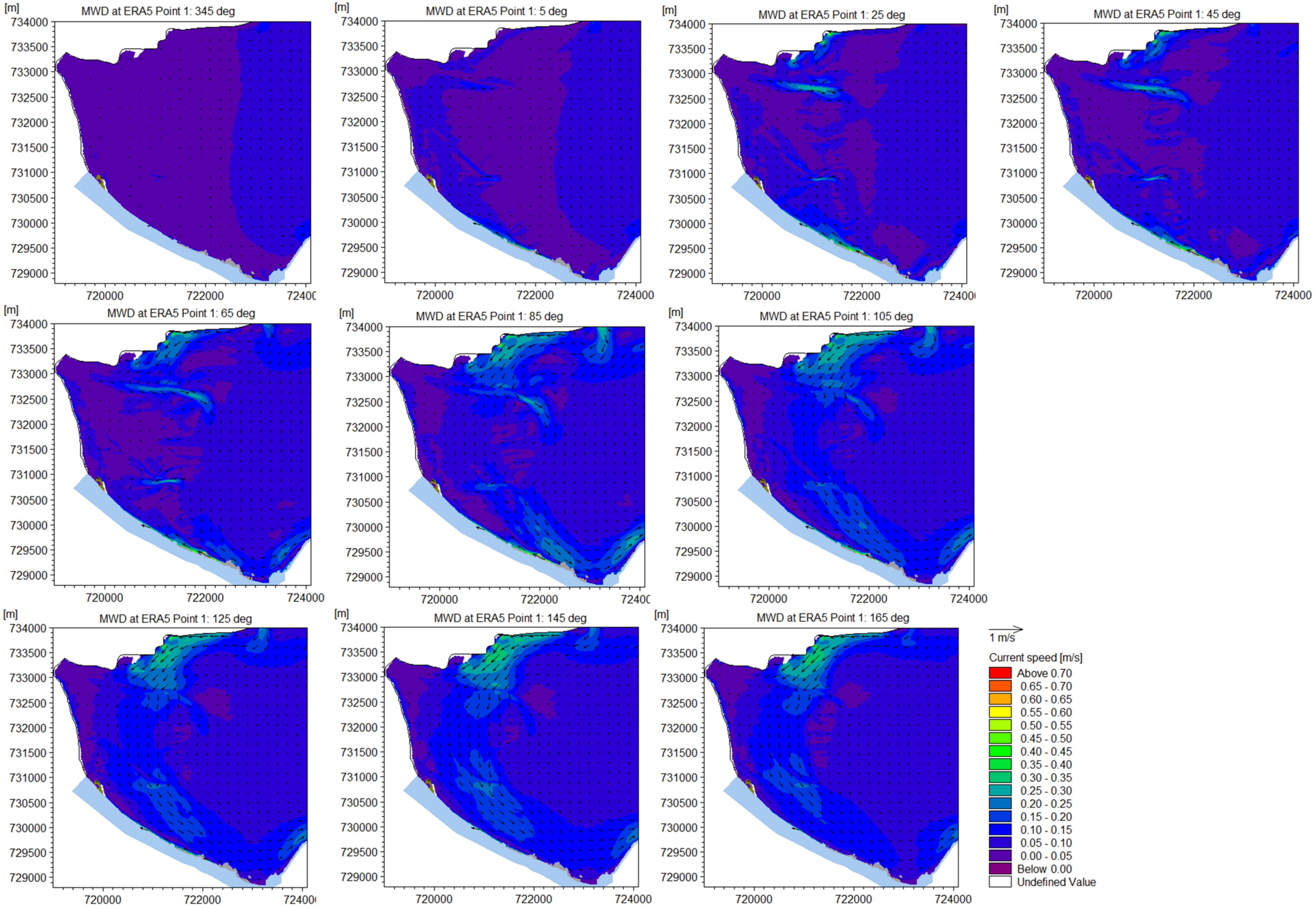


Figure A.3-9. Tidal currents across CCA1 at high tide with selected offshore waves from 345deg to 65deg

A.4 Sediment Transport

Snapshots of the sediment transport along with currents and waves at 3 hours before high tide, high tide and 3 hours after high tide for representative waves with MWD at ERA5 Point 1 from 65°N are shown in Figure A.4-11, Figure A.4-12 and Figure A.4-13 respectively. This representative wave condition was chosen as it is the dominant case for sediment transport in the nearshore.

Figure A.4-11 shows that on the rising tide sediment transport rates are generally low, with the highest rates seen on the rocky outcrops to the west of Seapoint Beach and southward along the edge of the Dun Laoghaire harbour. At high tide the higher transport rates are seen moving westward from Blackrock close to the defences (Figure A.4-12). Figure A.4-13 shows that on the falling tide the high rates southward along the edge of the Dun Laoghaire harbour return, but most of the transport is offshore, this is due to a combination of the high currents across the sand flats and wave agitation bringing sand into suspension (the tide only runs show low transport rates in these areas). Note that these rates may be artificially high due to the uncertainties in the bathymetry in that area and the lack of morphological feedback within the model.

A.4.1 Annual sediment transport rates

The annual sediment transport rates are very low, less than 1200 m^3/yr; therefore, the bed levels in CCA1 are predicted to be stable under typical conditions. Most of the sediment transport is occurring within 100m of the shoreline (see Figure A.4-10). Applying 1m of sea level rise for the climate change scenario means that the waves have more time over a tidal cycle to interact with the beach sediment. The rates increase but remain low at 1700 m^3/yr.

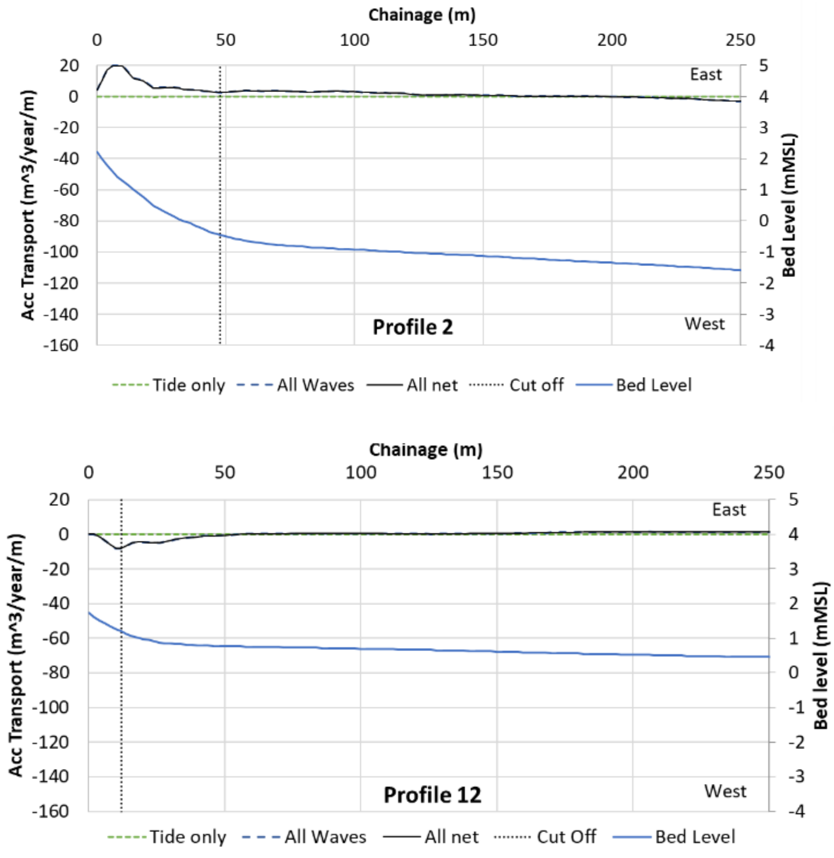


Figure A.4-10. Sediment transport rates along the bed (chainage 0 is the shoreline) at Seapoint Beach (Profile 2) and Blackrock Station (Profile 12)

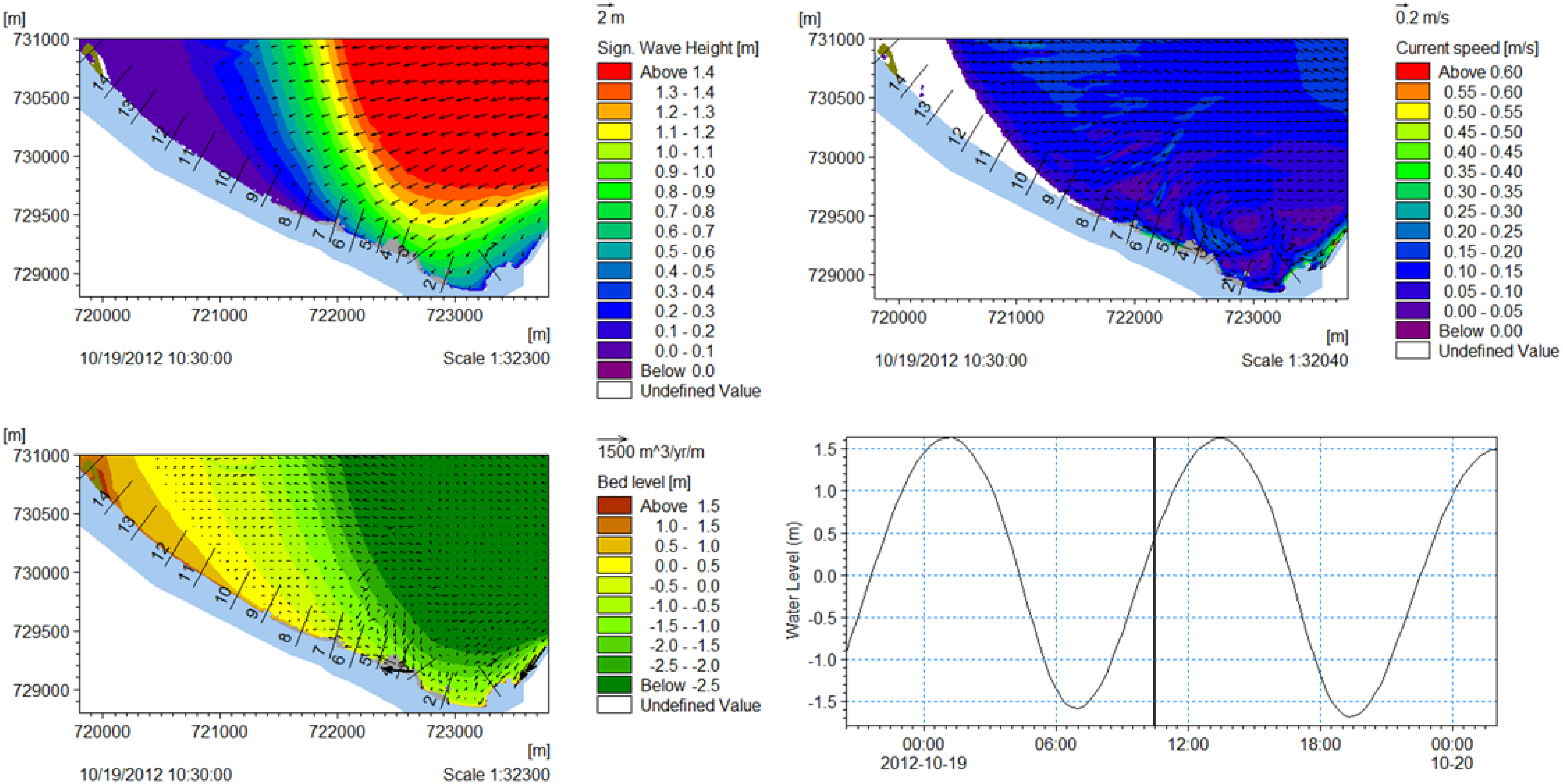


Figure A.4-11. Snapshot of CAM results for waves from 65 deg at ERA5 pt1 3 hours before high tide. Showing waves (top left), currents (top right) and sediment transport (bottom left). A time series of water level with the time of the snapshot marked is also provided.

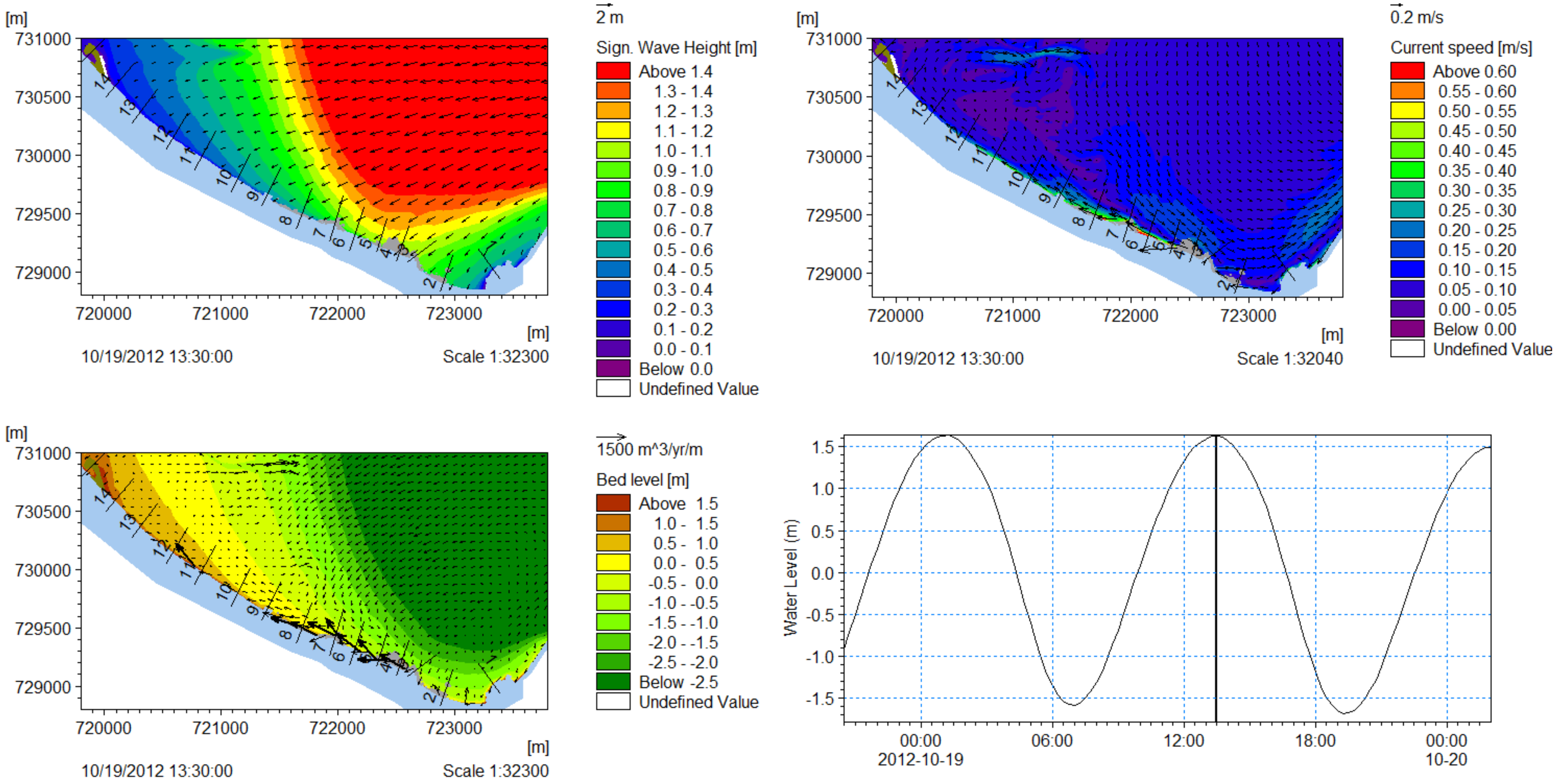


Figure A.4-12. Snapshot of CAM results for waves from 65 deg at ERA5 pt1 at high tide. Showing waves (top left), currents (top right) and sediment transport (bottom left). A time series of water level with the time of the snapshot marked is also provided.

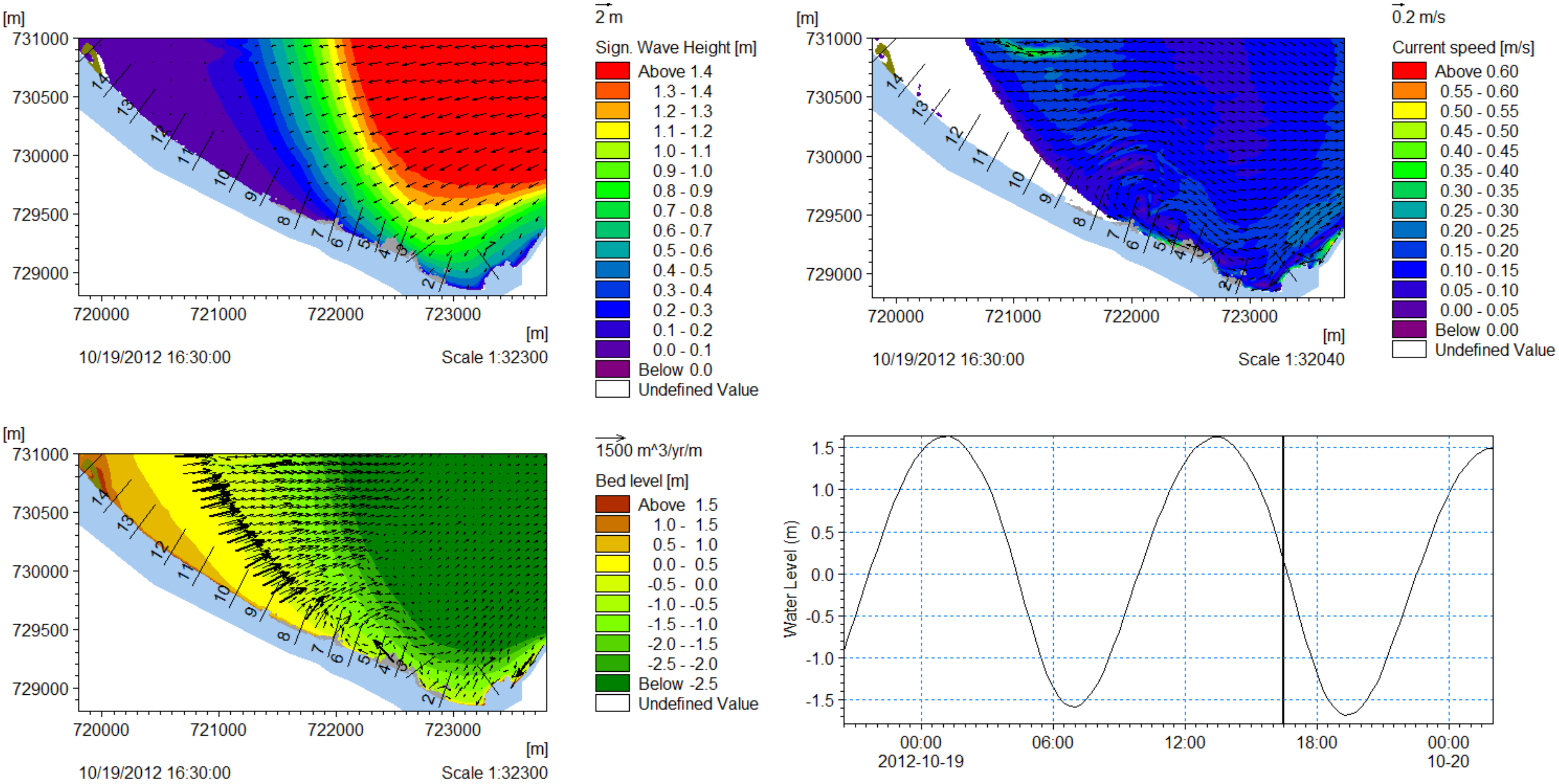


Figure A.4-13. Snapshot of CAM results for waves from 65 deg at ERA5 pt1 3 hours after high tide. Showing waves (top left), currents (top right) and sediment transport (bottom left). A time series of water level with the time of the snapshot marked is also provided.

A.5 CCA6.1-E (Seapoint)

The CCA1-E Option B comprises rock groynes and beach nourishment on the eastern side of Seapoint. To evaluate the best groyne arrangement, beach equilibrium shape analysis was undertaken, which defines the alignment that the beach will tend to, reaching an equilibrium when there’s minimal sediment transport for the dominant wave direction. This alignment might temporarily change, due to seasonality wave condition change or due to storms. This analysis informs the required length and position of the groynes to hold the design beach profile, the expected beach alignment and the critical locations where the beach crest width is the minimum defined.

A.5.1 Equilibrium Beach Shape

An equilibrium bay shape was modelled using the software Coastal Modelling System (SMC), based on Hsu & Evans, “Parabolic Bay shaped and applications” (1989) formulation.

The beach control structures (e.g groynes and breakwaters) diffract the oncoming waves, reducing their height and changing the wave direction adopting a parabolic shape on the lee side of the structure. This effect is commonly noticed in closed bays and shapes the equilibrium beach. Outside of the zone of influence of the control structures, the beach adopts a direction perpendicular to the wave direction. Where two zones of influence overlap, the beach adopts a shape in between the two lines.

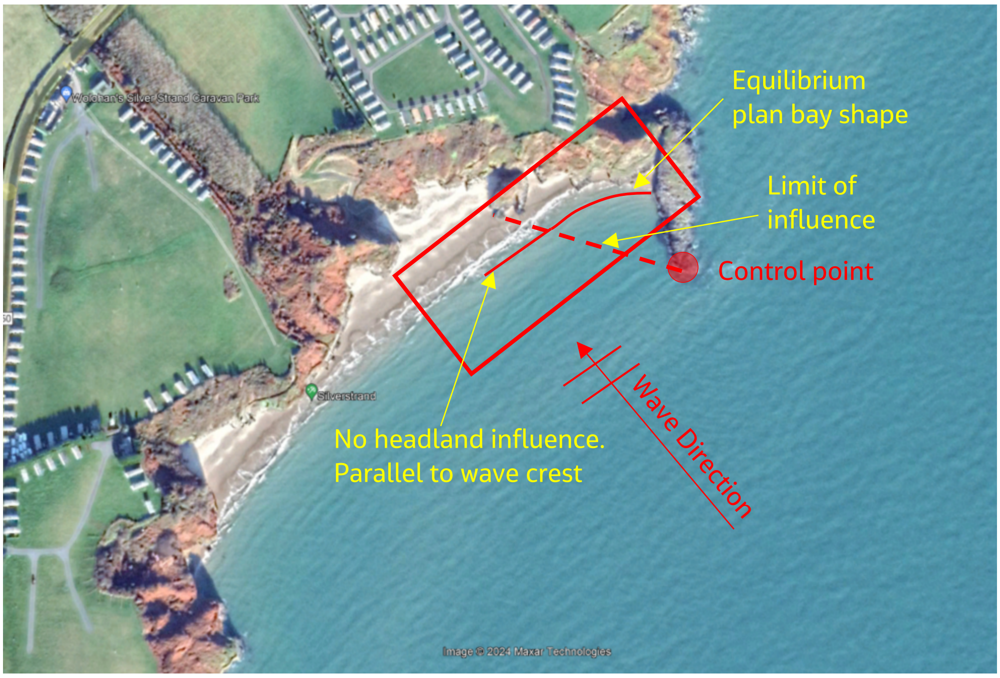


Figure A.5-14. Parabolic bay shape example. Imagery from Google Earth (06/01/2020), 2024 Maxar Technologies.

A.5.2 Beach parameters

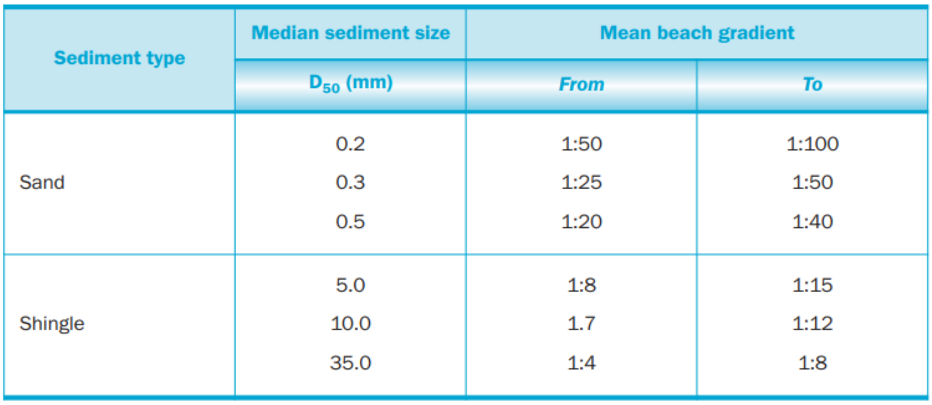
The main parameter for equilibrium beach analysis is the wave direction. At Seapoint Beach, it can be seen in Figure A.2-4, a rotation of the waves towards north-east, while in the overall CCA1 cell the waves approach more from an easterly direction. From analysis of a nearshore point (approximately 250m from shore) wave data, it was determined that the average wave direction for most extreme waves varies between 35 and 40 degrees, with the largest wave heights, with higher potential for sediment transport, aligning closer to 35 degrees. This also aligns with historical aerial imagery of the area which shows the waves, as shown in

Figure A.5-15, with the waves approaching from approximately this direction. **A predominant wave direction of 35 degrees was defined for concept design.**

Figure A.5-15. Wave approach angle at Seapoint. Imagery from Google Earth (06/01/2020), 2024 Maxar Technologies.

At CCA1, the only available sediment sample is from the sand spit in CCA1-B, with sediment size varying between 0.16 and 0.19mm, which is characterised as sand. From visual inspection at CCA1-E, it was defined the typical beach material as sand, with some pockets of shingle material, and assumed that the predominant sediment in this location is coarser than the sediment size at the sand spit. The Beach Management Manual (CIRIA C685, 2010) provides typical beach slopes for varying sediment sizes, as shown in Table A.5-2 below. **For Seapoint beach, a beach slope of 1 in 25 was assumed.** This corresponds to the lower limit of 0.3mm sediment size, which is larger than the sampled sediments, due to the presence of shingle.

Table A.5-2. Typical beach slopes for various mean sediment sizes (Table 14.4 in Beach Management Manual (CIRIA C685, 2010).



Sediment type	Median sediment size	Mean beach gradient	
	D_{50} (mm)	*From*	*To*
Sand	0.2 0.3 0.5	1:50 1:25 1:20	1:100 1:50 1:40
Shingle	5.0 10.0 35.0	1:8 1.7 1:4	1:15 1:12 1:8

A beach crest level of +2mODM and 20m width was assumed. The MLW level of -1.9mODM was defined as beach toe, assuming that the sediment transport will occur mainly above this level.

A.5.3 SMC analysis

To define the location of the groynes, the current use of the beach for swimming and sailing was considered. There is a popular swimming route from the west of Seapoint Beach (Figure A.5-16), therefore the new groynes were located landward and at a safe distance from this. For sailing, there is currently an access ramp to the east of the bay which is understood to be the main access. The groynes orientation was then optimised to maintain the minimum beach crest width defined of 20m, but also to have a wide angle of approach in between the groynes, increasing the safety when sailing. The wind was not taken into consideration in this analysis, but it was assumed that a wider gap is beneficial.

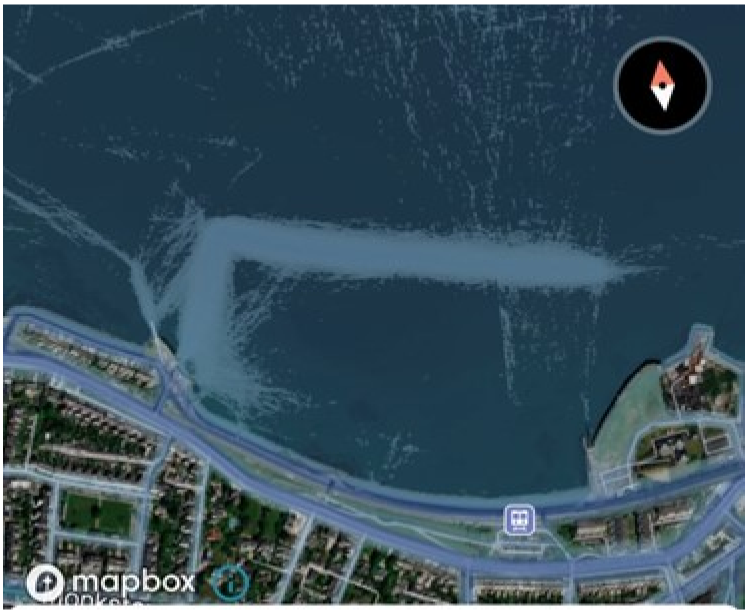


Figure A.5-16. Swimming path at Seapoint.

Using SMC, the two control points were defined, east and west side and obtained the MSL (-0.11mODM) beach equilibrium line. This MSL line was offset landward by 50m to define the beach crest line at +2mODM and 50m seaward to define beach toe line, approximately -2mODM. Figure A.5-17 shows in blue the estimated equilibrium MSL beach line, and, in red, offsets every 10m, with the last landward line representing the crest of the beach and the last seaward line, the toe of the beach. The pink triangle shows the potential angle of the approach for the access of the sailing boats between the groynes, to the eastern side access location.

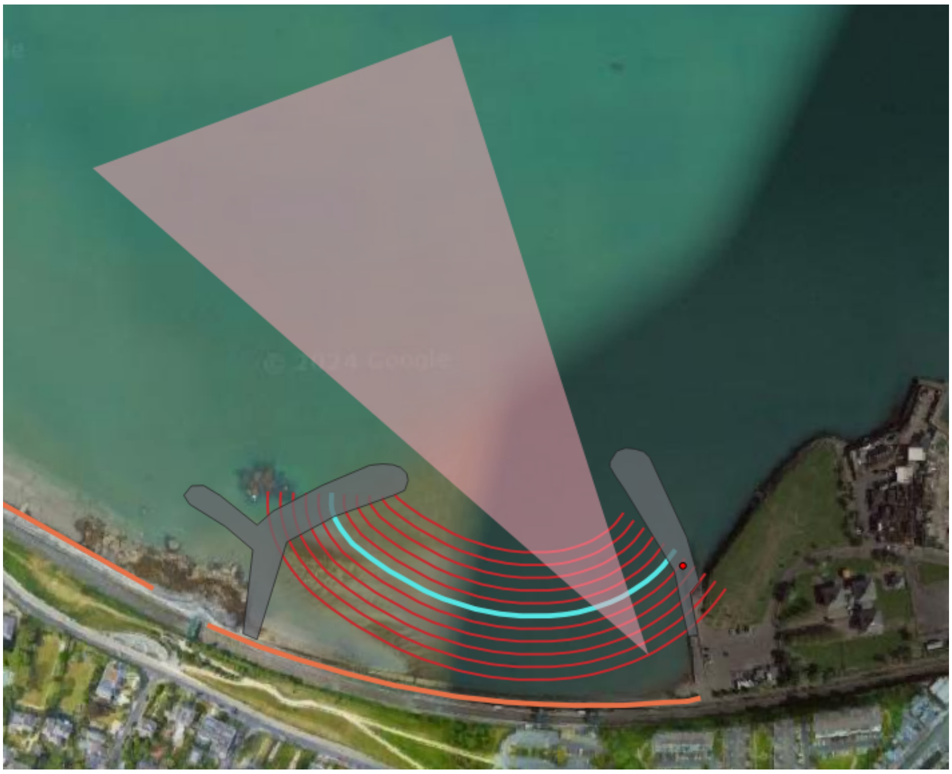


Figure A.5-17. Beach equilibrium shape and groynes location at Seapoint.

Lowering of the foreshore levels can occur on the unprotected side of the groyne. For this reason, a left arm was added to the middle groyne, further protecting the central area where large overtopping events have been recorded, and promoting the sediment accumulation on the western side as well.

The groynes will hold the equilibrium beach shape and reduce the loss of sediment within the bay, but it is unlikely that it will be effective in trapping sediment from longshore drift given the low sediment transport rates. To create the proposed beach, beach nourishment will be required following the construction of the groynes.

Figure A.5-18 shows the proposed groyne arrangement and equilibrium beach for Seapoint Beach Option B. Both groynes extend approximately 200m from the shore. Both of these structures act partly as attached breakwaters given their position and design.

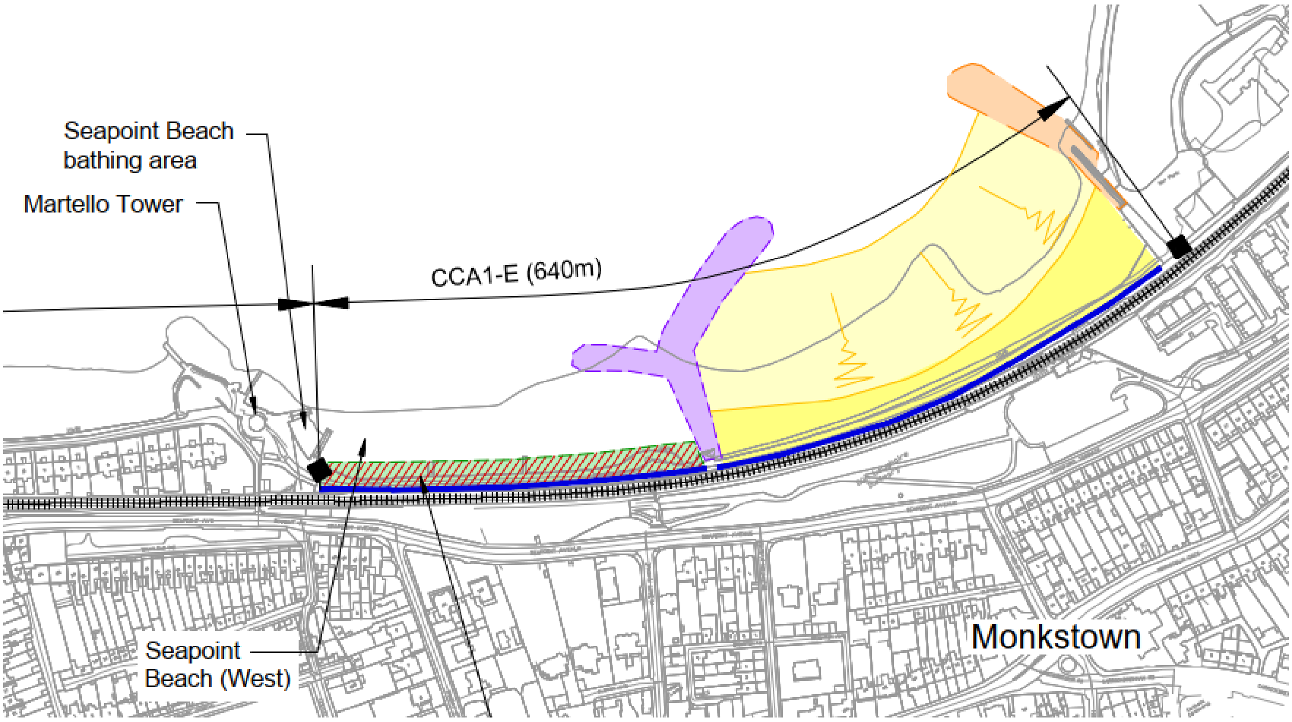


Figure A.5-18. Seapoint Option B groynes arrangement and equilibrium beach (adapted from Drawing 7694-CCA1-P2-DWG-CV-JAC-0101 Revision C)

A.6 Summary

Wave heights within CCA1 are moderate, with wave heights of 3 to 4m expected at the nearshore wave points. With climate change, small increases in wave height are predicted. Sea level rise of 1m over 100 years is expected; this is likely to have more of an impact on design of options due to the current low-lying railway alignment.

Currents within CCA1 are low, typically less than 0.2m/s at all stages of the tide. These are not expected to have a significant effect on the design of options.

Sediment moves from east to west along the frontage except for an area on the western side of Seapoint Beach. The rates are highest around Blackrock and reduce towards Booterstown Strand as the bed level increases and the duration of tidal inundation reduces.

The potential sediment transport is highest in the 100 m closest to the defence, however due to the presence of exposed bedrock and the defences themselves there is no sediment available to move where the peaks occur. The transport rates calculated where sand is available are low (less than 1200 m^3/year) and the corresponding average annual changes in bed level is also estimated to be low (< 0.1 m/year).

Climate change increases the transport rates as the length of time waves can act on the nearshore increases with sea level rise. However, rates remain low, less than 1700 m^3/year and the corresponding average annual changes in bed level is also estimated to be low (< 0.1 m/year).

The railway line along CCA1 is protected by seawall along the entire frontage. Thus, the risk to the railway line is likely to be due to failure of the seawall. This can be due to undermining at the toe of the wall or excessive overtopping leading to structural failure. This analysis suggests that the risk of undermining due to beach drawdown is low, since the sediment transport rates are low.