

# Detailed Design of Aberaeron Coastal Defence Scheme

Sediment Transport Modelling Report

Ceredigion County Council

26 October 2021

5182114-ATK-MAR-GEN-RP-C-1038



# Notice

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## Document history

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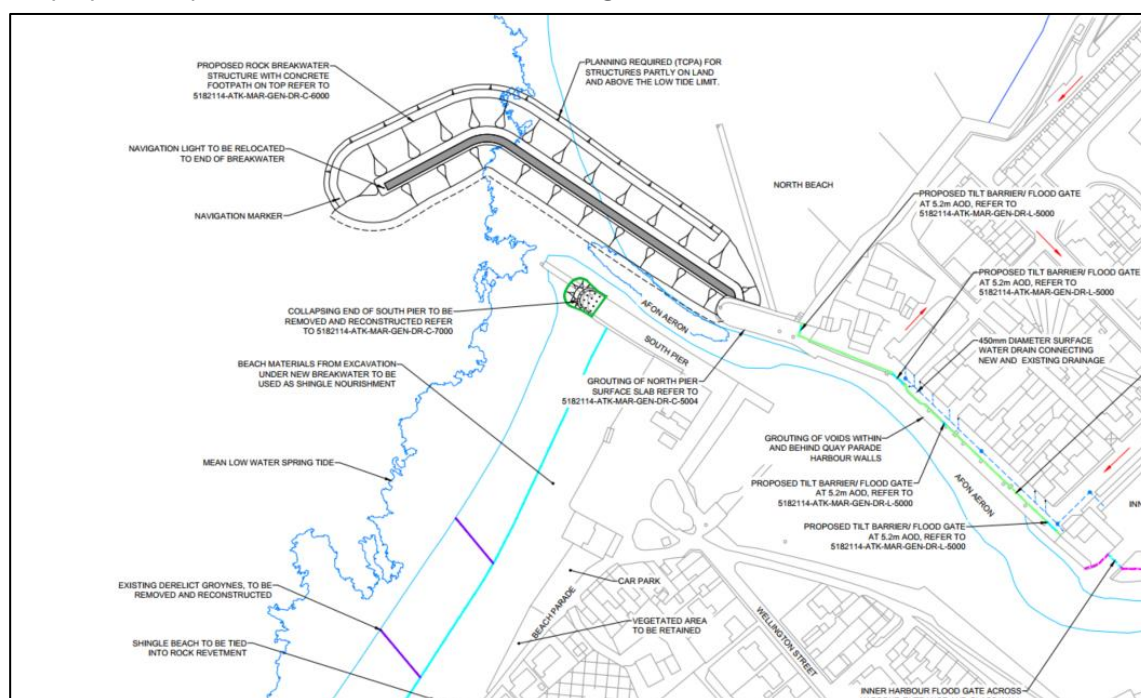
# 1. Introduction

## 1.1. Purpose

This report summarises the results of the work undertaken by Atkins to understand the effect of a proposed breakwater structure on sediment transport at Aberaeron, Wales. An outline modelling methodology is presented along with model outputs and conclusions based upon bed level change plots. The numerical modelling considers the best practice requirements detailed in NRW Guidance Note GN041 [1], NRW Evidence Report No 208 [2] and NRW Evidence Report No 243 [3].

## 1.2. Client objectives

Ceredigion County Council has commissioned Atkins to complete the detailed design of the proposed coastal defence scheme at Aberaeron. Atkins has previously performed numerical modelling to analyse various proposed layouts of engineering structures that would act to reduce wave heights within Aberaeron harbour [4]. The modelling identified that the most effective option for reducing wave heights in the harbour to meet the required standard of protection for overtopping was 'Option 3 - Extension of Northern Pier' by construction of a rock breakwater. However, in that report, it was identified that there was a need to assess the effect of the proposed breakwater on sediment movements (erosion and deposition). Figure 1-1 below shows the location of the proposed Option 3 breakwater which has a length of 220m, a width of 30m and a crest level of +5mOD.



**Figure 1-1 - Option 3 breakwater location**

As detailed in Section 2, particular attention needs to be paid to the likely impact of the structure on receptors particular at the adjacent Sabellaria reef (shown in Figure 2-7) and on the potential for sedimentation/siltation in the navigation channel.

## 2. Conceptual Understanding

A conceptual understanding of the physical processes has been drawn together to inform the requirements for baseline data requirements and to support decisions on the type of numerical modelling that might be used for the study.

### 2.1. Hydrodynamics

#### 2.1.1. Water Levels

The normal spring tidal range is approximately 4m, ranging from -1.79mOD at Mean Low Water Springs (MLWS) to +2.52mOD at Mean High Water Springs (MHWS). Extreme water levels can be up to an additional 1.5m higher (at present day) in the 1 in 1000 scenario. There are no water level control structures within the harbour and the harbour bed is exposed at low tide.

#### 2.1.2. Waves

Hindcast data [5] over a period of 40 years is available to determine representative wave conditions. This shows that waves within Cardigan Bay approach Aberaeron from a broad sector covering the southwest through to the northwest. The dominant wave direction is from the southwest to west, however waves from the northwest can also be significant during storm conditions.

The SMP2 [6] also demonstrated that there can be variation in net wave direction on a decadal scale such that in any period of time there may be a slight shift around the normal southwest to west dominance at the shoreline [6].

During north-westerly storms, waves are generated, which despite the presence of the two piers at Aberaeron, are able to enter the harbour. The shape of the harbour entrance means that wave heights increase as they are funnelled through the entrance and move through the entrance channel of the harbour. [7]

Waves from a north-westerly direction enter the harbour and run along the harbour wall on the north side of the harbour, which results in waves overtopping the harbour wall and the secondary wall too. [7]

### 2.2. Sediments and Geology

The bedrock geology of the Cardigan Bay area is dominated by a sedimentary succession of sandstones, siltstones and mudstones of Silurian to early Devonian age. Glacial and glaciofluvial sequences were deposited on local bedrock during several major phases of ice-sheet glaciation that culminated approximately 18,000 years ago.

The coastline is dominated by soft boulder clay cliffs, and mudstone outcrops and headlands. The hard points along the coast of New Quay head, Llanina Point, Aberaeron Harbour, Morfa Mawr, the mouth of the Afon Wyre, Carreg Ti Pw, Allt Wen, Aberystwyth Harbour, Castle Hill, Constitution Hill and Sarn Gynfelyn have created a stepped coastline, where the shore is eroding back in shallow bays [8]

A subtidal video survey of the seabed along the Aberaeron coastline, undertaken for this Scheme in 2019 [9] identified a dominant presence of mixed sediments of bedrock, boulders, cobbles and coarse gravel in the subtidal area, with occasional patches of fine sand. The nature of the sediment type is patchy across the site though sand was largely restricted to the south western portion and a gradient from sand to coarser sediment was evident from shore to sea.

### 2.3. Topography / Morphology

This part of the coast along the frontage of Aberaeron coast is characterised by gently sloping bathymetry and there are no notable bedforms or notable seabed features.

The coastal topography to the south of Aberaeron consists of cliffs and moving north from here the land falls to the valley of the Afon Aeron. The beach frontage is formed of shingle and the foreshore is quite wide. Further inland is the harbour around the mouth of the Afon Aeron. North of the harbour is the North beach which has a wide foreshore consisting of shingle.

## 2.4. Problem definition and study objectives

### 2.4.1. Baseline conditions

The stepped nature of this coast, with headlands and bays, demonstrates that the processes shaping the coastline are the dominant wave direction and the geology i.e. erosion and landward retreat of the coastline has occurred in the areas of softer geology, with the harder rocks remaining prominent as headlands. Without current coastal management measures, continued landward retreat would be expected. Increased sea level rise will tend to narrow the intertidal area, and allow larger waves to attack the cliffs, accelerating the recession. Some erosion of the clay cliffs at Aberaeron South Beach is occurring and this could over time allow a breach into a lower-lying area behind, adjacent to the southern flank of the harbour.

Sources of beach sediment are limited along this stretch of coastline, predominantly due to the presence of headlands reducing the longshore sediment transport to adjacent bays, as well as the more-resistant hard rock cliff outcrops which are less susceptible to erosion. Erosion of the clay cliffs at Aberaeron South Beach contain little beach supply material and do not have a significant impact on sediment supply [6].

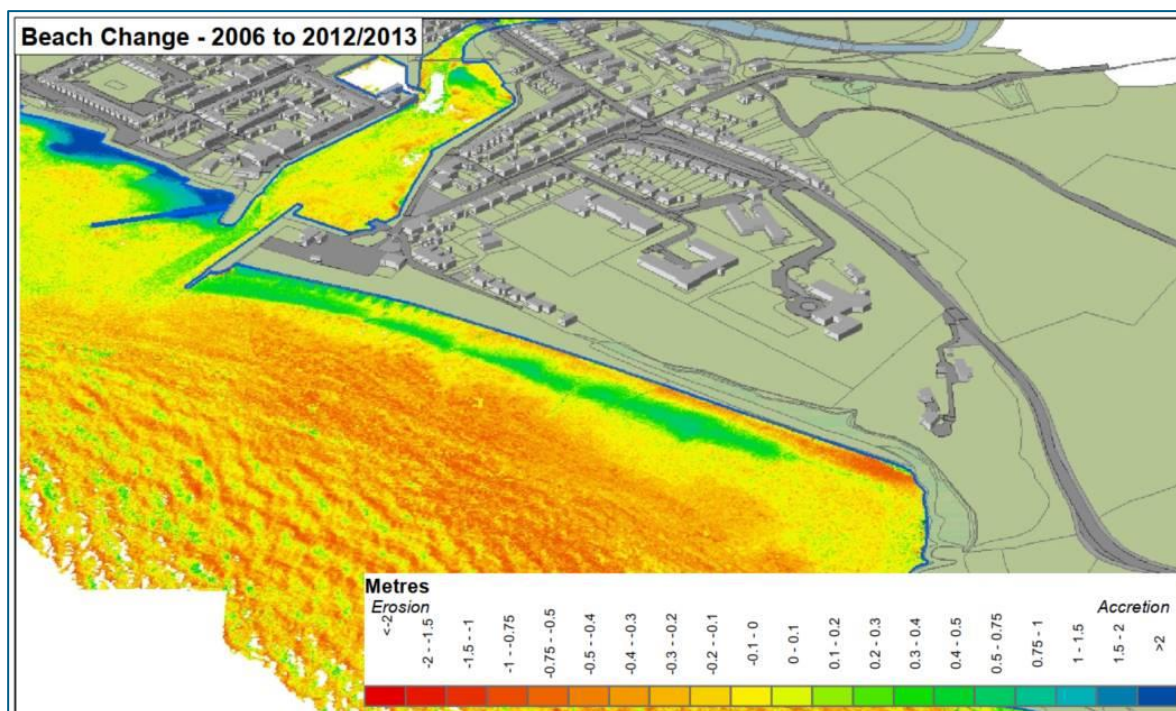
Longshore sediment transport processes are in a north-easterly direction. However, the amount of sediment transported is considered to be limited due to the limited supplies of sediment [6]. There is very little movement of material offshore.

South Pier has a significant influence on the coastal processes of the North and South beaches at Aberaeron. The presence of the South Pier retains a significant amount of material that is being transported in a northerly direction by the prevailing longshore drift processes, enabling a channel to be maintained into Aberaeron Harbour. Although it acts as a barrier to drift along the frontage to the north, some nearshore movement beyond the influence of the pier is indicated, although this is limited to finer sediment. This has led to a reduction in material being deposited on North Beach. As stated above, the construction of new groynes and beach nourishment at North Beach as part of a coast defence scheme in 2009 along with regular beach maintenance, has improved beach volumes here.

The presence of South Pier artificially maintains a wide beach crest at the northern end of South Beach, reducing the occurrence of tidal flooding and erosion of the land behind the beach. However, despite the sediment retention role provided by South Pier, as South Beach does not receive a large natural supply of sediment, timber groynes have been installed on the beach to help retain the limited sediment supplies. Additionally, a rock revetment at the southern end of the beach provides protection to the rear of the beach from landward erosion.

Beach monitoring was undertaken on an annual basis at Aberaeron between 2009 and 2012 and a Beach Profile Monitoring report was produced in 2013 [10]. This report indicated that the southern end of Aberaeron South Beach has eroded, with accretion at the northern end of the beach, towards the South Pier. Further, a LiDAR comparison between 2006 and 2010 indicated that there is evidence that the southern end of South Beach is retreating, while to the northern end it is accreting (see Figure 2-1).

This reflects the dominant wave direction from the south west. It is recognised, however, that if this beach is subject to waves from the northwest, then there is likely to be a tendency for the material to return southwards again. As well as general accretion at the northern end of South Beach, the report indicated that there is evidence of some steepening of the beach; with a narrow strip of erosion in line with and perpendicular to the end of the South Pier. In contrast, erosion to the south is tending to flatten the beach. The general pattern of change highlights the importance of the Pier as the main control feature, holding the northern section of South Beach.



Source: Royal HaskoningDHV, 2012 [10]

**Figure 2-1 - Beach Change 2006 to 2012/2013**

A further comparison of beach sections using LiDAR data from 2009 with latest dataset dated 2015 (Lle.gov.uk) has also been undertaken and contained in Appendix B. Over this period there was very little difference in measurements showing a discernible pattern of retreat or steepening. Drawing 5182114-ATK-MAR-GEN-DR-C-8001 (which is also contained in Appendix B) shows a comparison between 2015 LiDAR and a 2019 topographic survey. Sections E and F on the above referenced drawing show that some local increase of the shingle has been occurred. These sections are to the northern extent of the South Beach, supporting the previous observations that shingle accretes in this area.

Within the harbour, sediment is brought in from both the sea and from upstream river flows. Accretion in the harbour is, however, limited, particularly due to the limited offshore sediment supplies along the Aberaeron coastline and the presence of the two piers. Bed levels vary between the north and south sides of the harbour. The River Aeron channel runs along the northern side of the harbour. Here, the bed level is lower as the river flows prevent accumulation of sediment, whereas on the southern side of the harbour bed levels are higher where sediment has accumulated. As a result, the harbour is dredged by CCC in March (usually on the last Spring tide before the end of March). The dredging is timed to coincide with the start of annual summer use of the harbour moorings. Boats are removed from the harbour at the end of October for storage over winter (due to the risk of storm damage) and returned to the harbour at the end of March. Pwll Cam is not dredged. The arisings are deposited on South Beach.

### 2.4.2. Predicted natural changes

The Shoreline Management Plan 2 [6] indicates that Aberaeron South is an erosional coastline, dominated by wave direction and geology. At the time the SMP was written the effect on erosion of the 2009 Aberaeron North Beach defences was not able to be assessed but is likely to have reduced erosion if the design intent was realised.

The effect of sea level rise described in the SMP2 is affected by geology with some areas eroding more rapidly, while in other areas there could be greater accumulation of sediment, but that the area of greatest erosion will vary over time.

### 2.4.3. Predicted anthropogenic changes

The only predicted man-made changes are likely to be related to the creation of sea defences, to reduce the effect of flooding from waves, rising sea levels and erosion. The predominant effect of these changes is likely to

reduce rates of erosion. The removal of the South Pier either deliberately or through lack of maintenance would have a significant effect on the width of the beach, lead to increased erosion and spilling of sediment material into the navigable channel.

#### 2.4.4. Short term impacts due to storms and ability to recover

The impact of storms on the South Beach is likely to result in movement of shingle onto the hinterland behind along with potential erosion of sandy hinterland to the more central part of the South Beach. The loss of the hinterland to the central part of the beach will be an irreversible loss, whereas the movement of shingle will require increasingly frequent intervention as sea levels increase to move shingle off car parking and roadside areas.

The ability of the beach to naturally recover to its existing situation is considered very low.

#### 2.4.5. Protected Sites and Habitats

The Scheme lies within the Aberarth-Carreg Wylan SSSI, designated for its geological, geomorphological and biological interest. The geology and geomorphological processes have enabled a wide range of marine and coastal wildlife to exist along this stretch of coastline, including a large extent of *Sabellaria alveolata* reef. The SSSI extends from the Afon Arth at Aberarth in Ceredigion, south to Carreg Wylan near Ceibwr Bay in north Pembrokeshire. At Aberaeron, the reef is visible at low tide on the lower foreshore along North Beach. A walkover survey carried out by a marine ecologist in summer 2020 did not identify any visible reef area at low tide along South Beach.

Specific locations of geological interest listed in the SSSI citation sheet on NRW's website<sup>1</sup> are: Cwmtudu (cliffs and foreshore), Traeth Penbryn (cliffs), Mwnt (cliffs) and Poppit (shore platform). These are all south of Aberaeron beyond the extent of the works to be undertaken (Cwmtudu is the closest at 11km south of Aberaeron).

There are no Regionally Important Geological and Geomorphological Sites (RIGS) in the vicinity of the works. The closest site is south of the scheme at New Quay; the New Quay Coastal Section and Frondolau Old Quarry.

The site also lies within the Cardigan Bay SAC and the West Wales Marine SAC. The Cardigan Bay SAC is primarily designated for its sandbanks, reef and submerged or partially submerged sea cave habitat. Of relevance to Aberaeron is the presence of reef along the foreshore, particularly at North Beach. The SAC is also designated for bottlenose dolphin, sea lamprey, river lamprey and grey seal. The West Wales SAC is designated for its populations of harbour porpoise.

#### Intertidal Ecology

The intertidal zone of Aberaeron South Beach is gently sloping, composed of shingle on the upper beach, and sand on the lower beach, which makes it popular with tourists, locals and visitors alike.

The Countryside Council for Wales (CCW, now Natural Resources Wales (NRW)) undertook habitat surveys around the whole of the Welsh coast between 2007 and 2010 known as the HABMAP Scheme. Data from this survey Scheme has been downloaded and the intertidal biotopes in the area of the Scheme are presented in Table 2-1.

The descriptions provided of the biotopes have been taken from the corresponding Marine Nature Conservation Review (MNCR) Marine Habitat Classification on the JNCC website<sup>2</sup>. As these surveys were undertaken using previous MNCR classification systems, the biotopes have been converted to the most recent EUNIS (2007) classifications. The biotopes in the area of the Scheme are shown in Table 2-1.

**Table 2-1 - Intertidal Biotopes within the Scheme Area**

Biotope (MNCR)	EUNIS classification 2007	Description
LGS.S.AEur	A2.223	Amphipods and <i>Scolecopsis spp.</i> in littoral medium-fine sand

<sup>1</sup> [www.naturalresources.wales/media/641262/SSSI\\_0355\\_Citation\\_EN0018c6a.pdf](http://www.naturalresources.wales/media/641262/SSSI_0355_Citation_EN0018c6a.pdf) [Accessed March 2021]

<sup>2</sup> JNCC (2015) The Marine Habitat Classification for Britain and Ireland Version 15.03. [Accessed March 2021]. Available from: <https://mhc.jncc.gov.uk/>

LGS.S.AP.P	A2.2311	Polychaetes, including <i>Paraonis fulgens</i> , in littoral fine sand
LGS.Sh.BarSh	A2.111	Barren littoral shingle
MLR.Sab.Salv	A2.711	<i>Sabellaria alveolata</i> reefs on sand-abraded eulittoral rock
SLR.FX.BLit	A2.431	Barnacles and <i>Littorina littorea</i> on unstable eulittoral mixed substrata
SLR.FX.EphX	A2.821	Ephemeral green and red seaweeds on variable salinity or disturbed eulittoral mixed substrata
SLR.FX.FcerX	A1.327	<i>Fucus ceranoides</i> on reduced salinity eulittoral rock
SLR.FX.Fves	A1.313	<i>Fucus vesiculosus</i> on moderately exposed to sheltered mid eulittoral rock
SLR.MX.MytX	A2.721	<i>Mytilus edulis</i> beds on eulittoral mixed substrata
ELR.MB.BPat	A1.1121	Chthamalus montagui and Chthamalus stellatus on exposed upper eulittoral rock
LR.L.UloUro	B3.115	<i>Ullothrix flacca</i> and <i>Urospora</i> spp. on freshwater-influenced vertical littoral fringe soft rock

Source: <https://naturalresources.wales/about-us/our-Schemes/marine-Schemes/habmap>

Intertidal habitat types of conservation importance identified within the area of the Scheme include *Sabellaria alveolata* (Honeycomb worm) reefs on sand-abraded eulittoral rock in the area next to South Pier and along South Beach and extending into the subtidal zone.

The Honeycomb worm (*Sabellaria alveolata*) form littoral biogenic reefs (reefs made of living creatures, in the lower intertidal area and shallow subtidal), which help to stabilise the boulders and cobbles. Other species found in this habitat include barnacles *Elminius modestus* and *Semibalanus balanoides*, mussel *Mytilus edulis*, and whelk *Nucella lapillus*. The crab *Carcinus maenas* and the anemone *Actinia equina* can be present in cracks and crevices of the reef.

Despite *S.alveolata* being identified as present in the HABMAP survey, an ecological walkover survey carried out in 2020 by a member of the Scheme team found no *S.alveolata* reefs or encrustations in the intertidal area along South Beach or around the piers. Mussel beds on North Beach were visible at low tide. Species observed on the wooden groyne and piers included limpets, barnacles and seaweed species. Images taken during the site visit of the head of the South Pier, groyne at the base of the South Pier and a weathered groyne along South Beach show no evidence of *S.alveolata* reefs. Further discussion of *S.alveolata* in the subtidal zone is discussed in the next section below.

Mussel (*Mytilis edulis*) beds on eulittoral (lower intertidal area) mixed substrates are located along the North Beach of Aberaeron. 'Mussel mud' formed by blue mussel waste is an important source of nutrients for animals living within the seabed<sup>3</sup>.

Within the harbour, the southern shoreline is exposed at low tide, with Table 2-1 showing a habitat type of ephemeral green and red seaweeds as well as bladder wrack algae. The northern shore remains submerged at low tide and comprises a mix of fine river sediment, sand and shingles. The harbour mouth and channel is dredged annually to maintain a navigable depth. The dredged material is recycled onto South Beach.

### Subtidal Ecology

The habitats in the area of the Scheme are presented within Table 2-2, with the MNCR biotope classification system converted to the most recent EUNIS (2007) classifications.

**Table 2-2 - Subtidal Biotopes within the Scheme Area**

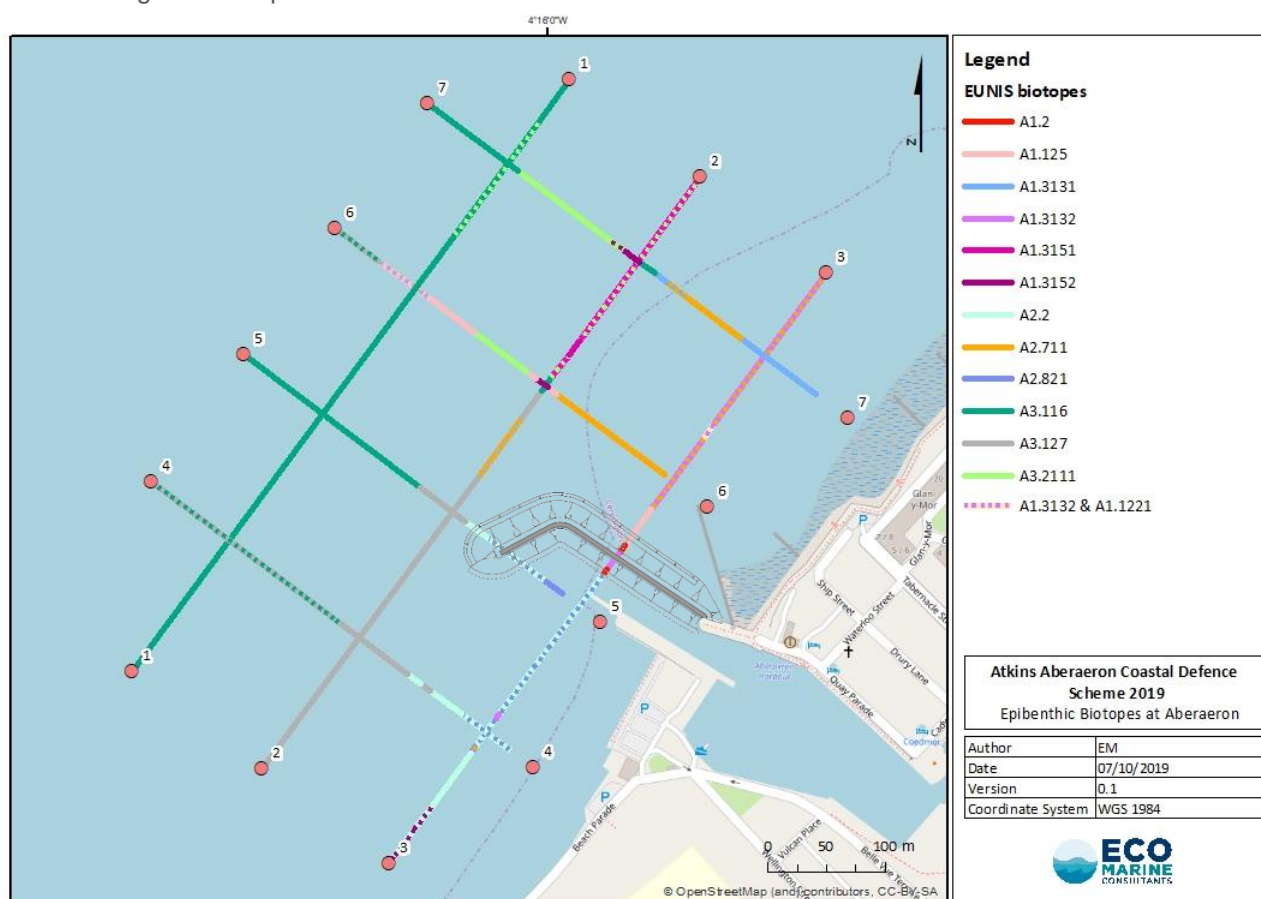
<sup>3</sup> JNCC (2015) The Marine Habitat Classification for Britain and Ireland Version 15.03. [Accessed March 2021]. Available from: <https://mhc.jncc.gov.uk/>

Biotope (MNCR)	EUNIS classification 2007	Description
CR.MCR.EcCr.FaAlCr	A4.214	Faunal and algal crusts on exposed to moderately wave-exposed circalittoral rock
SS.SMp.KSwSS.LsacR	A5.521	Brown algae <i>Laminaria saccharina</i> and red seaweeds on infralittoral sediments

Source: <https://naturalresources.wales/about-us/our-Schemes/marine-Schemes/habmap>

The subtidal habitats identified from the HABMAP survey show two dominant biotopes. Closer to the shoreline, the subtidal habitat is composed of mixed muddy substrate communities characterised by foliose red algae and the kelp species *Saccharina latissima*. Further from the shoreline, the subtidal habitat is composed of wave-exposed and moderately wave exposed bedrock or boulders, subject to weak to moderate tidal streams. This habitat is dominated by algal (*Corallinaceae*) and faunal (e.g. *Parasmittina trispinosa*) crusts.

A subtidal habitat survey was also carried out in September 2019 by Eco Marine Consultants as part of the Scheme design (see Figure 2-2). The survey used a Remotely Operated Vehicle (ROV) or drop-down video to survey the seabed offshore of the harbour entrance. The survey was undertaken to establish the benthic habitats present as well as any species of conservation importance, which would be impacted by the footprint of the proposed breakwater. All ROV footage and image analysis was undertaken with JNCC guidance given in the Marine Monitoring Handbook (JNCC, 2001), the JNCC guidance on assigning benthic biotopes (Parry, 2015) and the NMBAQC and JNCC epibiota interpretation guidelines (Turner *et al.*, 2016). Biotopes recorded were assigned in accordance with the EUNIS classification scheme. The habitat description of each biotope shown in Figure 2-2 is provided in Table 2-3 further below.



**Figure 2-2 - Subtidal Survey 2019 Biotope Distribution**

Table 2-3 shows the subtidal biotopes recorded from the survey. A total of 12 intertidal and shallow subtidal biotope complexes were identified suggesting a diverse and ecologically varied site. There were numerous

stretches along each of the transects where two habitats were intermittently present, with more than one biotope description fitting the environmental conditions as well as faunal and algal species recorded. Where this was the case, two biotopes have been recorded in 'mosaic' form and are shown highlighted in blue in Table 2-3.

**Table 2-3 - Subtidal Biotopes from the 2019 Subtidal Survey**

Biotope (MNCR)	EUNIS Biotope Complex	Habitat Description	% Coverage
LR.HLR.FR.Mas	A1.125 (Level 5)	<i>Mastocarpus stellatus</i> and <i>Chondrus crispus</i> on very exposed to moderately exposed lower eulittoral rock	3.03
LR.M.LR	A1.2 (Level 3)	Moderate energy littoral rock	0.42
LR.LLR.F.Fves	A1.3131 (Level 5)	<i>Fucus vesiculosus</i> on moderately exposed to sheltered mid eulittoral rock	2.74
LR.LLR.F.Fves and LS.LBR.Sab.Salv	A1.3131 (Level 5) & A2.711 (Level 5)	<i>Fucus vesiculosus</i> on moderately exposed to sheltered mid eulittoral rock and <i>Sabellaria alveolata</i> reefs on sand-abraded eulittoral rock mosaic	0.68
LR.LLR.F.Fves.X	A1.3132 (Level 6)	<i>Fucus vesiculosus</i> on mid eulittoral mixed substrata	0.67
LR.LLR.F.Fves.X and LR.HLR.FR.Coff.Coff	A1.3132 (Level 6) & A1.1221 (Level 6)	<i>Fucus vesiculosus</i> on mid eulittoral mixed substrata and <i>Corallina officinalis</i> and <i>Mastocarpus stellatus</i> on exposed to moderately exposed lower eulittoral rock	0.45
LR.LLR.F.Fserr.FS	A1.3151 (Level 5)	<i>Fucus serratus</i> on full salinity sheltered lower eulittoral rock	0.41
LR.LLR.F.Fserr.X	A1.3152 (Level 6)	<i>Fucus serratus</i> on full salinity lower eulittoral mixed substrata	0.84
LR.LLR.F.Fserr.X and LS.Lsa	A1.3152 (Level 6) & A2.2 (Level 6)	<i>Fucus serratus</i> on full salinity lower eulittoral mixed substrata and Littoral sand	1.80
LR.LLR.F.Fserr.X and IR.MIR.KR.Ldig.Ldig	A1.3152 (Level 6) & A3.2111 (Level 6)	<i>Fucus serratus</i> on full salinity lower eulittoral mixed substrata and <i>Laminaria digitata</i> on moderately exposed sublittoral fringe bedrock mosaic	0.40
LS.Lsa	A2.2 (Level 3)	Littoral sand	3.78
LS.LBR.Sab.Salv	A2.711 (Level 5)	<i>Sabellaria alveolata</i> reefs on sand-abraded eulittoral rock	5.11
LS.LBR.Sab.Salv and LR.LLR.F.Fves.X	A2.711 (Level 5) & A1.3132 (Level 6)	<i>Sabellaria alveolata</i> reefs on sand-abraded eulittoral rock and <i>Fucus vesiculosus</i> on mid eulittoral mixed substrata	6.98
LS.LBR.Sab.Salv and LR.FLR.Eph.EphX	A2.711 (Level 5) & A2.821 (Level 5)	<i>Sabellaria alveolata</i> reefs on sand-abraded eulittoral rock and Ephemeral green and red seaweeds on variable salinity and/or disturbed eulittoral mixed substrata	0.23
LR.FLR.Eph.EphX	A2.821 (Level 5)	Ephemeral green and red seaweeds on variable salinity and/or disturbed eulittoral mixed substrata	0.55
LR.FLR.Eph.EphX and LS.Lsa	A2.821 (Level 5) & A2.2 (Level 3)	Ephemeral green and red seaweeds on variable salinity and/or disturbed eulittoral mixed substrata and Littoral sand	8.64

IR.HIR.KFaR.FoR	A3.116 (Level 5)	Foliose red seaweeds on exposed lower infralittoral rock	24.34
IR.HIR.KFaR.FoR and IR.HIR.KSed.ProtAhn	A3.116 (Level 5) & A3.127 (Level 5)	Foliose red seaweeds on exposed lower infralittoral rock and <i>Polyides rotundus</i> , <i>Ahnfeltia plicata</i> and <i>Chondrus crispus</i> on sand-covered infralittoral rock	7.49
IR.HIR.KSed.ProtAhn	A3.127 (Level 5)	<i>Polyides rotundus</i> , <i>Ahnfeltia plicata</i> and <i>Chondrus crispus</i> on sand-covered infralittoral rock	13.77
IR.HIR.KSed.ProtAhn and LR.HLR.FR.Mas	A3.127 (Level 5) & A1.125 (Level 5)	<i>Polyides rotundus</i> , <i>Ahnfeltia plicata</i> and <i>Chondrus crispus</i> on sand-covered infralittoral rock and <i>Mastocarpus stellatus</i> and <i>Chondrus crispus</i> on very exposed to moderately exposed lower eulittoral rock	1.65
IR.HIR.KSed.ProtAhn and LS.LBR.Sab.Salv	A3.127 (Level 5) & A2.711 (Level 5)	<i>Polyides rotundus</i> , <i>Ahnfeltia plicata</i> and <i>Chondrus crispus</i> on sand-covered infralittoral rock & <i>Sabellaria alveolata</i> reefs on sand-abraded eulittoral rock	1.86
IR.MIR.KR.Ldig.Ldig	A3.2111 (Level 6)	<i>Laminaria digitata</i> on moderately exposed sublittoral fringe bedrock	4.62
IR.MIR.KR.Ldig.Ldig and LR.LLR.F.Fserr.FS	A3.2111 (Level 6) & A1.3151 (Level 6)	<i>Laminaria digitata</i> on moderately exposed sublittoral fringe bedrock and <i>Fucus serratus</i> on full salinity sheltered lower eulittoral rock	5.90
IR.MIR.KR.Ldig.Ldig and IR.HIR.KFaR.FoR	A3.2111 (Level 6) & A3.116 (Level 5)	<i>Laminaria digitata</i> on moderately exposed sublittoral fringe bedrock and Foliose red seaweeds on exposed lower infralittoral rock	3.66

All of the fauna identified were typical for the intertidal and shallow subtidal habitats and are generally widespread along the coast of west Wales. The epibenthic fauna identified in both the video and stills were diverse for a small area and indicative of a relatively complex community. Notable features included extensive *Sabellaria alveolata* reef which was dominant in the north eastern portion of the site, specifically in the subtidal area off of North Beach and seaward of the proposed limit of the breakwater. No dominant areas of *Sabellaria* were identified along South Beach. Other species of conservation importance recorded during the survey was a small spotted catshark (*Scyliorhinus canicular*) which is listed on the International Union for Conservation of Nature (IUCN) Red List though is categorised as 'Least Concern' with the main threat considered to be fishing and harvesting of aquatic resources (Ellis *et al.*, 2009).

Several commercially valuable species including the European lobster (*Homarus gammarus*), edible crab (*Cancer pagurus*), European bass (*Dicentrarchus labrax*) and European plaice (*Pleuronectes platessa*) were recorded in low abundance. Anchored fishing pots were also observed at several locations in the site boundaries and surrounding areas. Discussion with a locally based skipper revealed that the survey area is well utilised by local fishermen targeting lobster, crab and spider crabs depending on the season.

No invasive non-native species (INNS) were identified from the footage and stills in 2019. However, there are records of an invasive species of seaweed, Japanese wireweed (*Sargassum muticum*) at Pen-y-gloyn, approximately 700m south-west of Aberaeron harbour entrance. It is possible that Japanese wireweed is present closer to the harbour. The species grows on hard substrata and is found in shallow subtidal waters.

#### 2.4.6. Potential sources, pathways and receptors

Using the example of Figure 2 in NRW Report 243, and based on the understanding of the available data, Table 2-4 below summarises the links between potential sources and their effects on the marine physical environment.

**Table 2-4 - Identification of potential sources, pathways and receptors**

Potential source	Potential pathways from changes to marine physical environment processes	Receptor groups
<p>New Sea Defences</p> <ul style="list-style-type: none"> <li>• Harbour walls</li> <li>• Breakwater</li> <li>• Groynes</li> <li>• Rock revetment</li> <li>• Beach Nourishment</li> </ul> <p>Retained Sea Defences</p> <ul style="list-style-type: none"> <li>• South Pier</li> <li>• Groynes</li> </ul>	<ul style="list-style-type: none"> <li>• Waves-&gt;Sediment transport-&gt;changes in seabed level/changes to inter-tidal coastal morphology/changes to the bed level of the navigable channel.</li> <li>• Currents-&gt;Scour/erosion</li> <li>• Water temperature</li> <li>• Suspended sediment plumes</li> <li>• Localised seabed change</li> </ul>	<p>Marine &amp; Coastal Physical Processes</p> <p>Marine Water &amp; Sediment Quality</p> <p>Marine &amp; Coastal Ecology</p> <p>Flood Risk</p> <p>Socioeconomics</p>

#### 2.4.6.1. Potential sources

##### New Sea Defences

- **Harbour walls**

Raised sea defences are proposed within the harbour itself, this is to reduce the effect of wave overtopping and prevent inundation due to sea level rise. The effect of raising existing sea defences on coastal processes is considered to be negligible. Conversely, if the wall was removed or allowed to fail erosion of the coastline would take place.

- **Breakwater**

The breakwater structure extends from high water to below low water i.e. the full intertidal range. It also has potential to affect currents and patterns of sediment deposition and accretion. It is not easy to predict the effects on coastal processes and modelling work would benefit understanding.

- **Rock revetment**

The proposed rock revetment is along the high-water line of the South Beach. The rock revetment will reduce wave overtopping and prevent erosion. The rock revetment will reduce reflection of waves and limit any effect on its immediate foreshore. The effect on coastal processes is likely to be limited to reducing erosion. There is limited benefit in carrying out modelling of the effect of the rock revetment and understanding of the coastal processes can be drawn from information in the SMP2.

- **Beach Nourishment**

The proposed beach nourishment is along the high-water line of the South Beach. The beach nourishment will reduce wave overtopping and prevent erosion. The location of the nourishment is in a location where limited dredging disposal already occurs and the pattern of dispersal of the shingle is well understood from observations which show there is very little movement of material in the short to medium term. The effect on coastal processes is likely to be limited to reducing erosion. There is limited benefit in carrying out modelling of the effect of the beach nourishment and understanding of the coastal processes can be drawn from information in the SMP2.

##### Retained Sea Defences

- **South Pier**

As discussed in Section 2.4.1 above and within the SMP2, the South Pier is a critical structure in retaining the beach and maintaining the navigable channel. The modelling will need to note this structure as being retained.

- **Groynes**

Timber groynes are already in place on the beach and have a role in containing shingle in bays along the South Beach but have reached the end of their design life. Replacement will be on a like for like basis. Given the observations in Section 2.4.1 above, the groynes together with the South Pier contribute to slowing migration of shingle to the north and slowing the effects of sediment migration. The effect on the coastal processes is likely to be limited to reducing erosion and with like for like replacement there is no change to the status quo. There is limited benefit in carrying out modelling of

the effect of the groynes and understanding of the coastal processes can be drawn from information in the SMP2.



**Figure 2-3 - Existing timber groynes on South Beach**

In summary, modelling is required to determine the effect of the proposed **breakwater** on marine physical environment processes.

#### 2.4.6.2. Potential pathways

The following potential pathways from changes to marine physical environment processes are outline below:

- **Waves**  
The hydrodynamic effect of waves is considered to be the main factor in driving sediment transport. Sediment movements are anticipated to result in changes in seabed level, changes to inter-tidal coastal morphology and changes to the bed level of the navigable channel.
- **Currents**  
Currents are anticipated to be less of an influence on coastal processes than the wave effects above. However, flows from the River Aeron keep the navigable channel clear in the harbour through the natural mechanism of scour. No observable erosion effects have been seen from the river current, despite a record river level recorded during Storm Callum in 2018.
- **Water temperature**  
Water temperature is not considered a significant factor in this area.
- **Suspended sediment plumes**  
The presence or creation of sediment plume is not considered a significant factor in this area.
- **Localised seabed change**  
From a review of observations, there is no reason to believe that localised seabed change occurs to any degree that is a factor in this area.

Summarising the above, the effects of **waves** is to be considered for the study, as this is the main factor identified above.

#### 2.4.6.3. Potential receptor groups

The following receptor groups have been identified however, these may be considered through modelling or other study:

- **Marine & Coastal Physical Processes**  
There is potential to affect these processes in the future and this should be considered in this study through modelling.

- **Marine Water & Sediment Quality**

There is potential to effect water and sediment quality, however modelling is not thought to add value to the assessment of the potential impacts. These impacts are likely to be assessed through desk study. A Water Framework Directive Assessment is to be carried out as a separate study.

- **Marine & Coastal Ecology**

A separate study of the effect on the marine and coastal ecology will be undertaken, based on intertidal and subtidal ecology surveys, biodiversity record searches and desk study. However, this is closely linked to any changes to the coastal processes which may affect habitats. The study should link the marine and coastal processes considerations to provide and understanding of the effects on intertidal/subtidal habitats.

- **Flood Risk**

Extensive modelling of flood risk has already taken place to assess the impacts of wave overtopping and sea level rise in combination with fluvial flooding.

- **Socioeconomics**

The impact of flooding on socioeconomics has been considered in a separate FCERM Business Case and will be more widely considered within the EIA.

In summary, this study will be focussed on receptor groups of the **marine and coastal processes** and the **marine and coastal ecology**.

### 2.4.7. Summary of key sources, pathways and receptors

From the sections above, the items highlighted in green in Table 2-5 below will form the areas of study to be considered.

**Table 2-5 - Potential sources, pathways and receptors to be considered in this study**

Potential source	Potential pathways from changes to marine physical environment processes	Receptor groups
New Sea Defences <ul style="list-style-type: none"> <li>• Harbour walls</li> <li>• <b>Breakwater</b></li> <li>• Groynes</li> <li>• Rock revetment</li> <li>• Beach Nourishment</li> </ul> Retained Sea Defences <ul style="list-style-type: none"> <li>• South Pier</li> <li>• Groynes</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Waves-&gt;Sediment transport-&gt;changes in seabed level/changes to inter-lidal coastal morphology/changes to the bed level of the navigable channel</b></li> <li>• Currents-&gt;Scour/erosion</li> <li>• Water temperature</li> <li>• Suspended sediment plume</li> <li>• Localised seabed change</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Marine &amp; Coastal Physical Processes</b></li> <li>• Marine Water &amp; Sediment Quality</li> <li>• <b>Marine &amp; Coastal Ecology</b></li> <li>• Flood Risk</li> <li>• Socioeconomics</li> </ul>

### 2.4.8. Summary of study objectives

Given the above consideration of sources/pathways/receptors, the study can be summarised as studying the effect of the breakwater as a source of change. The pathways created by waves will need to be considered to understand its effect on coastal processes and changes to the bed level or patterns of sediment deposition or scour. The study will be primarily concerned with the effect on marine and coastal processes, and link to the effect on intertidal and subtidal ecology.

It is considered that modelling will need to be undertaken, which is summarised in more detail in the sections below.

The objectives of the modelling will be to:

- Understand the effect of the construction and operation of the breakwater as a source of change.
- Understand the potential pathway of change to the marine physical environment and specifically:

- The changes to sea-bed level in the inter-tidal area.
- The changes to inter-tidal coastal morphology.
- The periods of time over which areas of reef and protected areas might be submerged (to inform an ecological assessment of the reef habitat).
- The changes to sea-bed level in the location of the navigable channel.
- Allow an assessment in an EIA to consider the effects on receptor groups, specifically:
  - Marine & Coastal Physical Processes
  - Marine Water & Sediment Quality
  - Marine & Coastal Ecology
  - Flood Risk
  - Socioeconomics

## 2.5. Numerical Modelling Approach

To meet the scope and aims of the study detailed above, it has been identified that a sediment transport model is required to model:

- Tidal and wave driven currents;
- Surface waves; and
- Sand transport.

The aim of the modelling is to compare the pattern of deposition and scour which naturally occurs throughout the whole year and how this pattern will change due to the construction of the breakwater. Specific observations will be made in respect of the Sabellaria reef and other protected areas.

As a consequence, a sediment transport model has been developed in MIKE21, a commercial software, developed by Danish Hydraulics Institute (DHI), consisting of three components; a Hydrodynamic (HD) model of tidal and wave driven currents, a Spectral Wave (SW) model of surface waves and a Sand Transport (ST) model. MIKE21 allows these models to be coupled so that feedback processes between the three elements can occur.

The hydrodynamic and wave models are coupled so that the wave field is applied to the hydrodynamic model to include wave driven currents. The wave model uses the water level variation from the hydrodynamic model so that areas of wave shoaling and breaking vary over the tidal cycle. Therefore, both wave and hydrodynamic models are used to force the sediment transport model. All the three components of the model use the same flexible mesh, which allows resolution to be increased where processes such as wave-breaking and wave driven currents need to be resolved over a small spatial scale.

## 2.6. Model Domain

Before deciding the extent of the model domain consideration was given to the zone of influence likely to be affected by the proposed breakwater structure.

Reference was made to SMP2 for understanding of the coastal processes in relation to sediment transport. A brief summary from the SMP2 is listed below in relation to each section of the coast described in respect of Coastal Processes.

- Aberaeron South Beach - Limited drift from the South, fed by long term erosion of the cliffs and the sediment is retained at Aberaeron South Beach, or through to the area to the north.
- Aberaeron North Beach – The existing coast protection works help control the northward drift which is recognised to be fairly high. Beyond the groynes to the north-east accretion occurs due to cliffs further north.
- Aberarth frontage – The frontage gains sediment principally from the cliffs directly to the south and beach material is retained in position partly by cliffs to the north.

Consideration was also taken of the numerical wave modelling [4] carried out for the breakwater. The numerical modelling shows that the breakwater reduces wave heights within the harbour and through the entrance channel, where the structure provides wave sheltering. Wave energy is dissipated on the structure through wave breaking, run-up and overtopping, resulting in partial reflection. Reflected wave energy causes local increases to wave heights on the seaward side of the structure (within 3-4 wavelengths).

The presence of the breakwater also affects the pattern of tidal flows local to the structure, with some locally increased current speeds around the toe of the structure.

From this, a zone of influence of <1km from the structure can be inferred.

On this basis it was decided that a large area should be used in model to cover beyond the potential zone of influence which is expected to extend between the cliffs to the South and past the existing coastal defence works on North beach. This involves a model extent over 1.8km of coastal frontage, which consists of around 850m south of the harbour entrance and 950m to the north of the harbour entrance. The northern boundary also stops where the coast begins to step into the next bay north of Aberaeron.

The model will extend more than 600m offshore, to match the wave generation zone in the numerical model rather than any consideration for sediment movement.



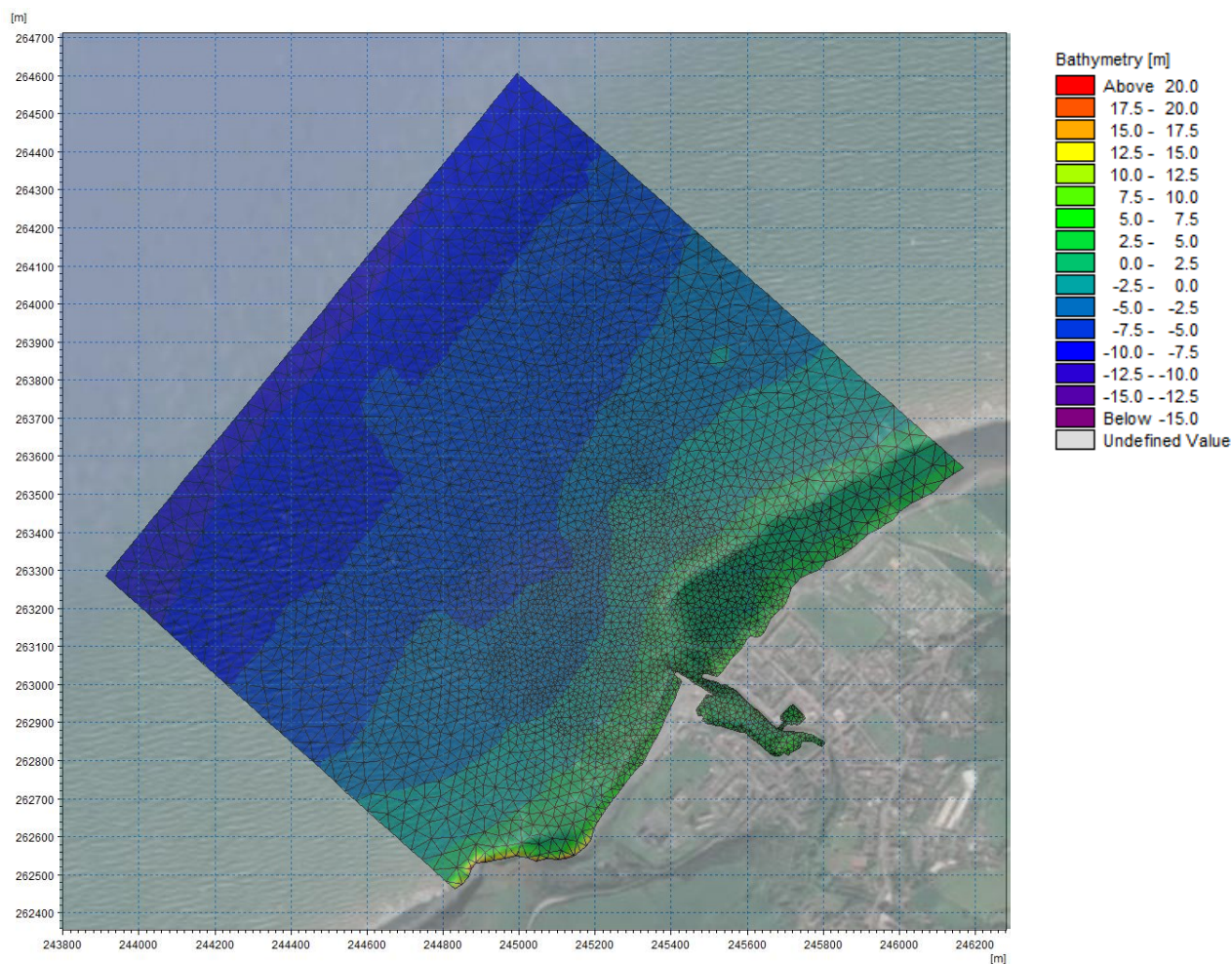
**Figure 2-4 - Zone of influence along coastal frontage considered for the model**

A computational grid defines the model domain area and mesh resolution which is tailored for the accuracy required for the numerical simulation.

Survey bathymetry at the harbour entrance in the location of the proposed breakwater was used along with two other datasets detailed (as listed below in Table 2-6) to obtain full bathymetrical coverage of the model domain at Aberaeron. The mesh used in all model runs is shown in Figure 2-5 below. The grid uses the British National Grid coordinate system and depths relative to Chart Datum.

**Table 2-6 - Datasets used in creating the model mesh**

Dataset Name	Data Type
Welsh Government	LiDAR
Bathymetric Survey	Bathymetry
EmapSite Data	Bathymetry



**Figure 2-5 - Model domain, mesh and bathymetry (depths in Chart Datum)**

## 2.7. Representative Wave Conditions

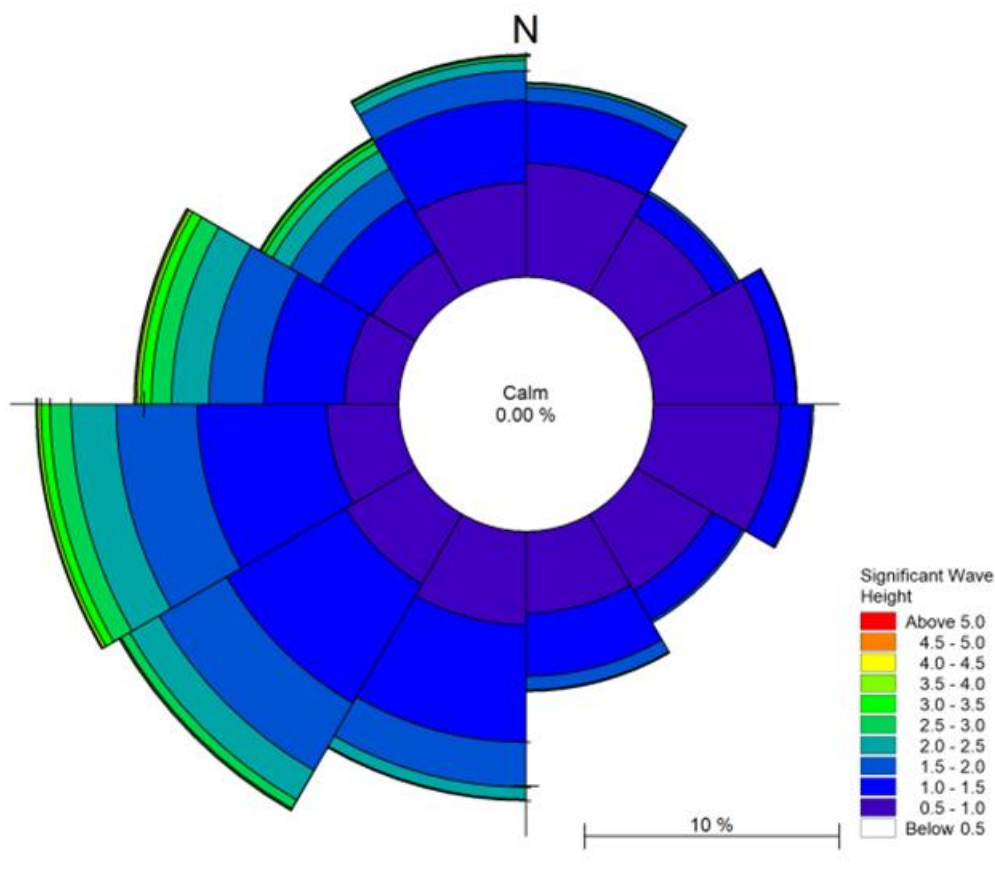
Wave climate data [5] over a period of 40 years has been used to determine representative wave conditions (see Table 2-7 below). This approach determines the contribution of waves from each directional sector to the

annual energy flux. Representative wave conditions are applied as boundary conditions in the spectral wave component of the coupled model to create characteristic sediment transport simulations for the 12 directional sectors.

**Table 2-7 - Representative Wave Climate**

Mean Wave Direction (degrees)	Significant Wave Height, Hm0 (m)	Peak Wave Period, Tp (s)	Equivalent Days	%age Frequency
15	0.84	8.31	21.43	5.87
45	0.68	10.53	17.92	4.91
75	0.66	10.51	22.23	6.09
105	0.35	10.46	21.21	5.81
135	0.85	11.33	19.27	5.28
165	1.05	10.93	28.11	7.70
195	1.18	10.25	46.87	12.84
225	1.41	9.38	53.11	14.55
255	1.78	8.56	43.62	11.95
285	1.67	7.72	31.68	8.68
315	1.29	7.23	27.16	7.44
345	1.09	7.18	32.41	8.88

Table 2-7 shows a wave rose plot for the representative wave climate, with each colour band representing percentage occurrence of the significant wave height values shown in the key.



**Figure 2-6 - Wave Rose Plot for the representative wave climate**

## 2.8. Model Parameters

The water surface elevation was set as 2.61m above chart datum throughout the domain. This value was chosen as it is the mean sea level (MSL) at Aberaeron. The maximum bed level change per day was set at 0.25m/day based on findings in the Geotechnical report [11] and guidance from the software developer, DHI.

A sediment transport table was prepared for the model runs. This creates a lookup table of sediment transport rates for a range of values for various model input parameters (e.g. wave height, period and direction, current velocity and direction, grain size, etc). The model uses this table to determine sediment transport throughout the domain at each timestep.

## 2.9. Output Plots

Models were run for each directional sector for a period of time based on the frequency of occurrence during a 'typical' year as presented in Table 2-7. This meant that once the 12 directional sectors were combined, a representative year of sediment transport could be obtained. Models were run for the existing layout and then with the proposed breakwater. Difference plots were then prepared to show the effect of the breakwater on the protected features of the foreshore.

The extent of the *Sabellaria Alveolata* Reef and other protected areas of the foreshore (these include biotopes of mussels, red and green seaweed and wrack) were obtained from the Welsh Government Geo-Portal (Lle, Welsh Government, 2020) as shown in Table 2-7. These protected areas are shown in the model output plots.

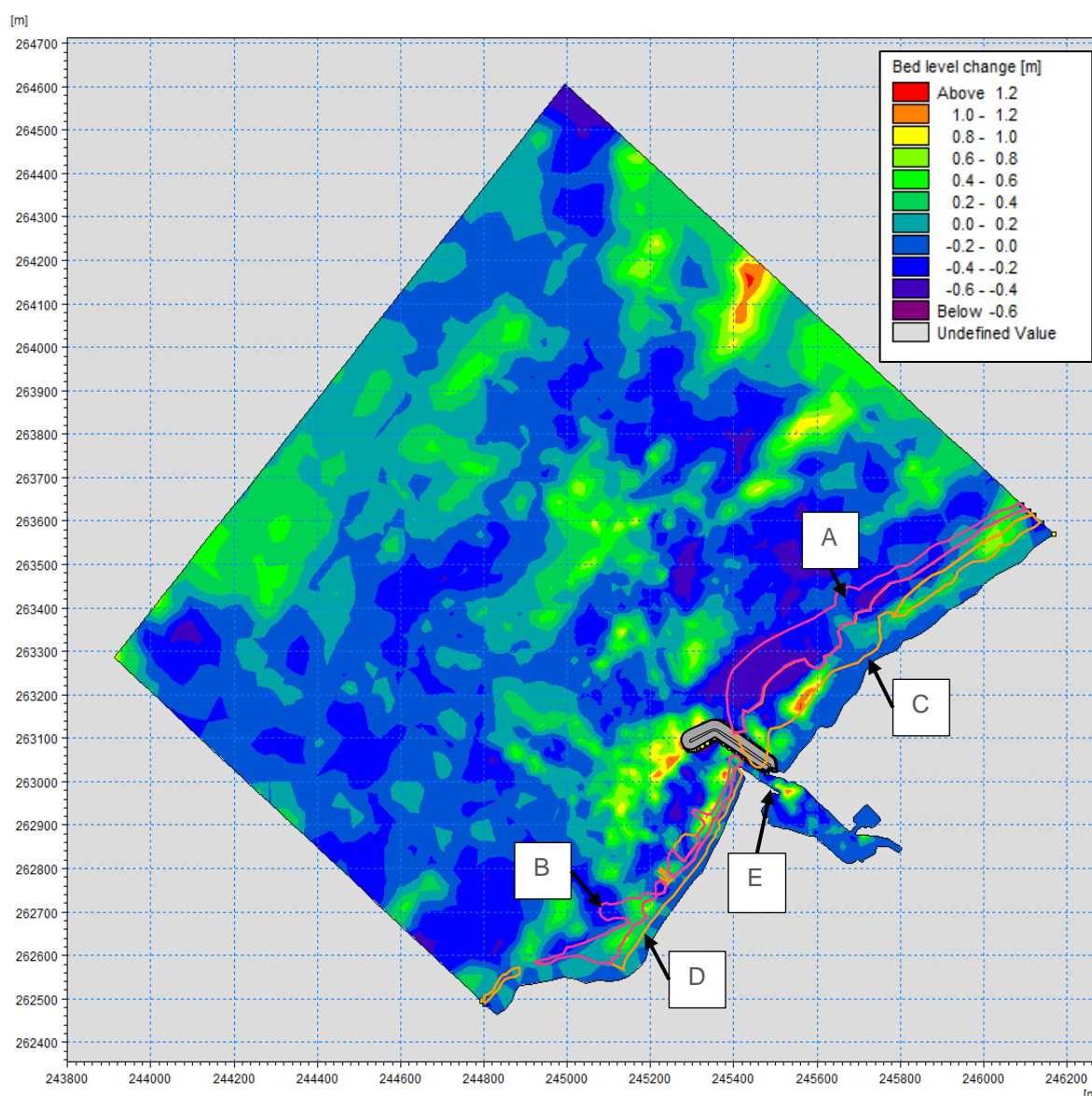


**Figure 2-7 - Extent of the Sabellaria Alveolata Reef and other protected areas**

### 3. Model Results

There is a pattern of deposition and scour which naturally occurs throughout the whole year. This pattern will change due to the construction of the Option 3 breakwater and to illustrate this difference plots have been produced to compare the existing situation with the proposed.

The difference plot presented in Figure 3-1 shows the bed level change over a representative year due to the presence of the Option 3 breakwater. The plot has been annotated with the extent of the breakwater, Sabellaria Reef (Areas A and B) and other protected features (Areas C and E) and the navigable channel (Area E). Positive values represent sediment deposition and negative values represent sediment erosion. Difference plots for each directional sector are presented in Appendix A along with the areas of interest (A-E); see Section 3.1 below.



**Figure 3-1 - Bed Level Change Difference Plot for a Representative Year**

### 3.1. Observations

The following observations can be made from the bed level change difference plot:

#### 3.1.1. Area A – Sabellaria Reef

Area A for the Sabellaria Reef is shown in Figure 3-2 below. There is limited change in sediment deposition in Area A due to the presence of the breakwater, with a maximum increase in the north-east of this area. In the south-west of Area A there are areas with a net loss of sediment over the course of a representative year.

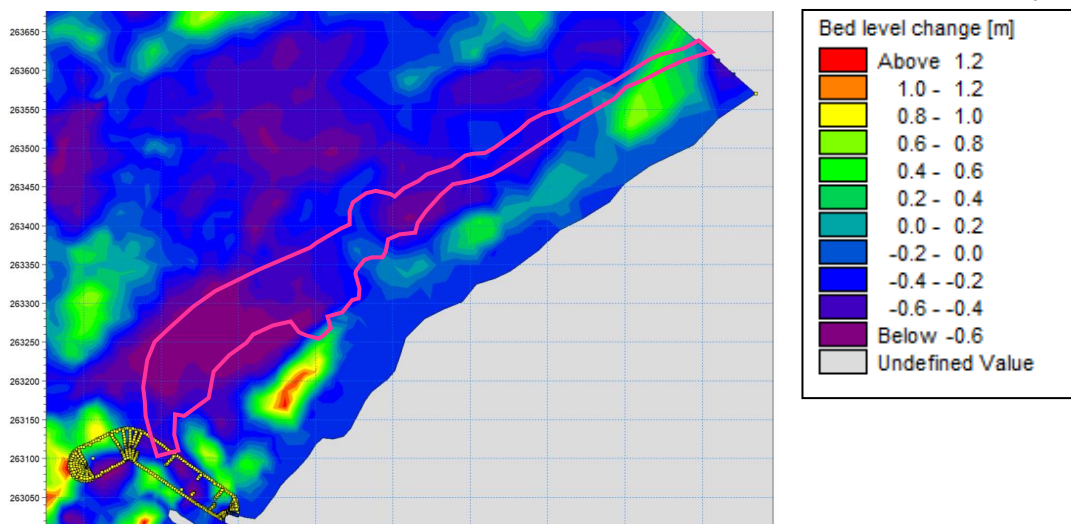


Figure 3-2 - Bed level change difference plot at Area A

#### 3.1.2. Area B - Sabellaria Reef

Area B is shown in Figure 3-3 below. The addition of the breakwater has a greater effect on sediment deposition in this area compared to Area A.

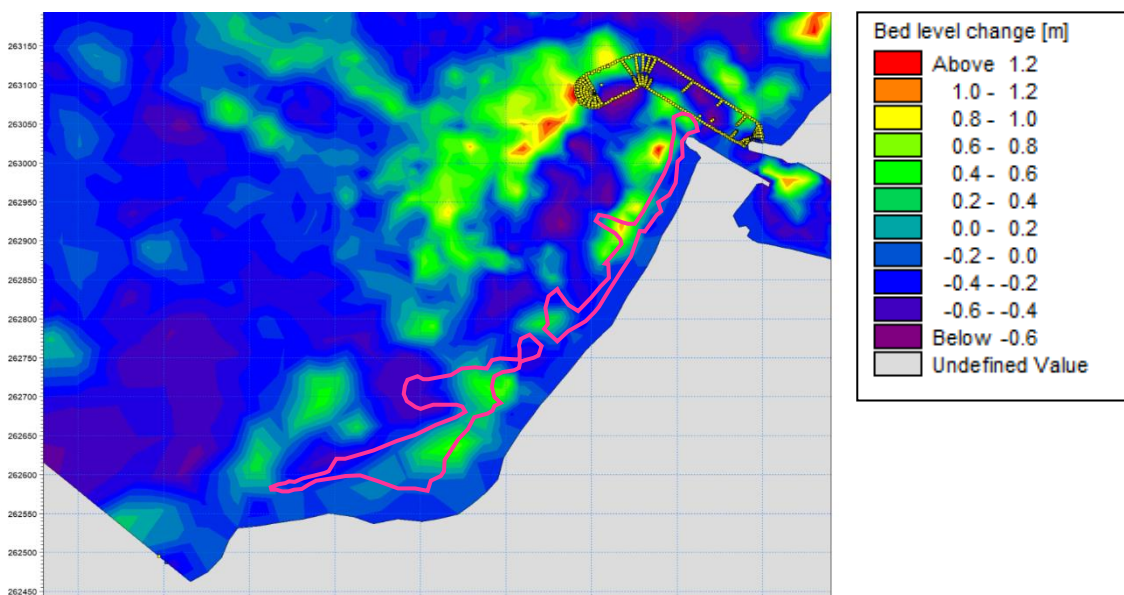


Figure 3-3 - Bed level change difference plot at Area B

### 3.1.3. Area C – Protected Area

Area C is shown in Figure 3-4 below. There is a larger variation in the bed level change across Area C. There is an area with more significant sediment deposition towards the south-west. Three other areas have a bed level increases, whilst other parts of Area C have a net loss of sediment.

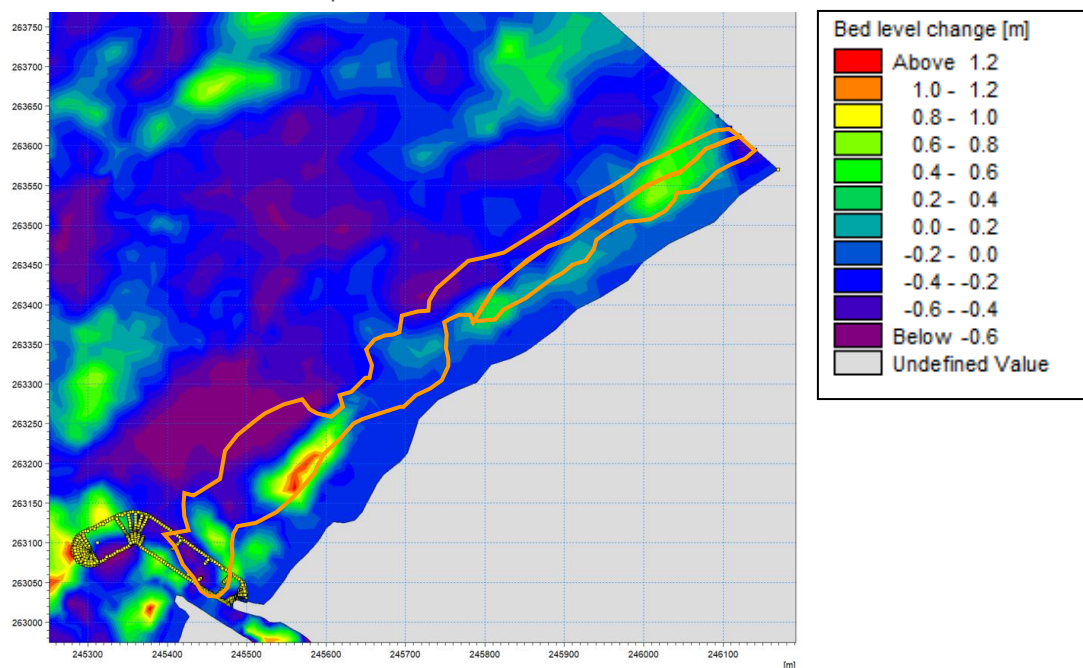


Figure 3-4 - Bed level change difference plot at Area C

### 3.1.4. Area D – Protected Area

Area D is shown in Figure 3-5 below. Area D has little change in bed level, there are areas towards the south-west in which sediment deposition depth increases.

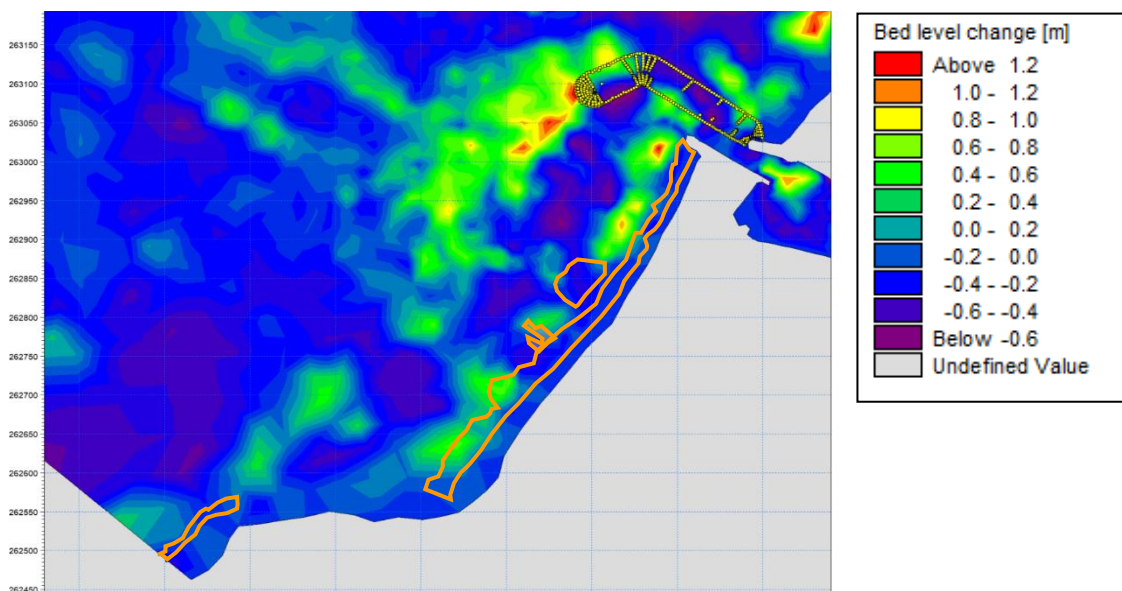


Figure 3-5 - Bed level change difference plot at Area D

### 3.1.5. Area E – Navigable Channel

One factor that was not able to be accounted for in the model was the flow out to sea from the River Aeron. This is due to the limitations of software to model this added complexity. The flow from the Aeron would decrease the sediment deposition in the navigable channel and would likely decrease the sedimentation shown in Figure 3-6 at the head of the breakwater.

Area E is shown in Figure 3-6 below. There is significant deposition of sediment just inside the harbour along the navigable channel. Other areas of the navigable channel have a bed level change both depositing and scouring. There is build-up of sediment at the head of the breakwater, this is due to waves from the south-west as shown in Appendix A.

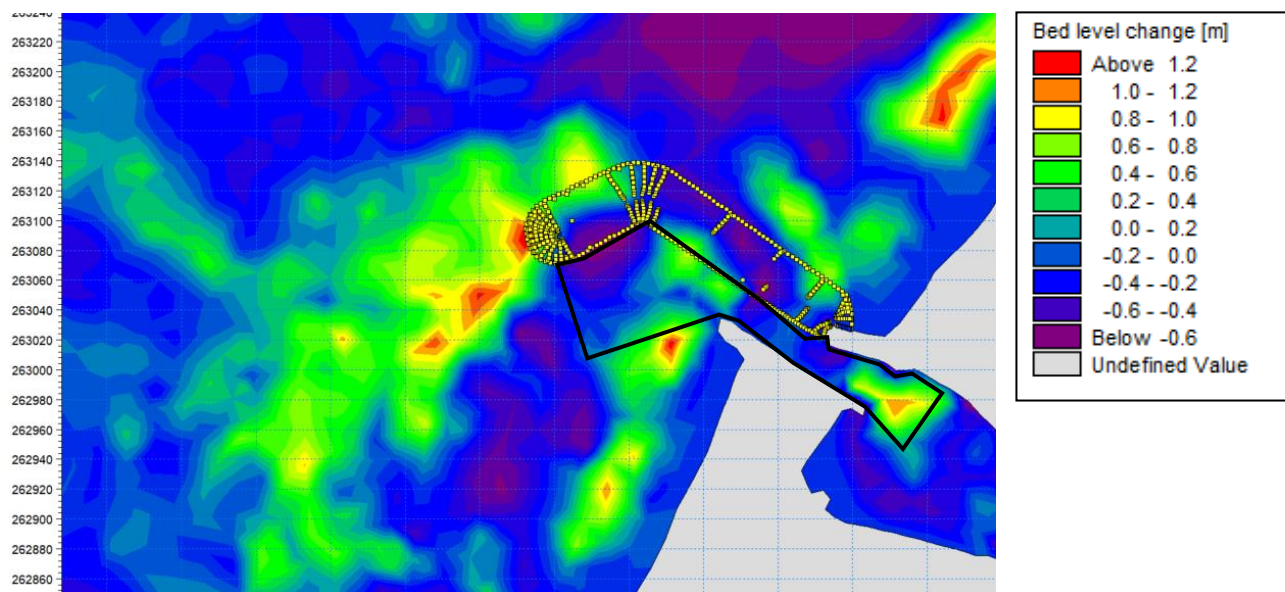


Figure 3-6 - Bed level change difference plot at Area E

## 4. Conclusions

The following conclusions are presented based upon the sediment transport modelling undertaken to date:

- The presence of the breakwater would alter sea-bed levels local to the structure compared to the baseline conditions, with the Sabellaria Alveolata reef and other protected areas having both sediment deposition and removal.
- The navigable channel has been predicted to increase in bed level in the model, although the effects of this will be significantly reduced with the flow of the River Aeron reducing sediment deposition along this channel. Further investigation may be required to quantify the effect of the river flow on sediment deposition in the channel.

A full assessment of the effect of the proposed breakwater on the Sabellaria Alveolata reef and protected areas will be presented in the Environmental Impact Assessment.

## 5. References

- [1] Natural Resources Wales, “GN041. Marine Physical Processes Guidance to inform Environmental Impact Assessment (EIA),” 2020.
- [2] Pye, K., Blott, S., Brown, J, “NRW Report No 208. Advice to Inform Development of Guidance on Marine, Coastal and Estuarine Physical Processes Numerical Modelling Assessments,” Natural Resources Wales, Cardiff, 2017.
- [3] Brooks, AJ., Whitehead, PA., Lambkin, DO., “NRW Report No 243. Guidance on Best Practice for Marine and Coastal Physical Processes Baseline Survey and Reporting Requirements to inform EIA of Major Development Projects,” Natural Resources Wales, Cardiff, 2018.
- [4] Atkins, “5182114-ATK-MAR-GEN-RP-C-1033, Aberaeron Coastal Defence Scheme: Options Assessment-Numerical Modelling Report (Rev1),” 2020.
- [5] Met Office, “Met Office WAVEWATCH III Wave Model Hindcast Data,” 2020. [Online]. Available: <https://www.metoffice.gov.uk/research/weather/ocean-forecasting/ocean-waves>.
- [6] Royal Haskoning, “West of Wales Shoreline Management Plan 2,” 2011.
- [7] Hyder Consulting, “Aberaeron PAR,” 2013.
- [8] Atkins, “Technical note: Aberaeron Coastal Defence Scheme – Desk Study Technical Note. Reference 20181465-GEO-NOT-001,” 2018.
- [9] Eco Marine Consultants, “Aberaeron Seabed Survey: Technial report for seabed imaging survey,” 2019.
- [10] Royal HaskoningDHV, “Ceredigion Beach Profile Monitoring Volume 1,” 2013.
- [11] Atkins, “Report on a Ground Investigation at Aberaeron North Beach - SI FR 1.03.,” 2007.
- [12] Atkins, “Environmental Statement, Appendix K,” 2021.

# Appendices



# Appendix A. Bed level change difference plots

Bed level change difference plots for the 12 directional sectors are presented in Figure A-1 to Figure A-12 below. Wave direction is shown by the black arrow at the top left of each plot.

15 Degrees

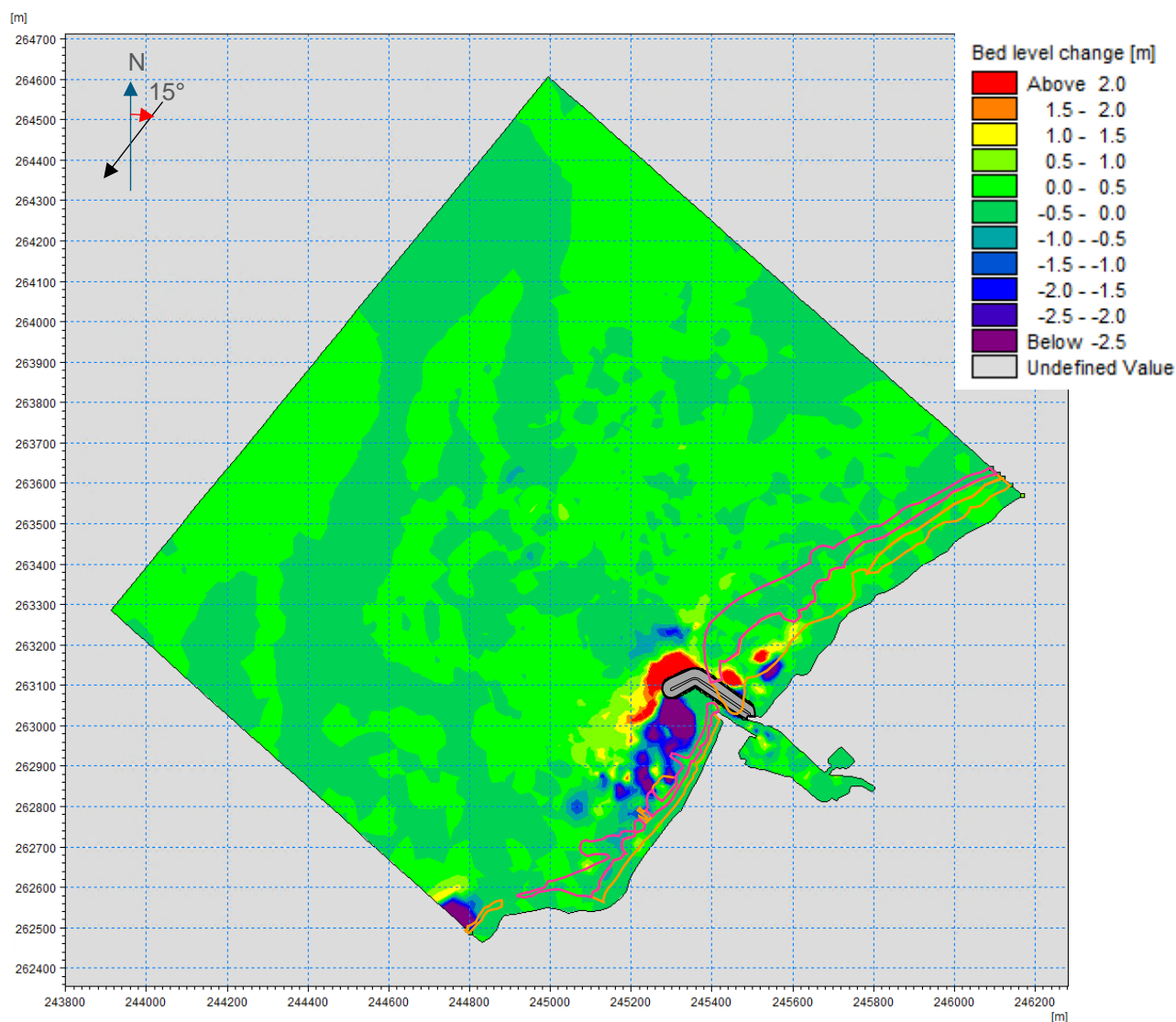


Figure A-1 - Bed level change (m) difference plot for 15-degree waves

45 Degrees

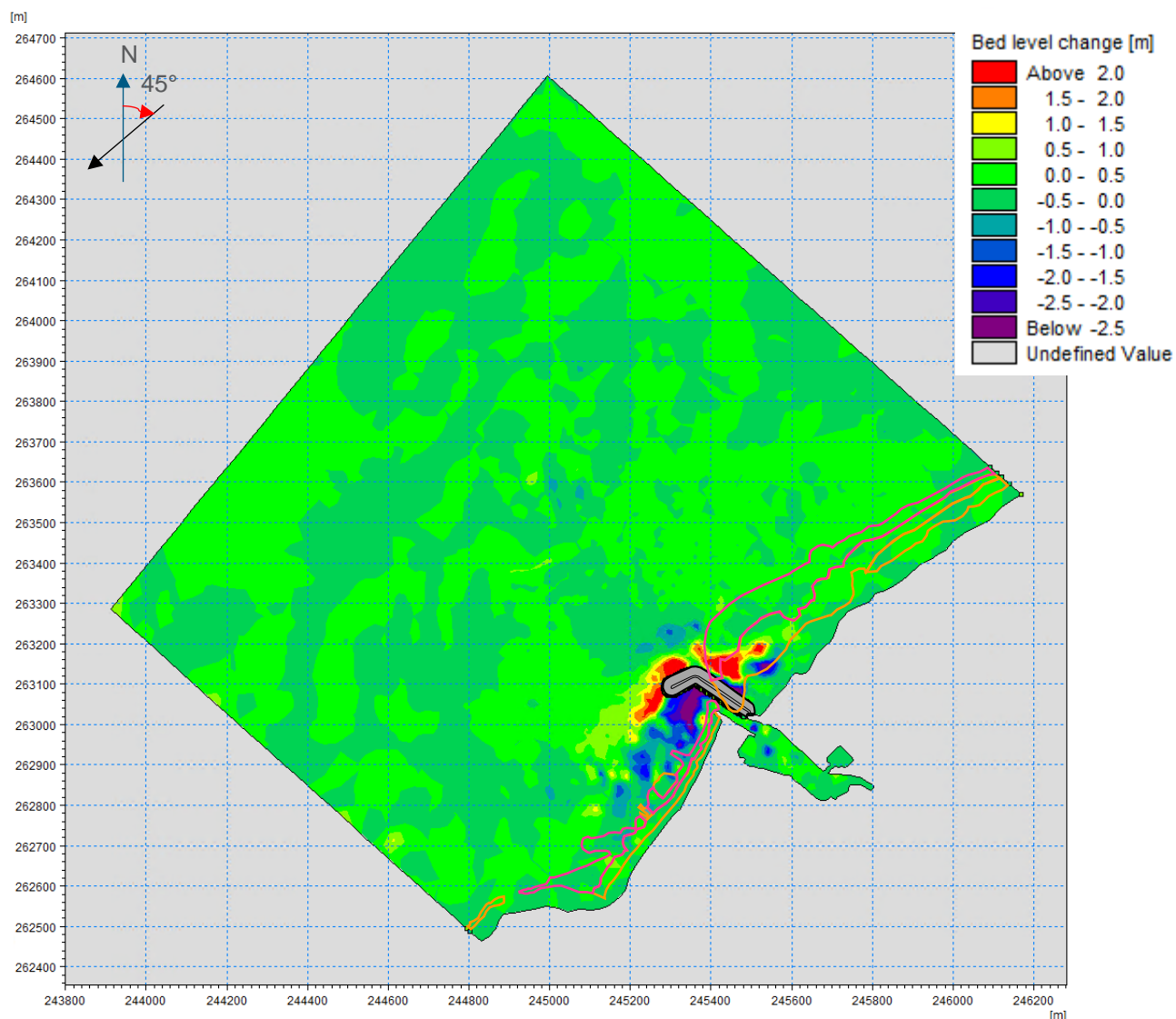


Figure A-2 - Bed level change (m) difference plot for 45-degree waves

75 Degrees

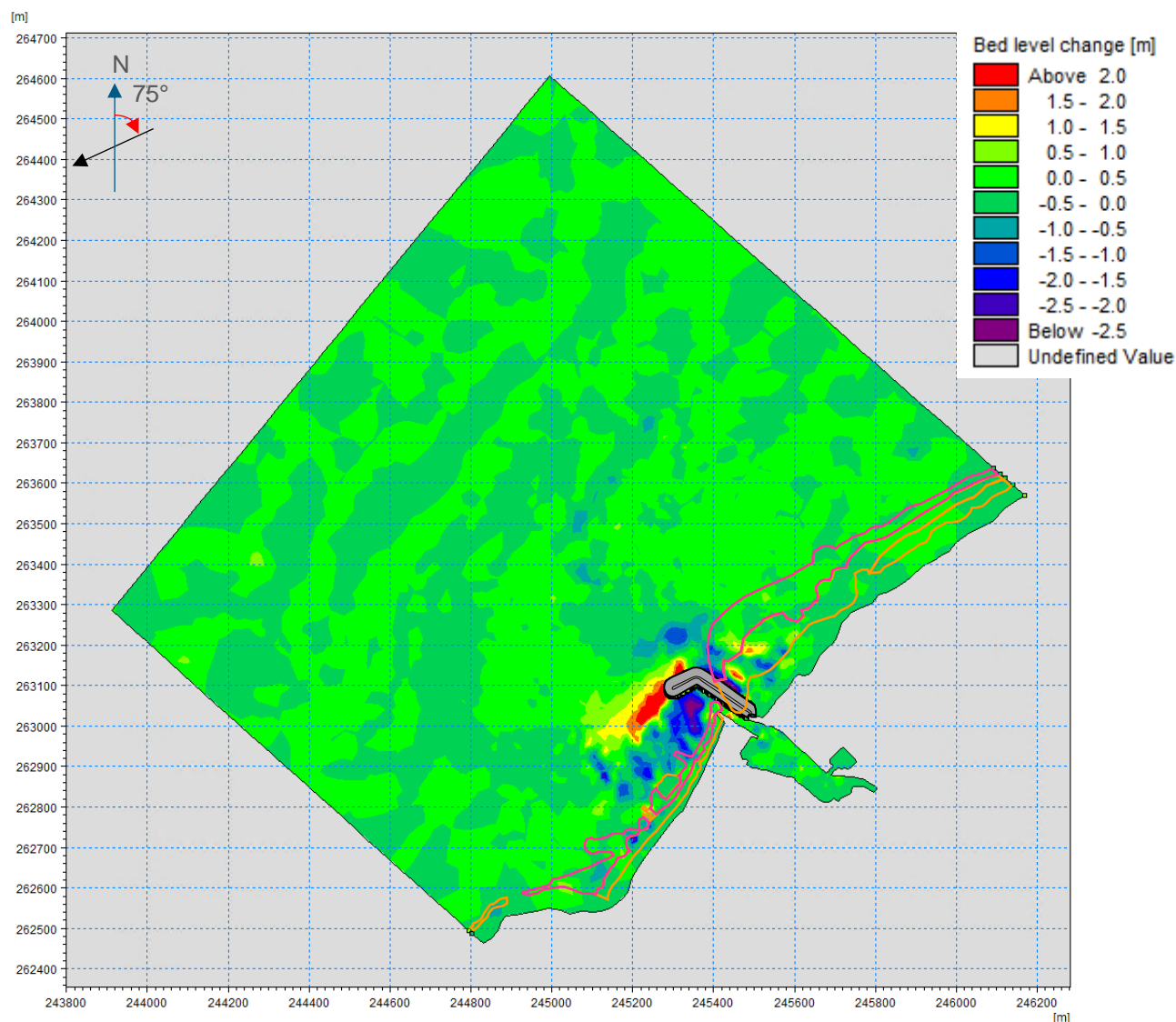


Figure A-3 - Bed level change (m) difference plot for 75-degree waves

105 Degrees

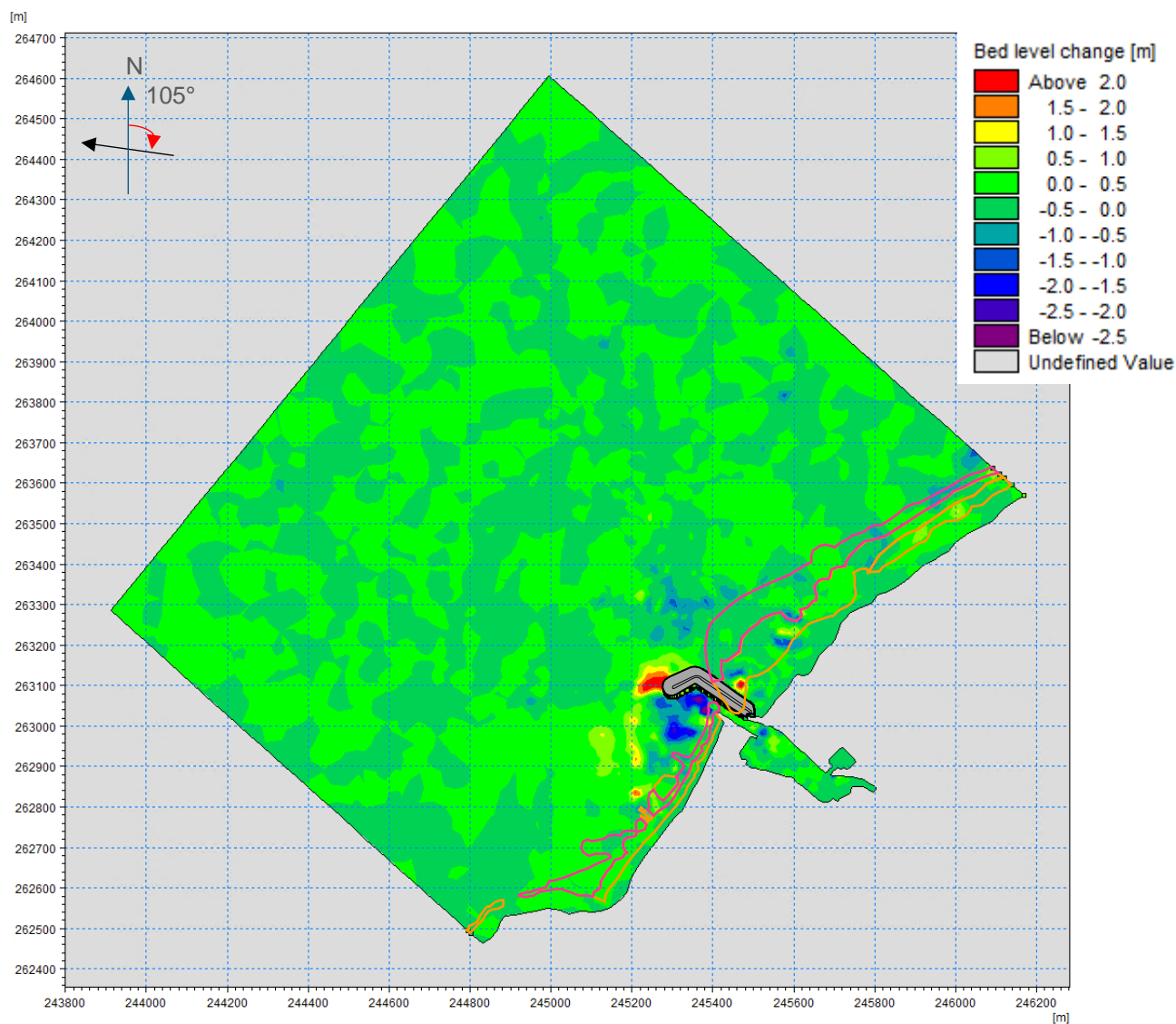


Figure A-4 - Bed level change (m) difference plot for 105-degree waves

135 Degrees

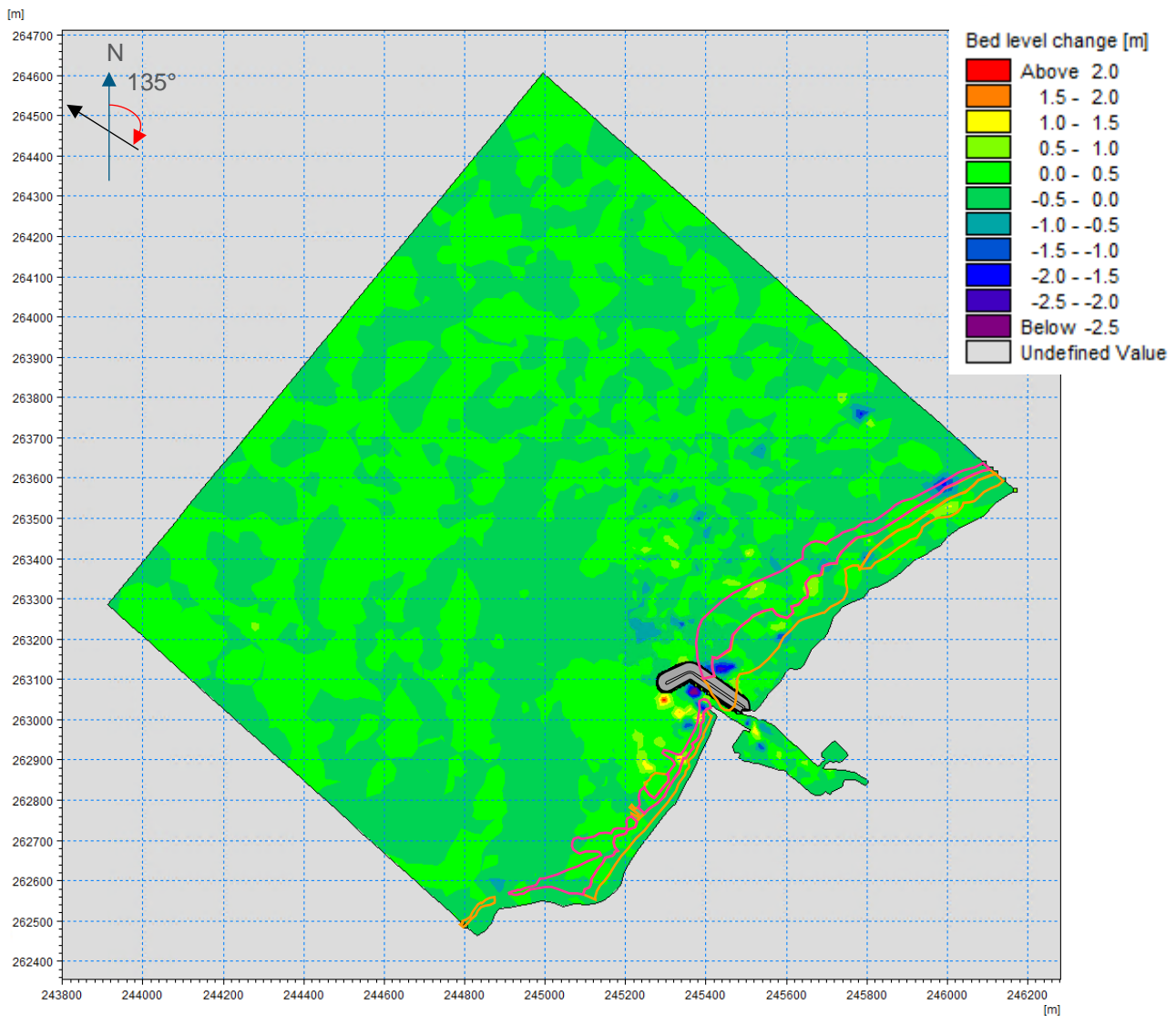


Figure A-5 - Bed level change (m) difference plot for 135-degree waves

165 Degrees

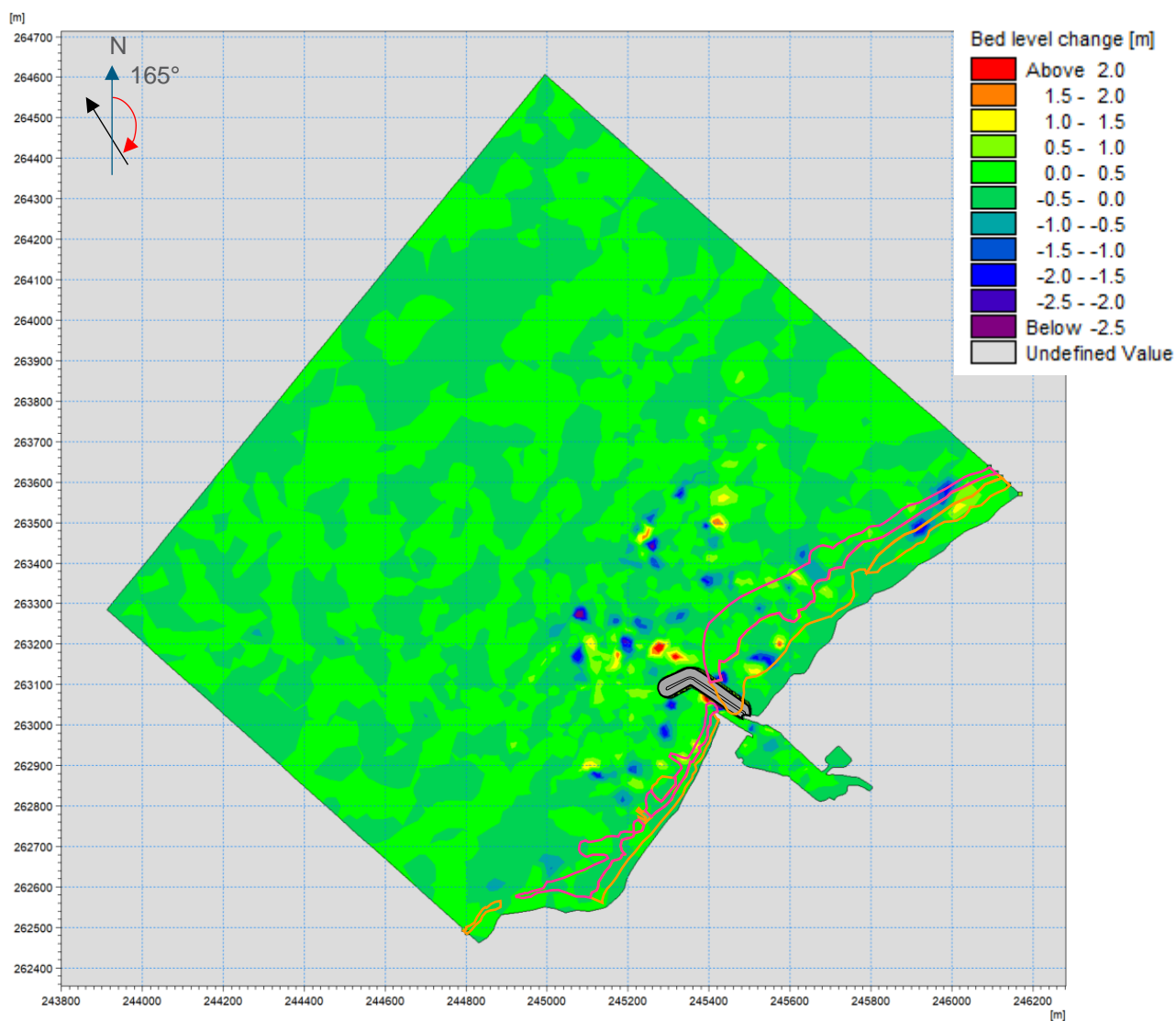


Figure A-6 - Bed level change (m) difference plot for 165-degree waves

195 Degrees

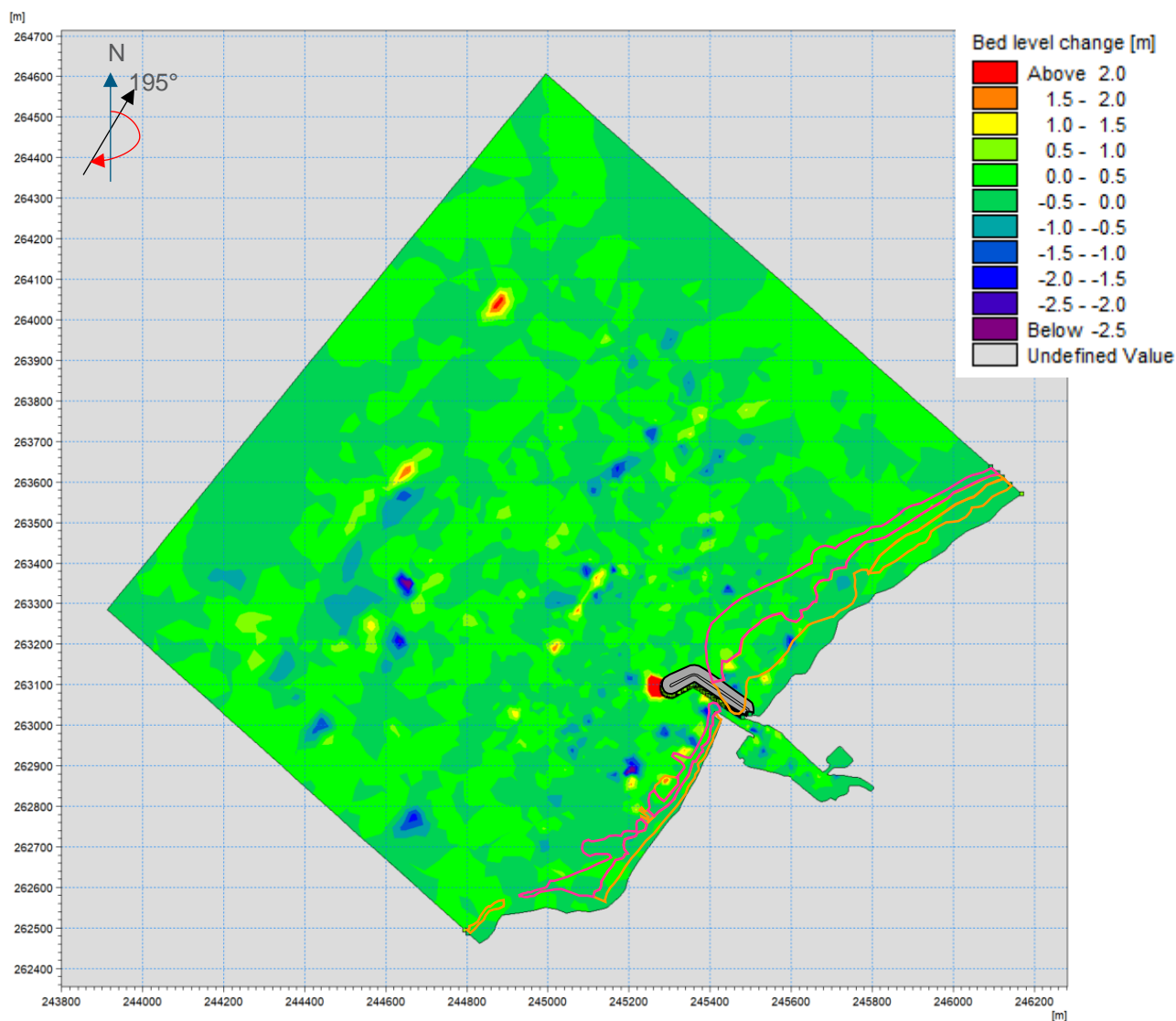


Figure A-7 - Bed level change (m) difference plot for 195-degree waves

225 Degrees

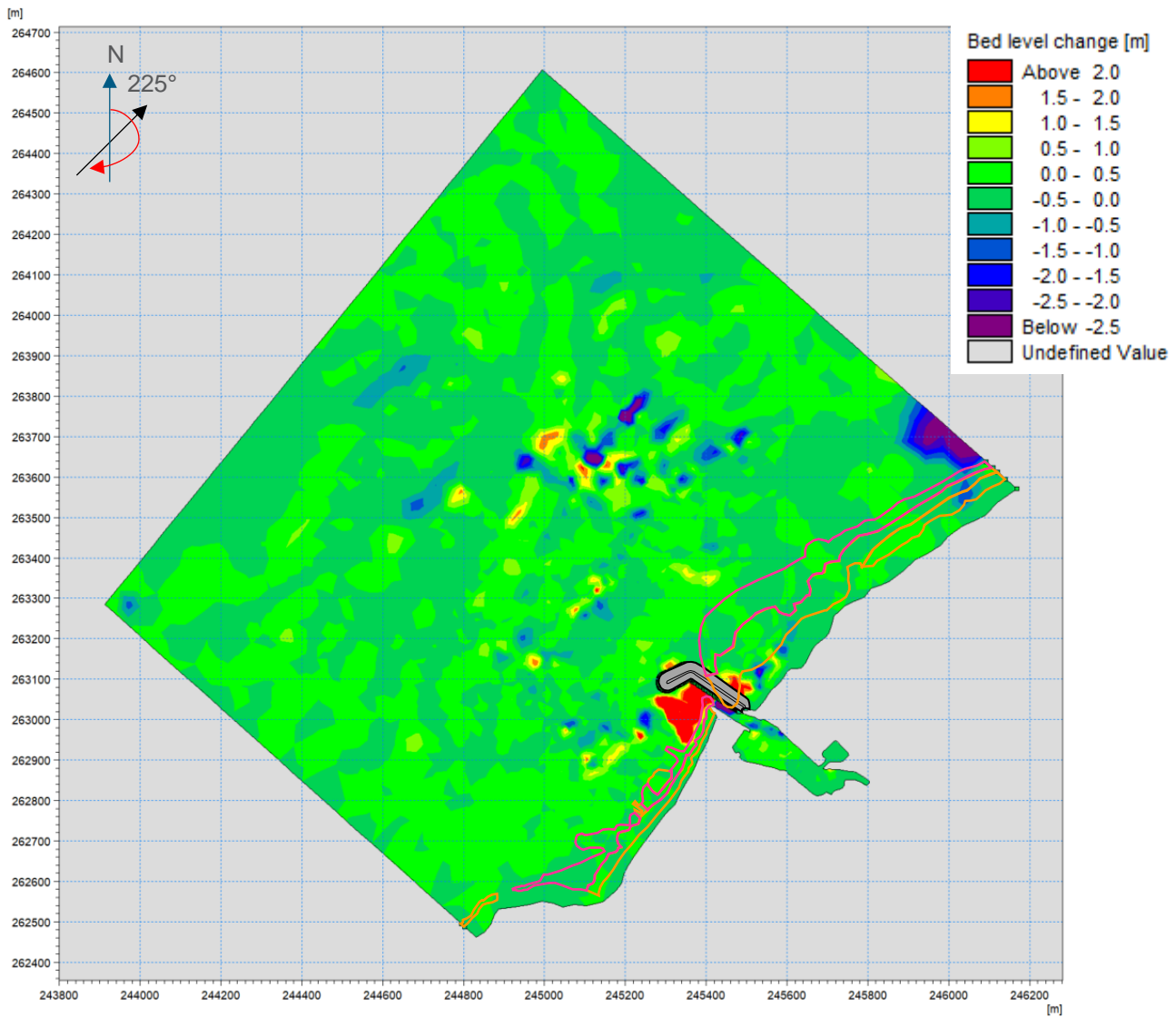


Figure A-8 - Bed level change (m) difference plot for 225-degree waves

255 Degrees

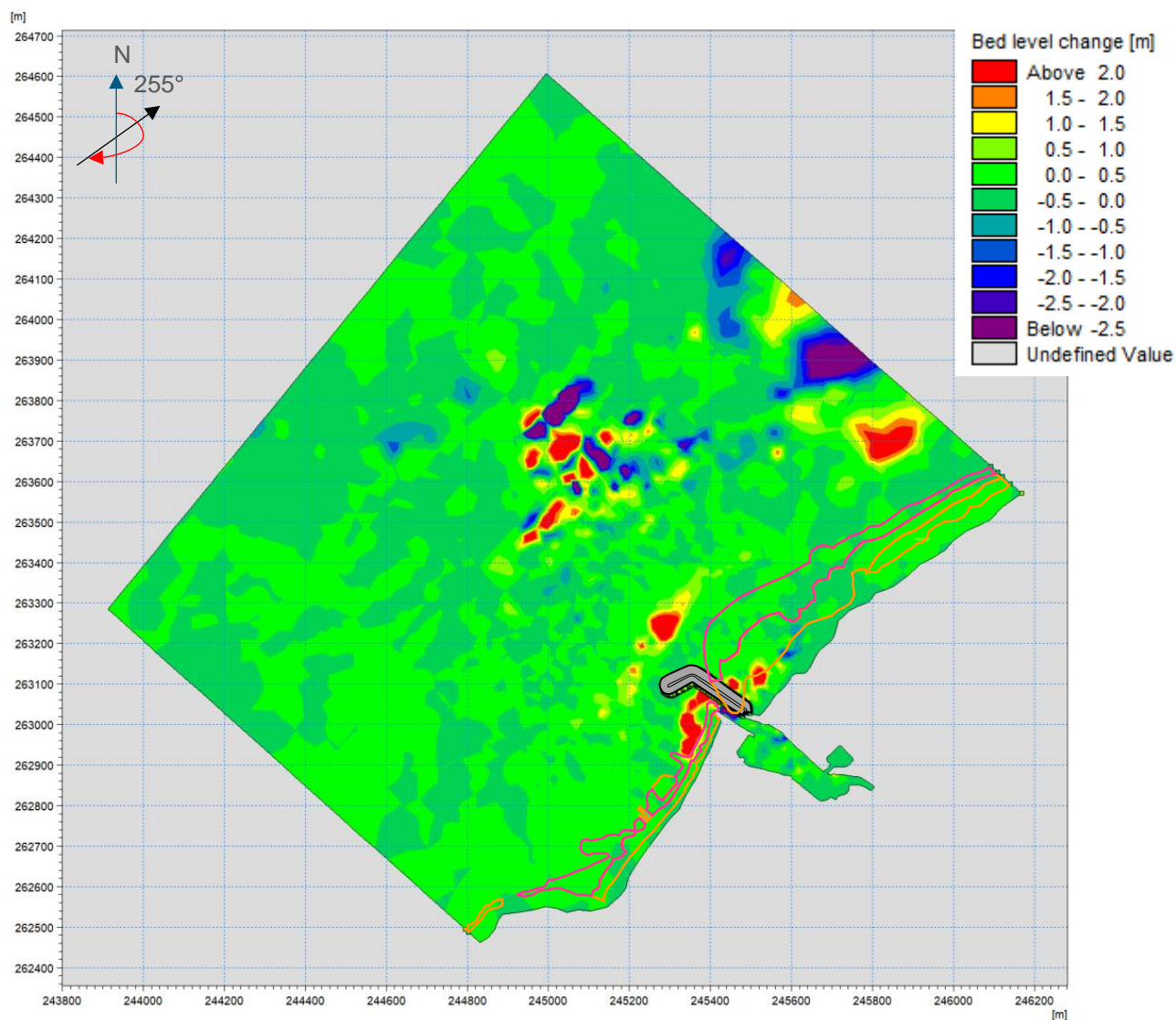


Figure A-9 - Bed level change (m) difference plot for 255-degree waves

285 Degrees

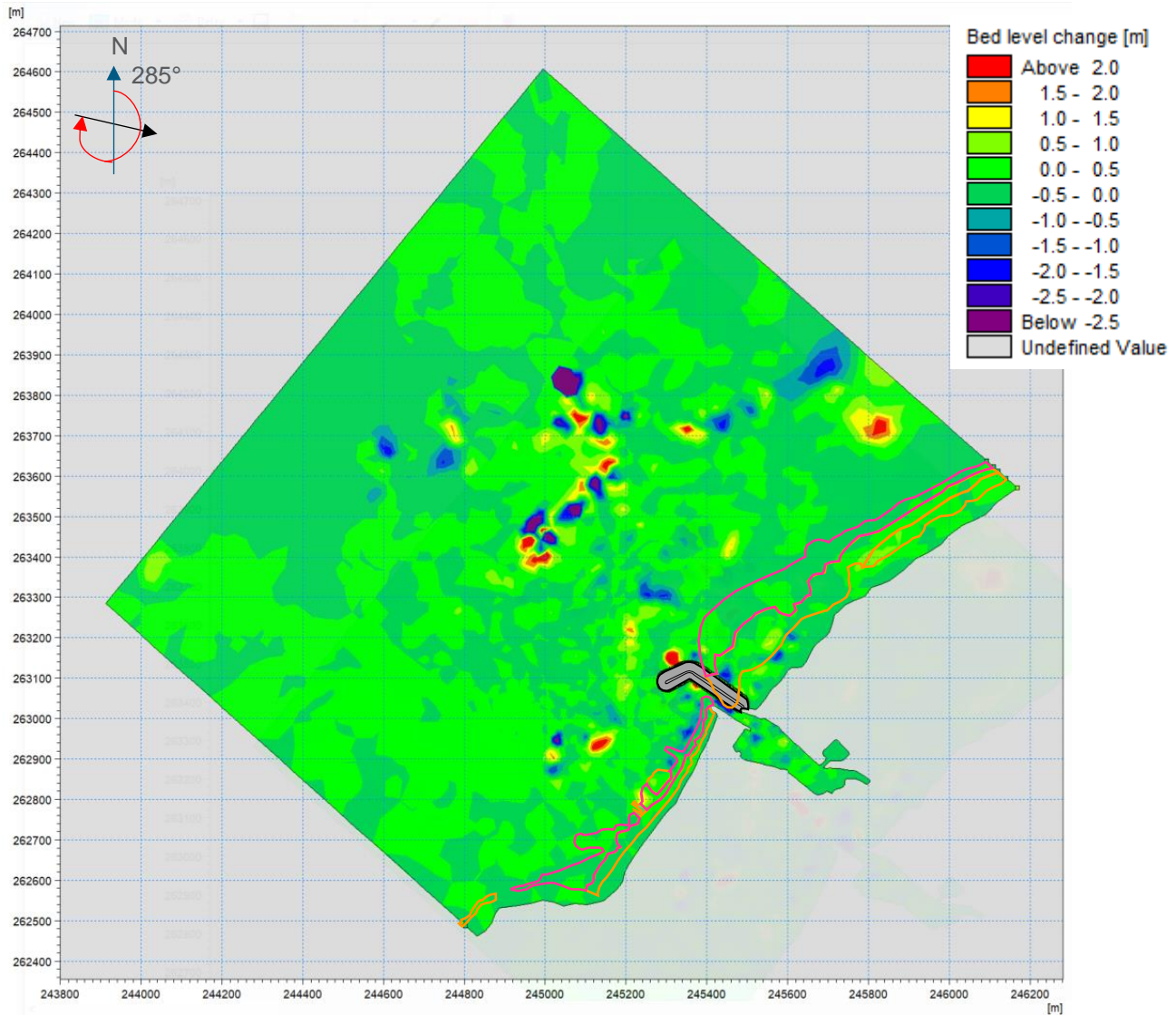


Figure A-10 - Bed level change (m) difference plot for 285-degree waves

315 Degrees

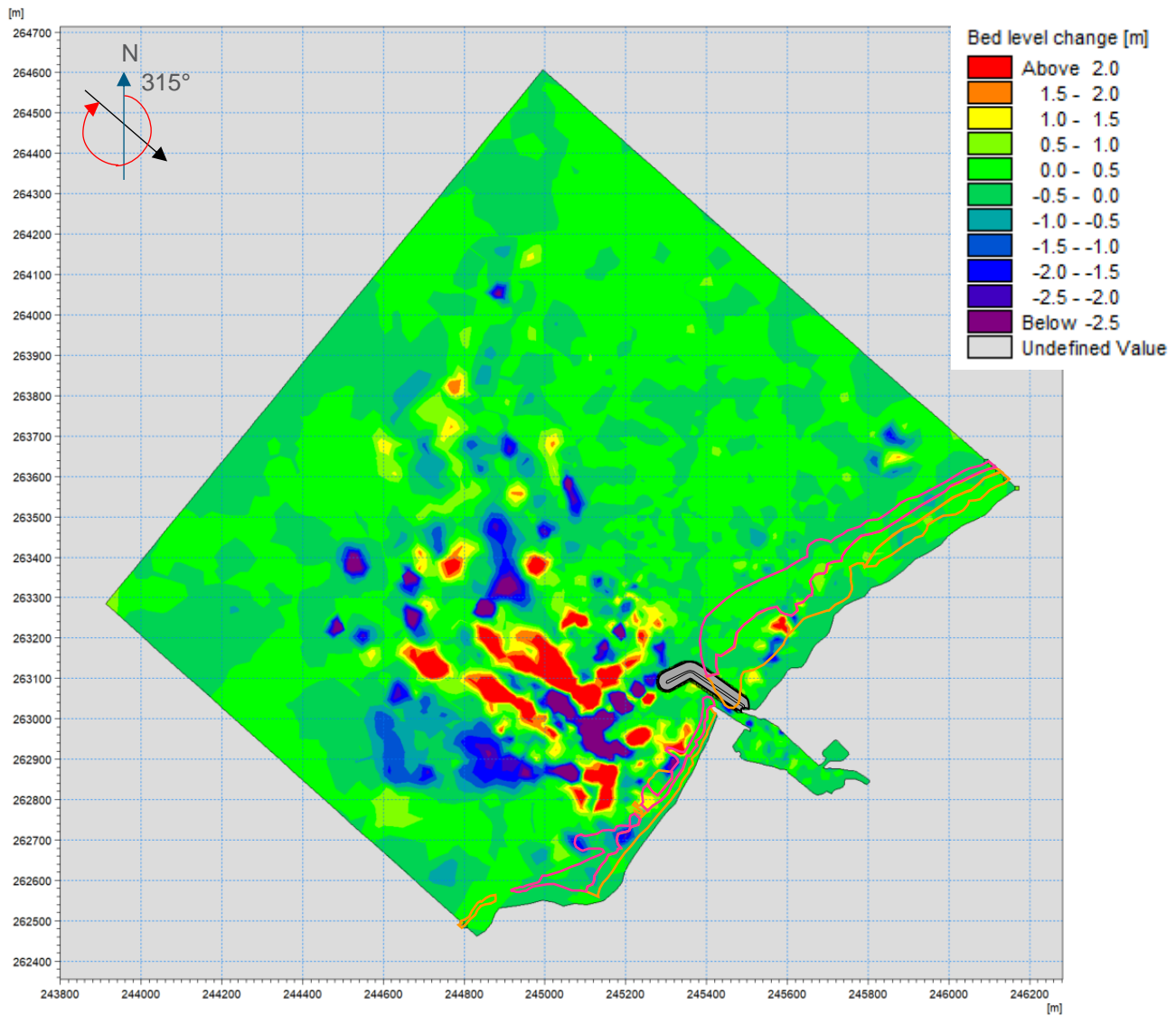


Figure A-11 - Bed level change (m) difference plot for 315-degree waves

345 Degrees

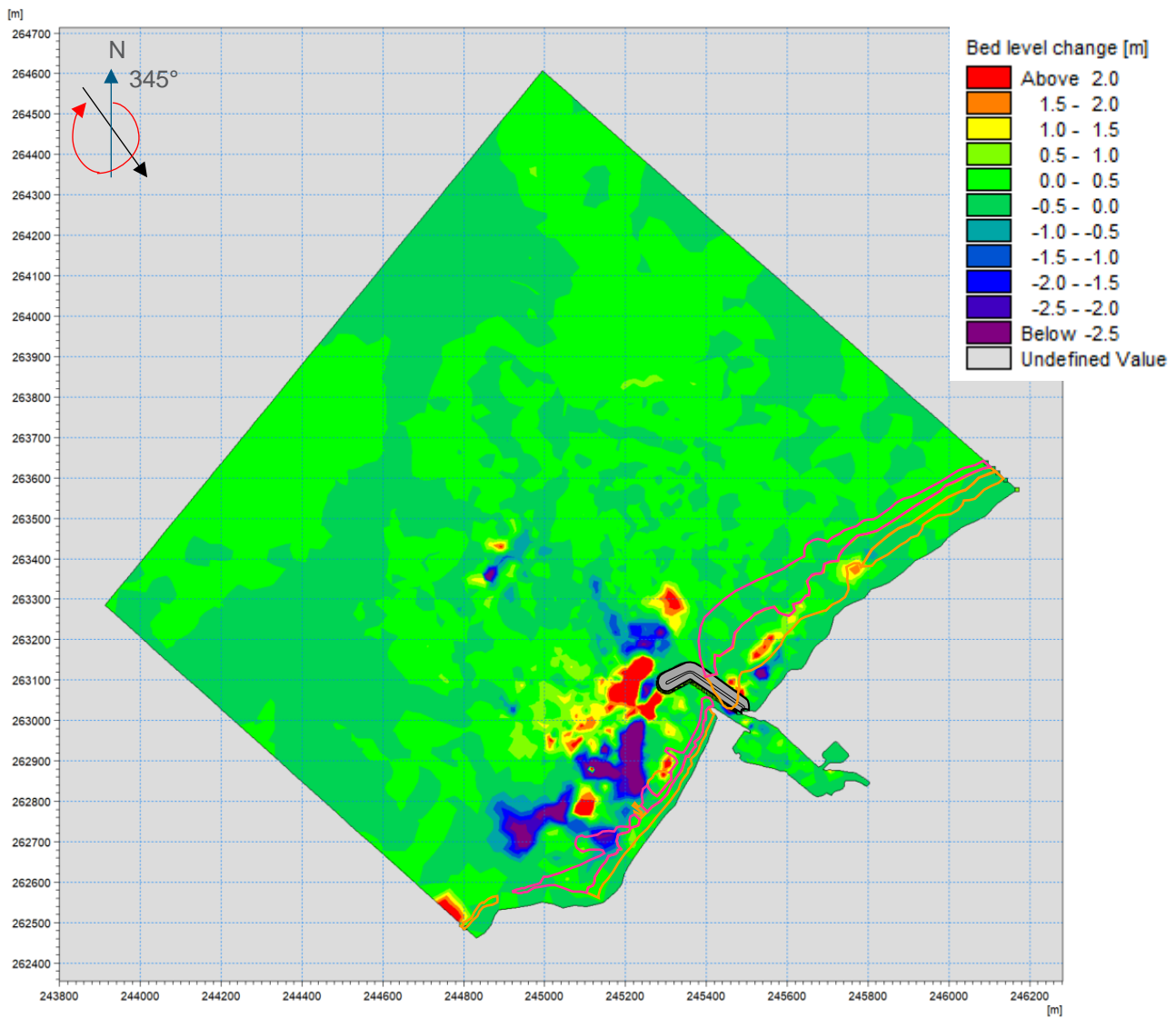
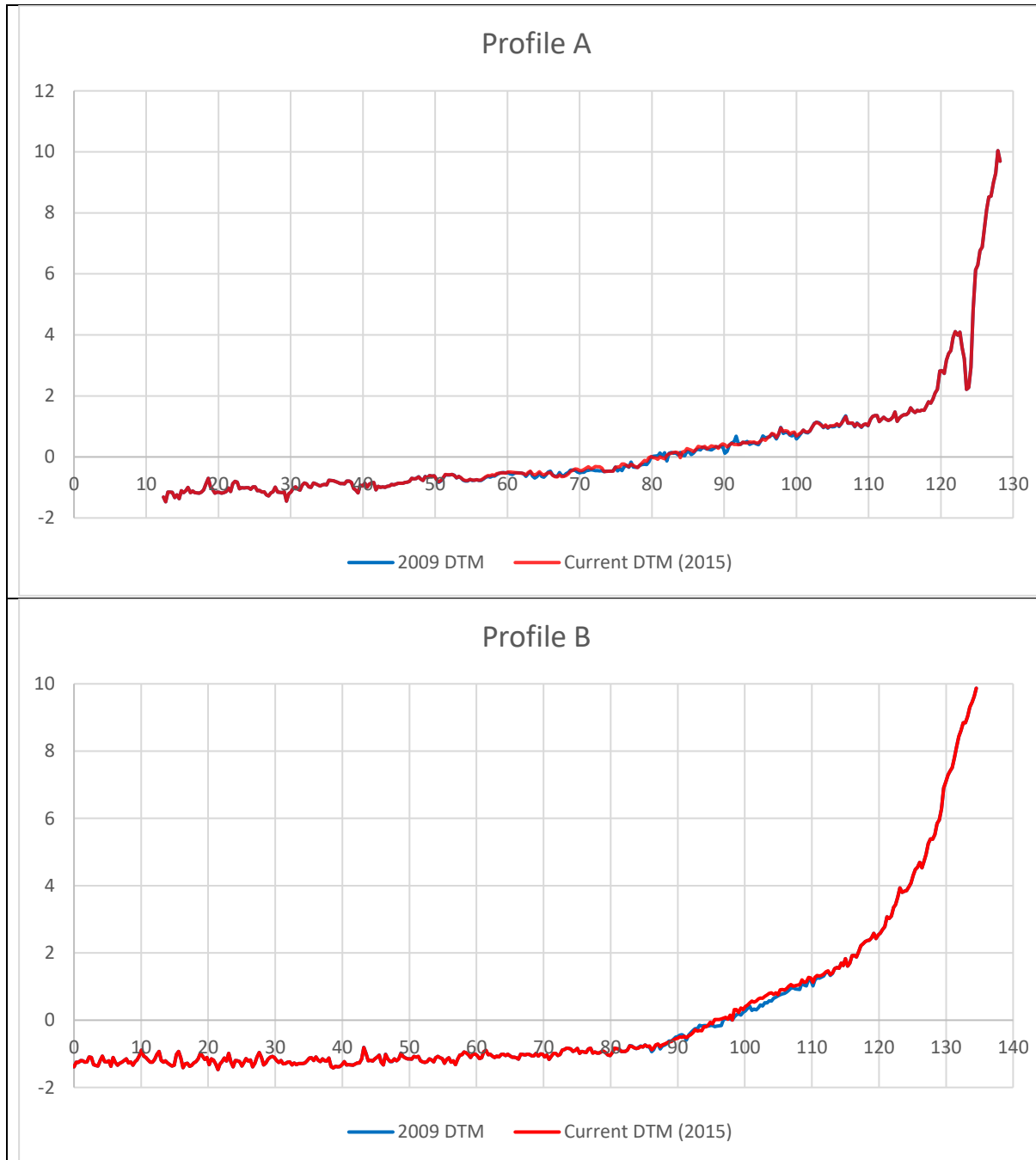


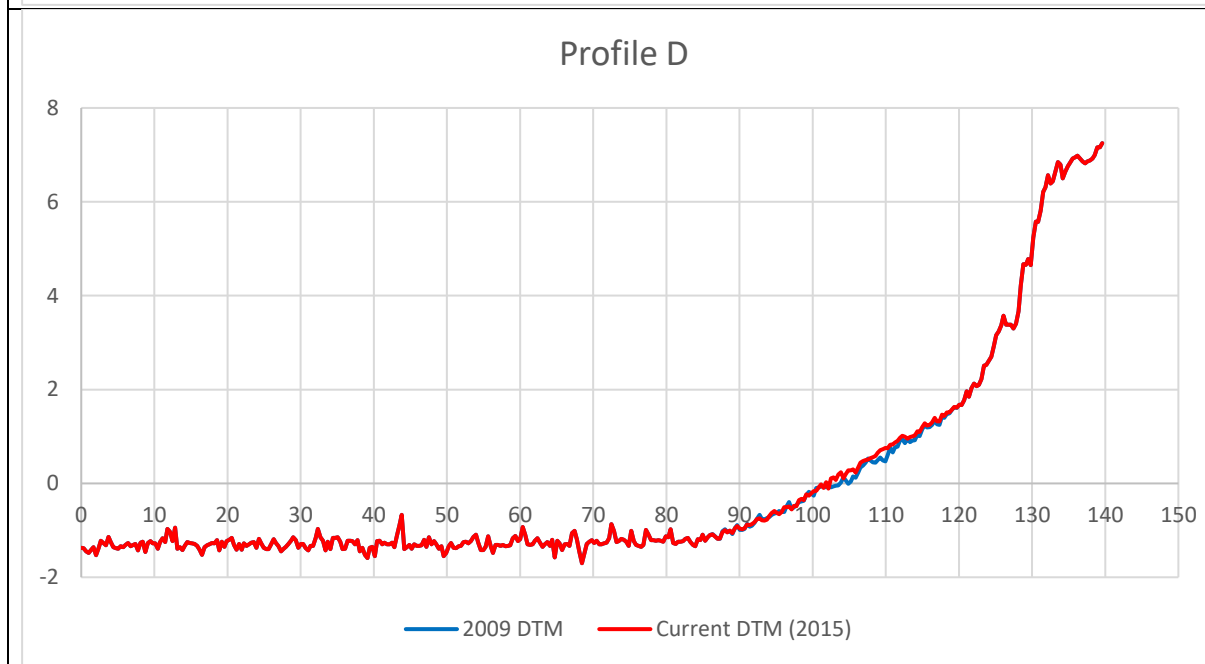
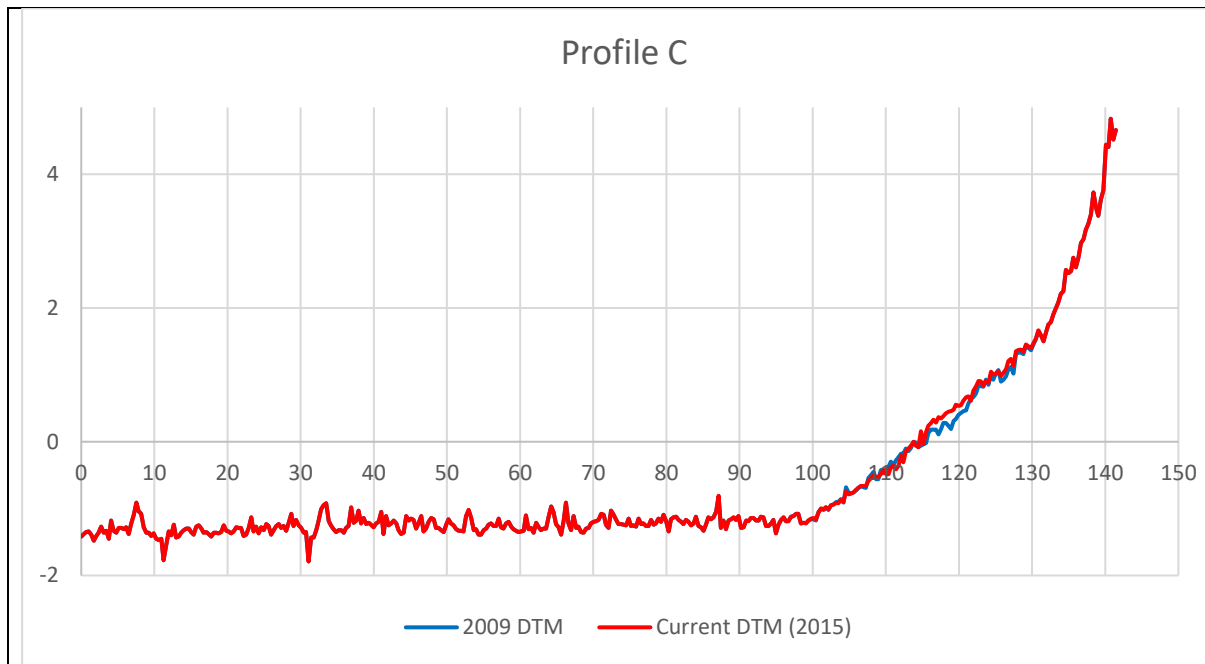
Figure A-12 - Bed level change (m) difference plot for 345-degree waves

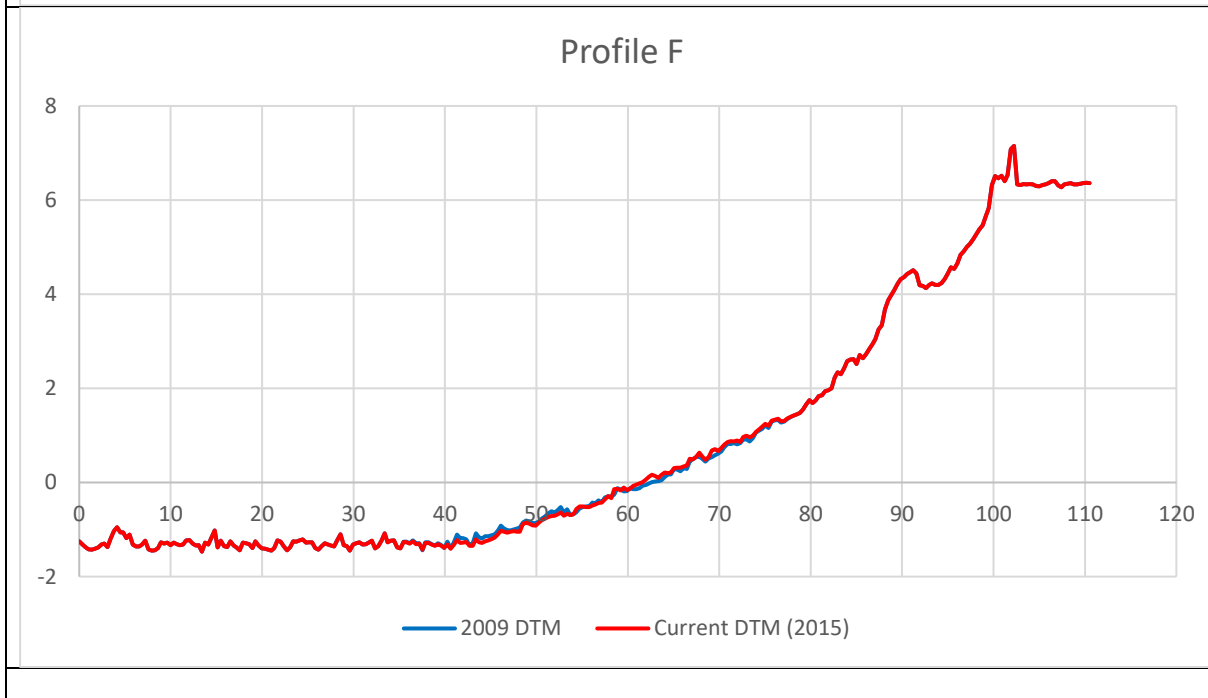
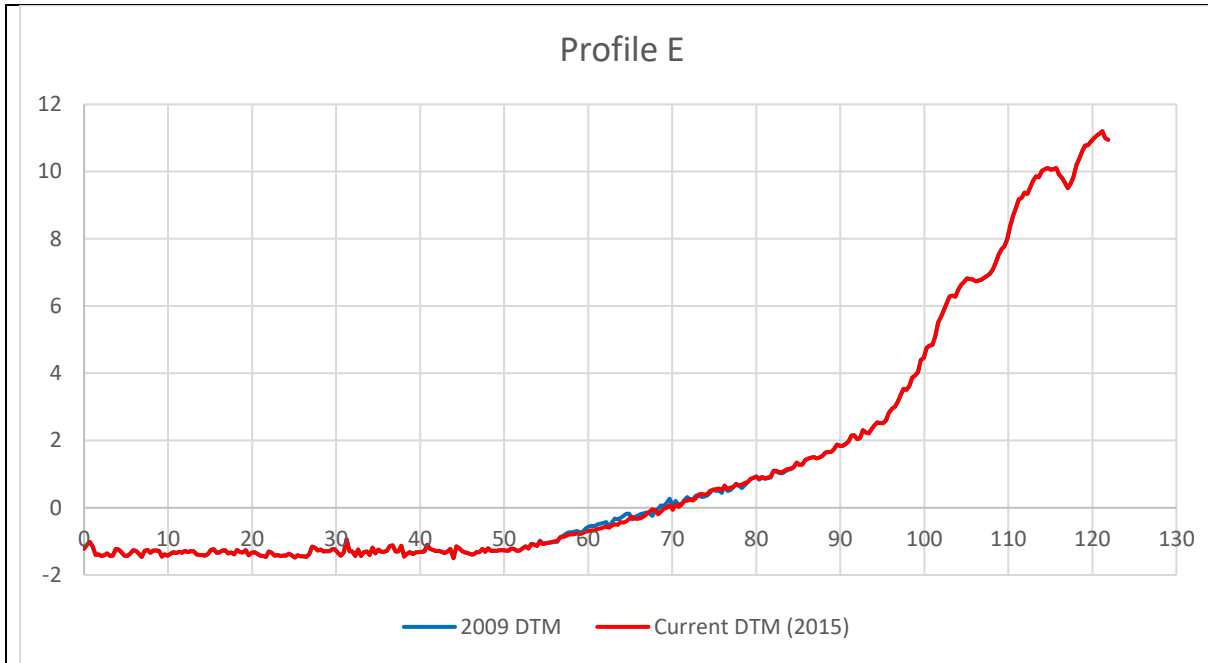
# Appendix B. Historic LiDAR Data Comparisons South Beach

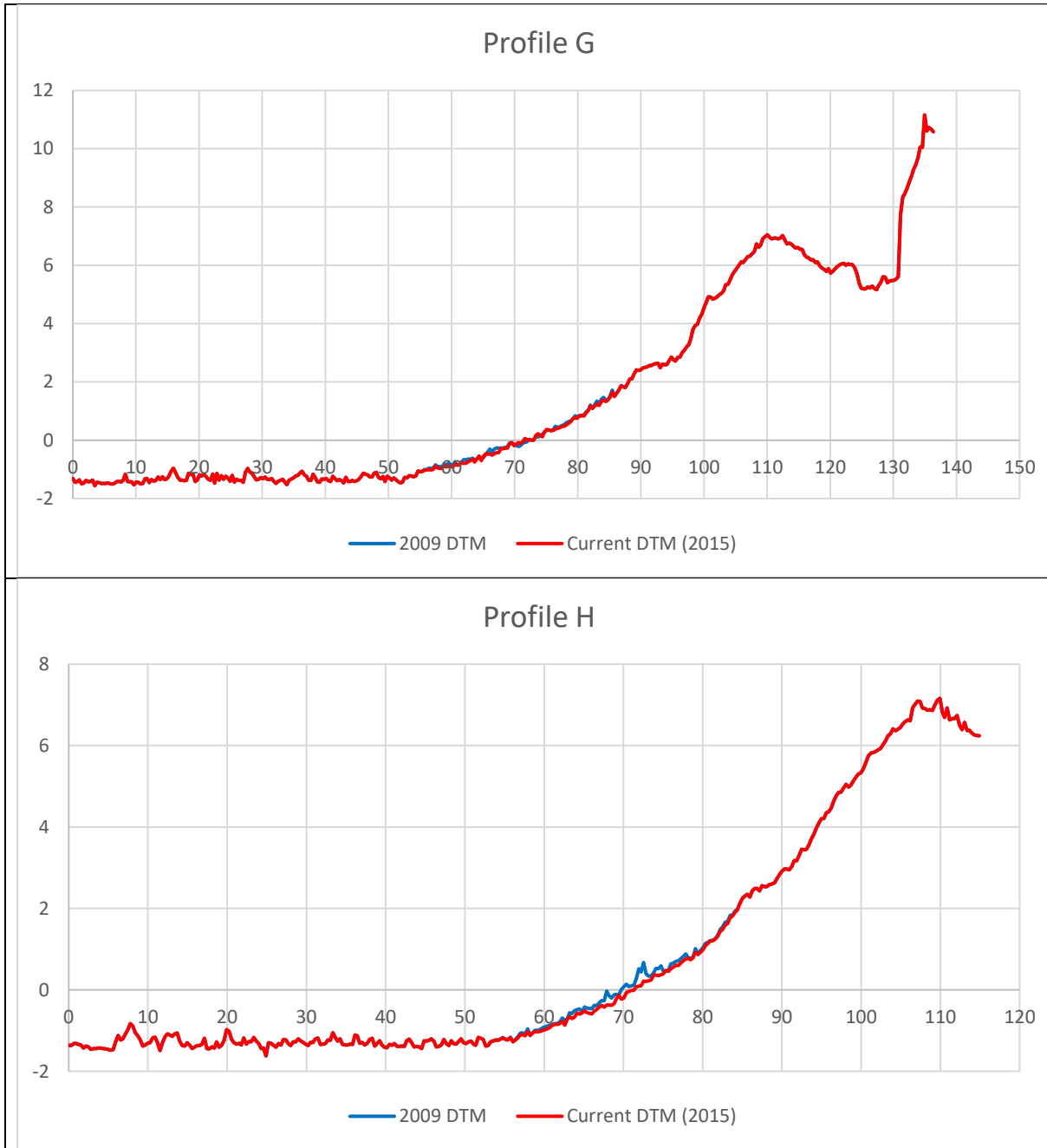


## Profile Comparisons 2009 Digital Terrain Model v 2015 Digital Terrain Model











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