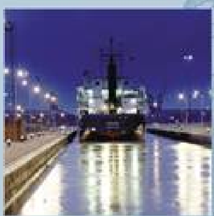
Porthcawl Conceptual Understanding

Porthcawl PAR

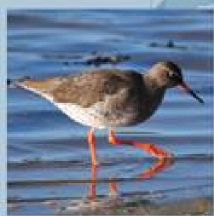
Ove Arup and Partners Limited

January 2017

Creating sustainable solutions for the marine environment







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1 Introduction

1.1 Study

The aim of the project for Bridgend County Borough Council (BCBC) is to investigate options for managing coastal flooding and erosion risk and preparation of a Project Appraisal Report (PAR) at Porthcawl. Improvements in the defences and flood risk are essential to fulfil the Councils' aspirations for regeneration and improved tourism around the Eastern Promenade and Sandy Bay frontages.

ABPmer has been commissioned by Ove Arup and Partners Limited ('Arup') to review the coastal processes to determine the parameters that cause potential flood risk at Porthcawl and within Sandy Bay. An extremes analysis has been completed to determine the volumes of wave overtopping of the defences for different return period events under existing conditions and allowing for 100 year climate change. These results have been provided separately as a series of spreadsheets.

The wave overtopping results are supported with two deliverable documents containing:

- **Process Understanding** (this document) - A summary of the coastal processes affecting the defences and the conceptual understanding of the dynamics of the Bay, particularly with respect to the influence on defences and stability of the beach.

- **Extremes Analysis** (separate document, ABPmer 2017) **-** A technical note which sets out the modelling results for the wave, water level and wave overtopping criteria for various sections (defined from the analysis) of the two frontages.

This analysis and associated documents provide input information for the assessment of the existing situation, the flood inundation modelling of extreme events and the development of protection options.

1.2 Coastal flood risk

With increasing pressures on the coastal zone, sustainable management of coastal flooding is becoming increasingly important. Contributing factors to coastal flooding such as Sea Level Rise (SLR), storm surge levels, tidal heights, wave heights, wind speeds and existing coastal defence structures all are highly variable both spatially and temporally. Gaining a fundamental understanding of the physical process interaction with the shoreline is key to providing accurate flood risk analysis such as wave overtopping rates and inundation levels, as well as identifying the risks of coastal erosion and defence failure due to beach lowering.

Whilst coastal flooding can also result from fluvial activity, the location of Porthcawl is a sufficient distance (approximately 4 km) from the nearest estuarine system, the River Ogmore, not to have an influence. The commissioned work is limited to coastal flood risk.

2 Site Description

2.1 Sandy Bay, Porthcawl

Sandy Bay is an approximately 700 m wide south south-west (SSW) facing coastal embayment located between Port Talbot and Ogmore-by-sea. The Bay is surrounded by a mixture of commercial and residential development, with Porthcawl town to the immediate north and west of the Bay, and a large holiday caravan park at Trecco Bay to the east.

Sandy Bay consists of a mixture of hard defence structures and natural frontages. For the purpose of both the conceptual understanding and the additional modelling analysis, Sandy Bay can be broadly summarised as having seven differing sections (Figure 1):

- The Porthcawl Harbour Boating Club, with a defence facing angle of 102 degrees. This lies directly in the lee of the main breakwater. The defence is a steeply back sloping near vertical wall, with a vertical flood wall at the crest at a height of 6.66 mODN.

- The eastern breakwater to Porthcawl Marina, extending due north inside of the main breakwater (Western Breakwater) for around 100 m and contains the existing marina. The defence is a steeply back sloping near vertical wall, with a vertical parapet at the crest at a height of 7.50 mODN with a facing angle of 88 degrees.

- The southeastern promenade to Porthcawl, connecting to the Eastern Breakwater. The defence is a steeply back sloping near vertical wall, with a vertical parapet at the crest at a height of 8.15 mODN with a facing angle of 116 degrees.

- The eastern promenade to Porthcawl, a 400 m stretch of seawall that runs north-to-south for around 400 m between the harbour immediately to the north of the marina, and the amusement park. Behind the promenade are the infilled remnants of the old inner harbour. The defence is a steeply back sloping near vertical wall, with a facing angle of 112 degrees and vertical parapet at the crest at a height of 9.00 mODN.

- The central section, of which the upper beach is backed by Coney Beach Amusement Park. The amusement park is defended by various private seawalls and revetments, including steeply sloping quarried stone and cement structures with a grass topped crest at crest elevation of 7.99 mODN, concrete stepped revetment style defence with a crest elevation of 8.66 mODN, and a smooth concrete slip way with a crest level of 7.35 mODN. Facing angles of these structures are around 182 degrees. These extend due east along the upper beach of Sandy Bay for around 350-400 m, merging into the relic dune system.

- The east side of the Bay contains a relic dune system, with barely vegetated land immediately behind which was a former campsite. This dune system rotates in an increasingly southerly direction for around 300 m and is partially defended at the eastern toe extent with rubble. These then lead southeast out to a limestone raised shore platform known as Rhych Point, which contains a viewing tower. The point has previously been stated to be importance in maintaining the overall shape of the Bay (Halcrow 2005).

2.2 Shoreline management policy

The study area lays within the Lavernock Point to St Anne's Head Shoreline Management Plan (SMP) Area 7. The SMP long term plan for Area 7 is to 'reduce the risk of coastal erosion and flooding to the developed area and various amenity and tourist facilities of Porthcawl subject to future availability of public funding for coastal erosion and flood risk management ' (Halcrow 2012). The plan within the specific policy unit containing Sandy Bay is as follows:

- Unit 7.3: Rhych Point to Porthcawl Point (Sandy Bay). The policy is hold the line by maintaining and upgrading existing defence structures throughout the short and medium term epochs subject to future availability of public funding.

Source: Google Earth, 2015. Map data ©2016 Google. Image © 2016 Terrametrics. Data © SIO, NOAA, U.S. Navy, NGA, GEBCO

Figure 1. Aerial photography of Porthcawl and Sandy Bay

3 Process Understanding

This section provides a detailed description of the marine and coastal physical processes within and around Sandy Bay. This characterisation forms the basis from which appraisal assessments of potential defence options can be carried out. The focus of the baseline has been tailored towards providing sufficient detail to support the options appraisal. Of particular interest are the water levels and local wave climate which will directly interact with coastal defence structures and the resulting wave overtopping (analysed and reported separately) during extreme events. This baseline understanding also informs options appraisal for reducing coastal flood risk.

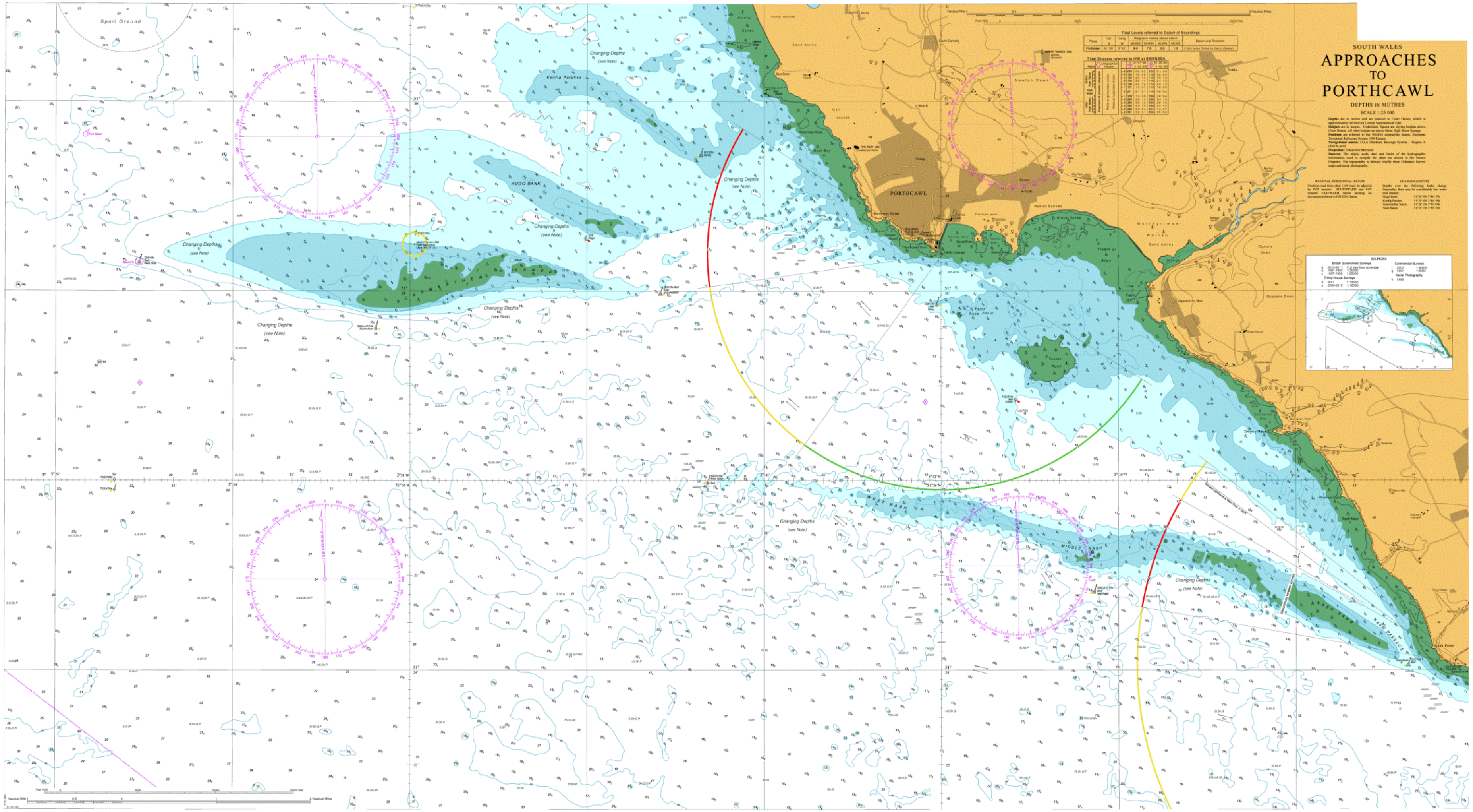
3.1 Offshore seabed description

The Bristol Channel is relatively deep, with maximum depths of approximately 60 m near its entrance. Depths decrease eastwards to about 20 m near Lavernock Point. A shallower shelf area, ranging in width from 4.5 to 20 km, extends along the northern side between the Gower Peninsula and Lavernock Point. Much of the Inner Bristol Channel sea floor lacks accumulated sediments due to the strong tidal currents. Areas of slightly muddy sands occur in northern Swansea Bay (British Geological Survey, 1986; Pantin, 1991). The thickness of sediments is generally less than 10 m (Pye & Blott, 2009).

The sediment regime of the Bristol Channel is an ebb-dominated system (Halcrow 2005). The resulting net sediment transport is westwards in the centre of the Bristol Channel with a circulation within Swansea Bay.

Out in the Bristol Channel the coarse grained sediments form low amplitude dunes and mega-ripples. The medium to fine sand exhibit either higher amplitude dunes or plane bed features. The bed morphology that occurs is dependent on the local near-bed current speeds (Collins, 1993). The principal sediment source is the reworking of Quaternary sediments in the offshore zone. Large quantities of finer sediments (mud and fine sand) are supplied to the Bristol Channel by the rivers (mainly the River Severn) and supplemented with coastal cliff erosion (Pye & Blott, 2009).

Offshore of Porthcawl the seabed morphology is determined by three large linear sand banks called Nash Bank, Scarweather Sands and Tusker Rock. These are oriented east-west direction and extend seawards from headlands at Nash Point, Porthcawl and Ogmore-by-Sea respectively, reducing the general seabed depths by between 10 and 20 m (Figure 2 and Figure 3).



Source: UKHO , 1999

Figure 2. UKHO chart of Porthcawl, including offshore sandbanks at Scarweather/Tusker Rock/West Nash

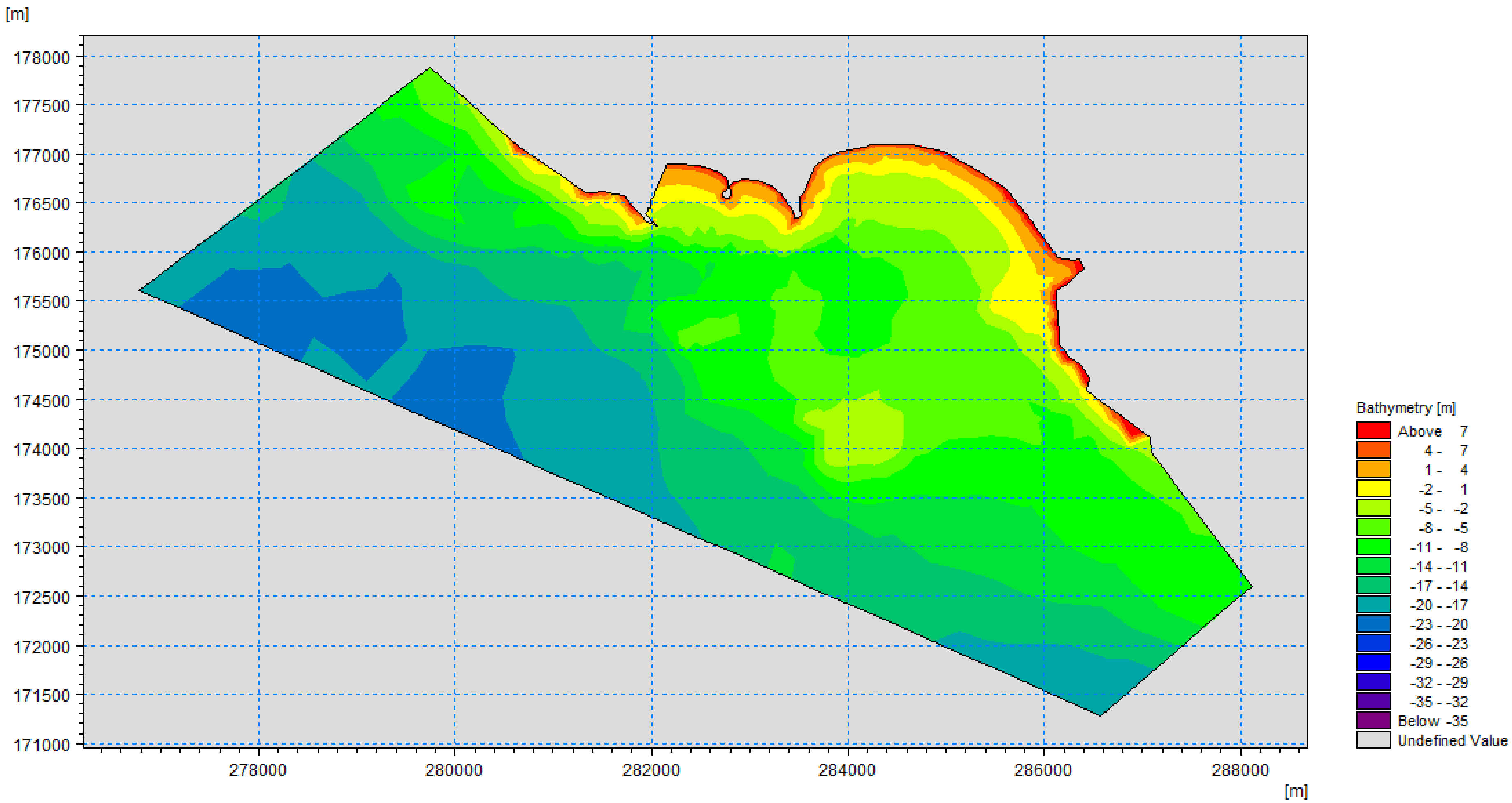


Figure 3. **Local bathymetry at Sandy Bay (ABPmer SEASTATES model bathymetry (mODN))**

3.2 Coastal description and morphology

3.2.1 Coastal description

The fundamental geomorphological character of the South Wales coast is controlled by resistant rock outcrops. The outcrops give rise to a series of headlands, sections of cliffed coast with intertidal shore platforms, and intervening Bays backed by sandy beaches and dunes (Pye 2009). This is the case of Sandy Bay, Porthcawl; however the natural processes occurring within the Bay are modified due to the construction of an approximately 180 m long Western Breakwater south-eastwards from Porthcawl Point, which provides protection from waves into the west side of the bay.

Several historic developments have been made to the harbour at Porthcawl within the last 200 years. The inner harbour was constructed in the mid nineteenth century (Halcrow 2005), replacing the original outer harbour (of which is now filled in and accommodates a car park behind the eastern promenade). A redevelopment of the inner harbour was undertaken in 2013 to install a new lock gate in order to provide an all-tide facility, which now provides protection from waves within the inner harbour.

3.2.2 Sandy Bay morphology

Sandy Bay is a small intertidal embayment infilled by a wide, shallow (1:50) gradient sandy beach with depths over 7 m above chart datum (mCD) near the upper beach in front of the central section. This shallow beach results in an extensive breaker zone. The intertidal consists predominantly of sand with gravel deposits located high on the foreshore (Halcrow 2005). The area behind the beach forms part of a dune system that extends 1 to 3 km inland (Pye 2009) but has been heavily modified to the west side of the bay behind man-made sea defences (Halcrow, 2005). This dune system consists mainly of dunes and sand sheets, with localised development of fore dune ridges and hummock dunes (Halcrow, 2012). The sediment within the dunes is largely relict; however an active interchange exists between the beach and the dunes, with the eastern-most dune toe protected from scour by a combination of gravel and rubble revetment around 10 m wide.

Between the 1970s and the caravan parks closure in 1998 the eastern dune system had undergone intense management, including the levelling of the dune crest and steepening of the face according to historical photography (Figure 4) with accumulation of sediment at the dune face. Since the closure of the caravan park in 1998 the management has ceased and the ‘soft’ sand that accumulated at the toe has been removed. This exposed the underlying relic dune. The most recent photograph shows that the dune face has reverted to a shallower, more natural gradient (Figure 4 and Figure 7). Currently accumulations of wind-blown sand and evidence of trample erosion at levels well above HAT are present in line with previous findings (Halcrow 2005).

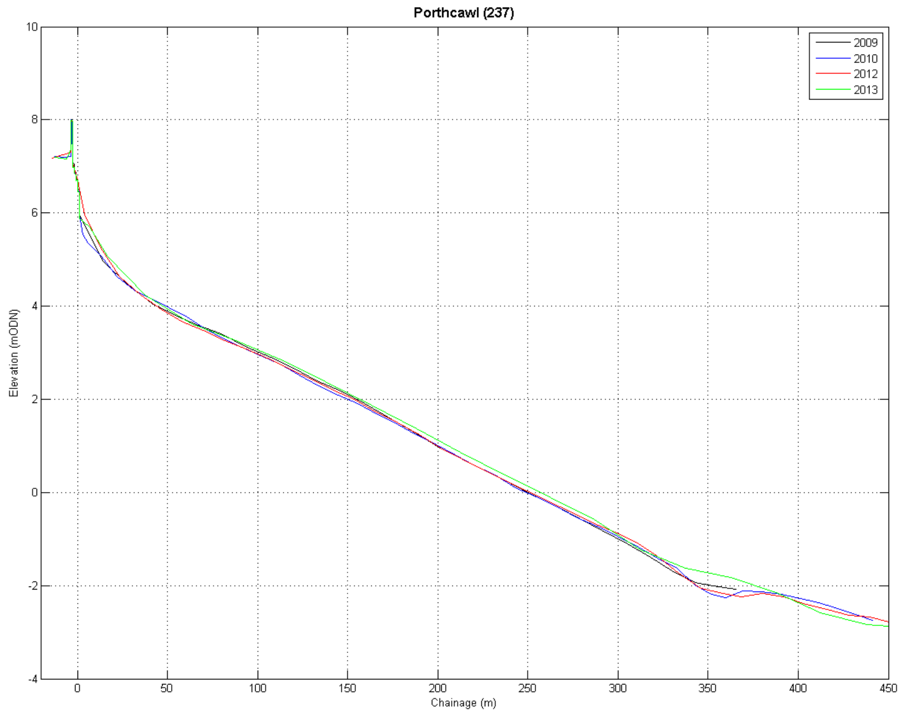
Sediment transport modelling conducted by Halcrow (2005) showed that the annual volume change is less than 6,000 m^3 in Sandy Bay. To support the understanding of beach and shoreline change, relevant beach profile surveys (Pye & Blott 2013) have been examined and results provided in Figure 5 to Figure 8. A profile to the west of the Western Breakwater (236) has been included to understand current and future risk to the structure throughout the “do nothing” scenario, along with two profiles located Sandy Bay (237 and 238). Between 2009 and 2013 beach levels were generally stable throughout the Bay, with profiles 237 (Figure 6) and 238 (Figure 7) showing variation at the defence/dune toe of less than 0.2 m. Similar values have been previously reported (Cedm 2005) and considered to indicate no significant change in overall beach levels within the Bay. At the location of profile 238 the dune toe is surveyed between 6-6.5 mODN. This is lower than both 2011

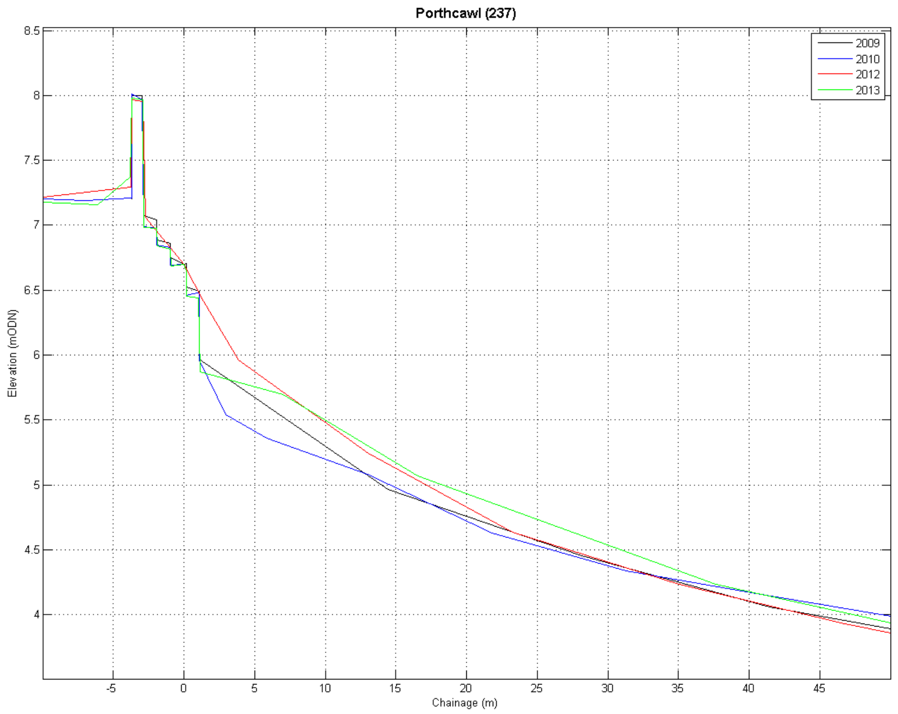
LiDAR (7-7.5 mODN) and previous reports (7.5-8 mODN, Halcrow 2005) suggest, and is therefore a conservative estimate in terms of exposure to toe scour.

Photo credited to Brian Batters

Figure 4. Dune frontage throughout existence of caravan park (top) reverting to a more natural system (bottom) following a cease of maintenance for the caravan park

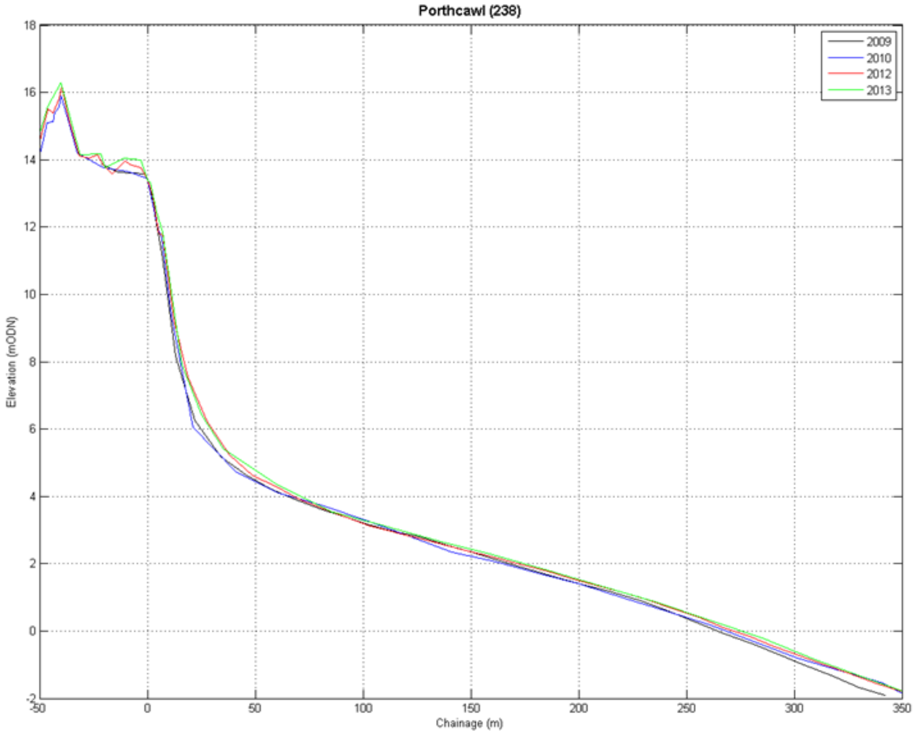
Figure 5. Topographic profile locations along Porthcawl front and within Sandy Bay

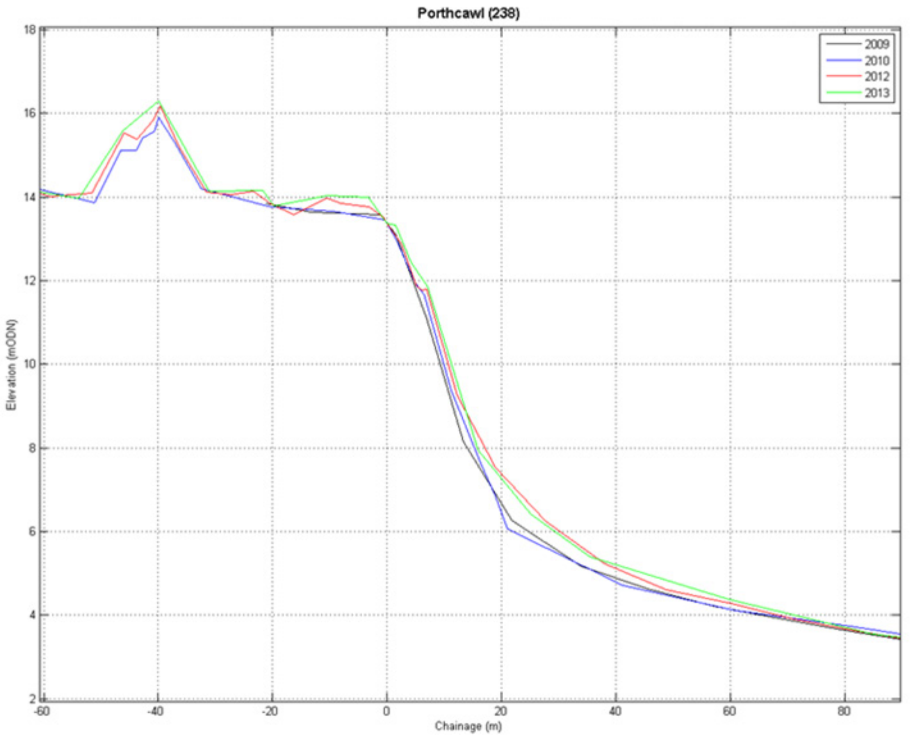




Note the lower point density for 2012 survey

Figure 6. Profile 237, located in the central section





Note the height of the dune toe compared to relative still water levels (Table 1)

Figure 7. Profile 238 within the relic dune

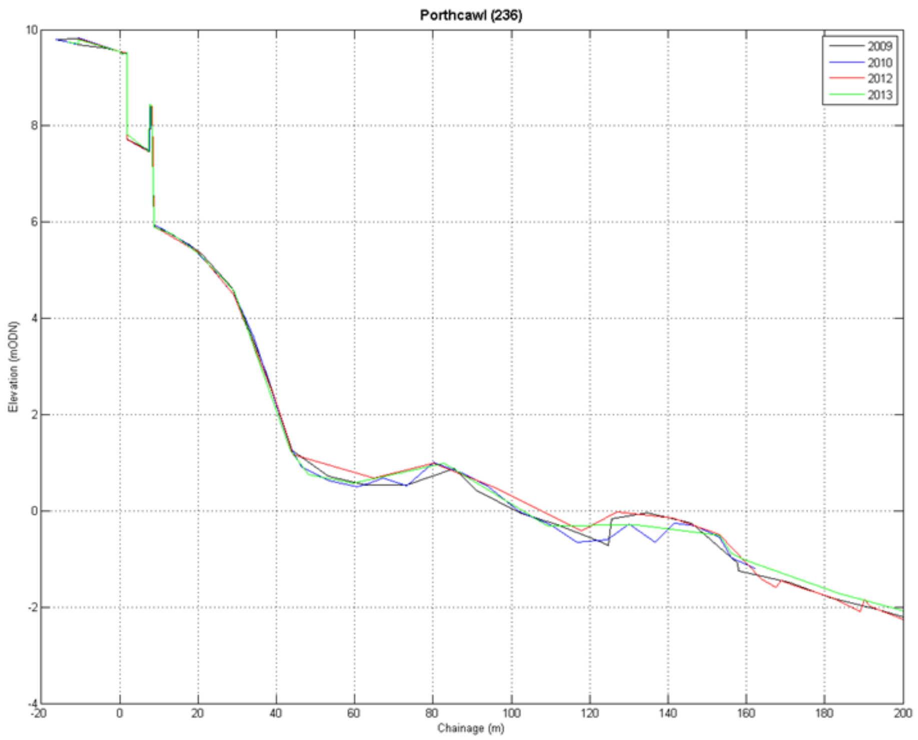


Figure 8. Profile 236, located west of the Western Breakwater

Insufficient LiDAR coverage of Porthcawl is available to provide a direct temporal comparison with topographic survey data. However analysis of beach elevation change between LiDAR flights in 2006 and 2011 (Figure 9) suggest small amounts of erosion in-between the rocky raised beach platforms to the west of the Western Breakwater (***A***), along the toe of the sea wall in the west of the Bay (***B***) and dune scarping in the north and northeast corner of the dune system (***C***).

A moderate area of accretion is apparent immediately to the north of the Western Breakwater (***D***), most likely due to more benign wave activity as a direct result of the breakwater presence. Beach crest level surveys show that the crest and toe levels of Sandy Bay generally increase from west to east (Halcrow, 2005), and both the LiDAR and topographic profiles support this with an elevation increase towards the eastern end of the dune system (Figure 7 and Figure 9 ***E***,) between surveys. The net littoral drift is therefore in a predominantly eastward direction, particularly to the east side of the Bay. The elevated eastern side is likely due to the relict dune system and/or potential rotation from the variable wave climate. An onshore berm migration between the LiDAR flights is also suggested (***F***), of which is likely to be a seasonal variance.

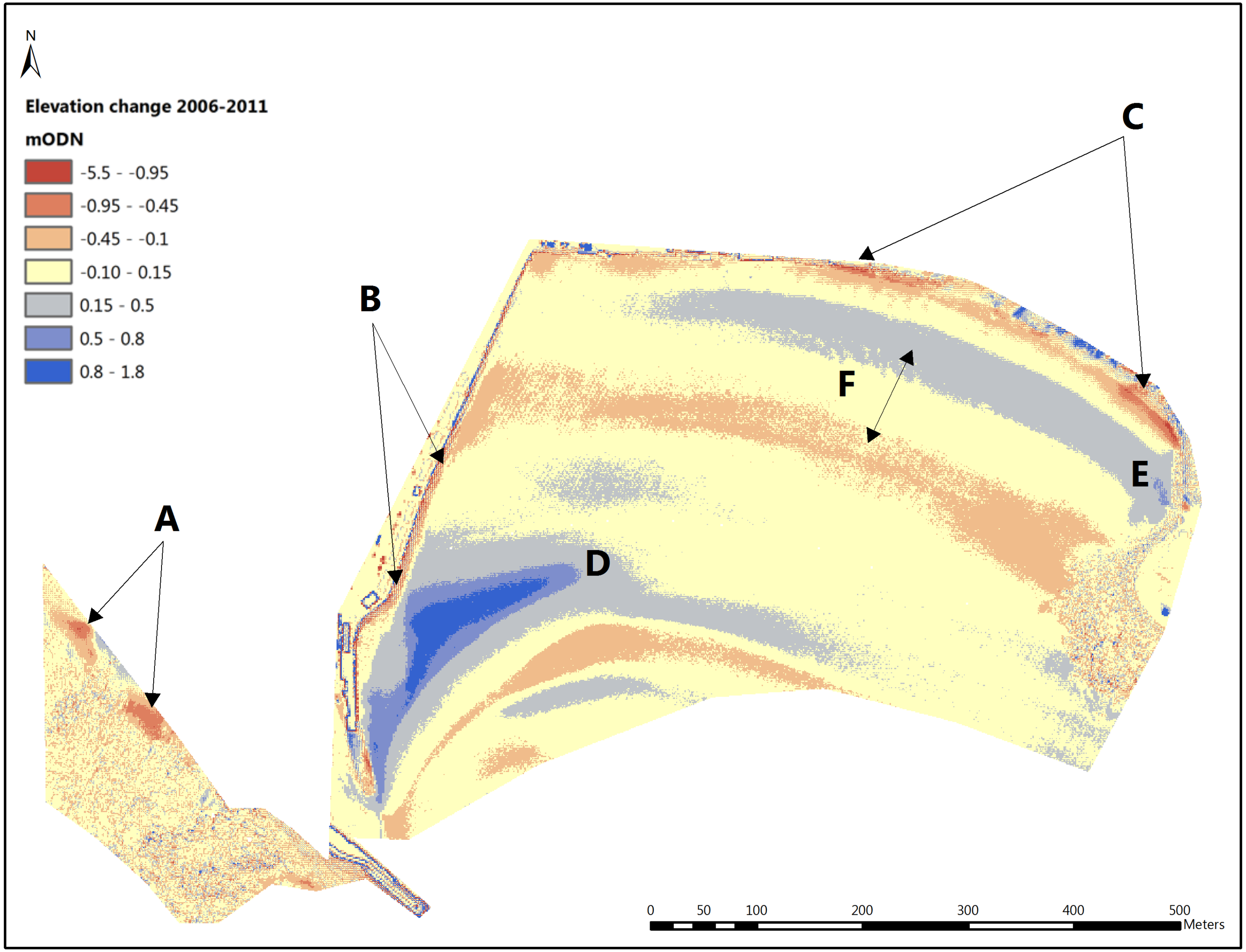


Figure 9. Beach elevation change between 2006 and 2011 LiDAR

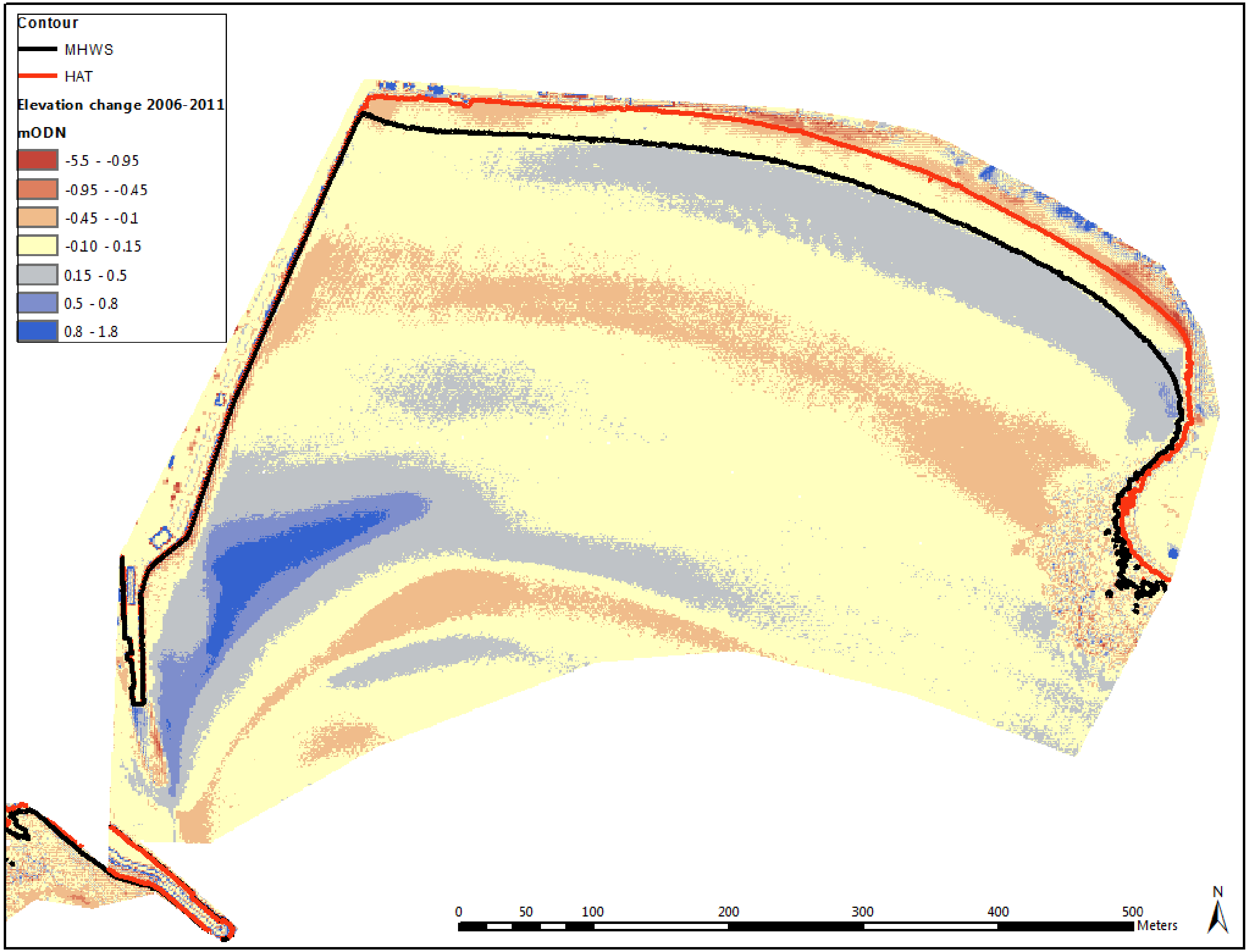


Figure 10. Elevation change in relation to relative still water levels (mODN). Note the location of MHWS level in relation to erosion activity

3.3 Future evolution

Predictions of the future evolution of the frontage have been provided in the SMP. Due to the highly developed nature of the Bay (predominantly the construction of the main breakwater), the natural processes have been altered and therefore the future evolution will also be strongly controlled by the ongoing shoreline management activities and the presence of coastal structures.

Under a 'do minimum' scenario, the defences would be patched and repaired including the Western Breakwater. This would result in coastal squeeze and increased pressure on the defences as the beach along the Eastern Promenade and in front of the amusement park is unable to roll-back in line with sea level rise.

It is predicted that under the 'do nothing' Scenario sea level rise will result in increased exposure and pressure on the existing defences (Halcrow 2012). This will result in the failure of the defences throughout the central section during the short term (present to 2029) epoch, exposing the amusement park to increased wave overtopping. The eastern promenade, harbour structures and main breakwater are all expected to remain, providing ongoing maintenance is continued. Beach levels throughout Sandy Bay are expected to remain stable, although exposure of the relic dune system to toe scour is apparent throughout storm conditions.

Continuing wave exposure and sea level rise throughout is likely to lead to a failure of the remaining defences throughout the middle epoch (2029-2059). Failure of the main breakwater would create a considerable increase in the wave climate in the area of the eastern breakwater, southeastern promenade, eastern promenade and central; although the hard rock underlying the main breakwater structure will likely still provide some level of wave dissipation to eastern parts of the Bay.

A retreat of the shoreline position would be expected throughout the Bay. Whilst the available data suggests that the dune system has reverted to a natural system, the SMP states that past modification will lead to 'erosion of the frontal dune rather than roll-back' (Halcrow 2012). Futurecoast predicts for an "unconstrained" scenario that the dune system would remain reasonably stable over the next century (Halcrow, 2002). Foreshore steepening and scarping is predicted to occur as a result of continued sea level rise (Halcrow, 2005), although the rocky headland at Rhych Point is expected to provide some protection for the dunes (Halcrow, 2012). The conservative estimate of the dune toe level (Figure 7) and the observation that the majority of beach lowering (Figure 10) occurs higher than 6 mODN, over 1 m above MHWS level but less than 0.5 m to HAT. Therefore current scarping is only expected to occur throughout storm or surge events (Halcrow 2005), as suggested previously.

Risk of access loss to Rhych Point is likely if this erosion does persist, however this is suggested to be a future access issue as opposed to a flooding issue from wave overtopping.

3.4 Water levels

3.4.1 Tidal water levels

The study area is within the Bristol Channel, which is within a hyper-tidal environment, with a spring tidal range in excess of 6 m. This is due to the behaviour of the tidal wave originating in the North Atlantic and the funnelling effect of the channel, which in turn modifies the behaviour of the tidal wave. Within the study area, the tidal range is nearly 9 m during spring tides, reducing to over 4 m during neap tides (Table 1), which is characteristic for coastal locations within the Outer Bristol Channel. The conversion from chart datum to mODN for Porthcawl is -5.3 m.

Table 1. Tidal characteristics at Porthcawl

Location	Reference Still Water Level							Mean Range (m)	
	HAT	MHWS	MHWN	MSL	MLWN	MLWS	LAT	Spring	Neap
Porthcawl (mCD)	11.0	9.9	7.5	5.3	3.3	1.0	0.1	8.9	4.2
Porthcawl (mODN)	5.7	4.6	2.2	0.0	-2.0	-4.3	-5.2		

Source: 2016 Admiralty Tide Tables

The hyper-tidal range at Porthcawl and shelving intertidal zone means that the existing sea defences on the west of Sandy Bay and immediately shore-side of the amusement park are only exposed to the incident wave climate for periods of the tidal cycle (Figure 11). Whilst the MHWS level extends along much of the Eastern Promenade seawall, MSL and MHWN level only cover between 25 to 50% of its overall length; therefore exposure to wave overtopping is limited by the tidal dynamics and is only likely to occur for much of the defences under either extreme weather events that occur at the time of spring tide water levels or lower levels enhanced by surge events.

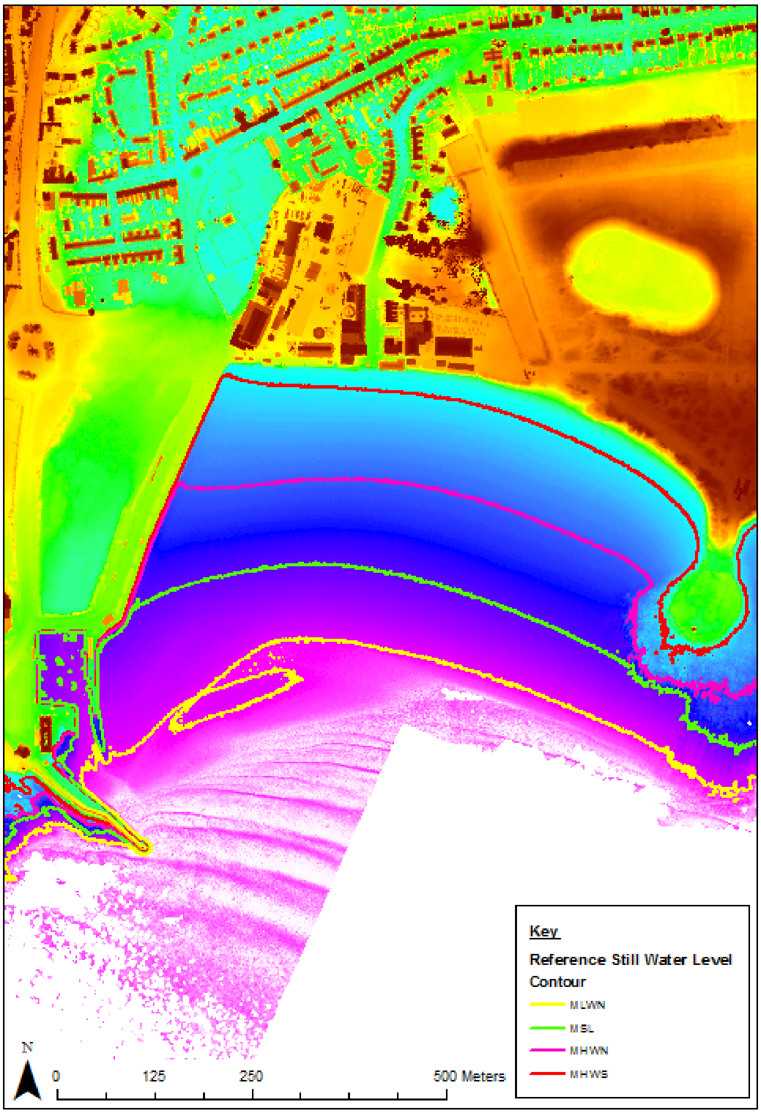


Figure 11. Water level contours for Porthcawl (mODN) overlaid onto 1 m DSM LiDAR

3.4.2 Surge

The Bristol Channel is affected by storm surges which are generated by the movement of Atlantic depressions across the United Kingdom. The most significant storm surges are associated with the events which track southerly across Ireland and generate strong south westerly winds. These winds force water up the Bristol Channel. The occurrence of surge events within the Bristol Channel has the potential to increase water levels. At Mumbles to the west of Porthcawl, the largest surge height recorded at 15 minute intervals by the tide gauge between 1990 and 2014 measured approximately 1.8 m (ABPmer 2005), whilst the greatest negative surge was around -0.90 m on the 13 February 2005 (NTSLF, 2013). The highest measured water level at the Mumbles gauge over this time period was 5.63 mODN, recorded on the 8 October 2006, which relates to a relatively small positive surge of approximately 0.22 m on a very large spring tide; equivalent to 0.12 m greater than HAT.

UKCP09 predictions for future change in storm surge across the region indicate an increase in the 1 in 50-year storm surge height of up to 0.8 mm/yr (Lowe *et al*., 2009). This projected increase remains an uncertain estimate as there is inherent difficulty in predicting storm surge events due to the complicated interaction of many marine and meteorological factors.

3.4.3 Extreme water levels

The Environment Agency coastal flood boundary dataset (CFBD) (Environment Agency, 2011) provides an assessment of extreme water levels offshore of Sandy Bay, which are summarised in Table 2 for the locations shown in Figure 12. These provide the extreme still water levels associated with different return periods ranging from 1 in 1 year to 1 in 1,000 years. It should be noted that the Environment Agency states that these levels are considered accurate only to one decimal place. Generally, it is the coincident occurrence of extreme surge heights with high water levels that is considered to bring about extreme water levels within the study region.

Observed occurrences of extreme water levels at Porthcawl between 1992 and 2014, indicated a height of 5.81 mODN, recorded on the on 20 February 2007. Over the 24 year observation period, there were eight occurrences of water levels at or above HAT (Table 3).

Table 2. Extreme water levels for base year of 2008 (Environment Agency CFBD, 2011) and adjusted to include sea level rise for 2018 and 2118 epochs – (EA Location Chainage 462)

Return Period (Years)	EA Chainage 462 (mODN)	Epoch 2018 (mODN)	Epoch 2118 (mODN)
1:1	5.59	5.64	6.40
1:10	5.86	5.91	6.67
1:20	5.95	6.00	6.76
1:50	6.07	6.12	6.88
1:75	6.14	6.19	6.95
1:100	6.18	6.23	6.99
1:200	6.31	6.36	7.12
1:1,000	6.66	6.71	7.47
Note: Epoch values have been calculated using a linear extrapolation of the time series beyond the published data			

Source: Environment Agency, 2011

Table 3. Water levels approximately reaching (or above) HAT at Porthcawl.

Date and Time	Water Level (mODN)
20/02/2007 08:00	5.81
03/01/2014 07:00	5.73
28/09/2007 19:00	5.69
19/02/2007 07:00	5.69
08/10/2006 19:00	5.67
29/08/1992 19:00	5.67
02/03/2014 07:00	5.67
10/03/2008 08:00	5.66
Observations from Mumbles tide gauge were locally adjusted for Porthcawl, with SEASTATES model filling any gaps within the time series. Red values indicate levels above HAT.	

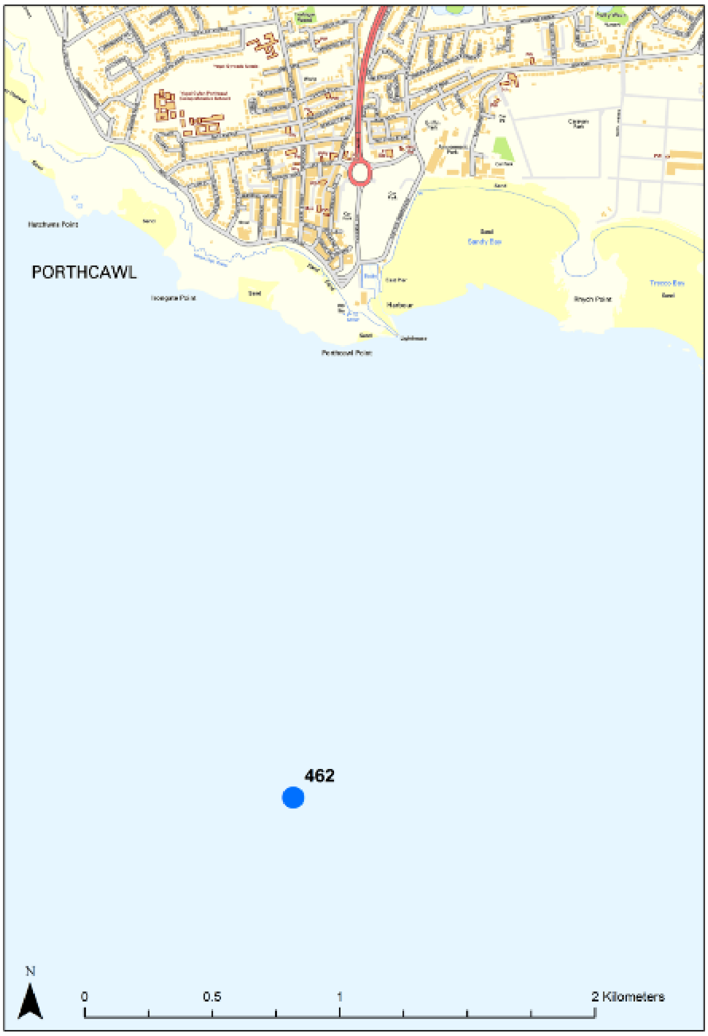


Figure 12. Location Environment Agency coastal flood boundary dataset

3.4.4 Relative sea level rise

The Bristol Channel has historically experienced changes in relative sea levels. More recently, the general trend for the southwest of the United Kingdom (UK) (as given at Newlyn, between 1916 and 1996) is of an increase in relative mean sea-level at an average rate of 1.7 ±0.12 mm per year

(Woodworth, *et al.*, 1999). A further analysis of the tide gauge data from Mumbles over a shorter period (between 1990 and 2010) suggests a rate of increase of 1.1 mm per year.

Future changes in relative sea level (RSL) are quoted as the net effect of geological adjustments in land levels and the projected absolute changes in mean sea level. A summary of the UKCP09 relative sea level rise projections up to 2100 for the grid cell 23470 at Sandy Bay, based on the medium emission scenario, for the range of confidence intervals are provided in Table 4. For the climate change simulations the medium emission scenario 95 percentile for an epoch *circa* 100 year in the future was calculated at 0.755 m (base year 2018) for 2118 as per Welsh Government Adapting to Climate Change Guidance (Welsh Government 2011[1]).

Table 4. Sea level rise predictions (UKCP09)

Year	Confidence Intervals 95 %ile (m)
2000	0.044
2010	0.093
2018	0.135
2020	0.146
2030	0.203
2040	0.265
2050	0.331
2060	0.402
2070	0.477
2080	0.556
2090	0.640
2100	0.728
2118	0.890

Source: UKCP09 Cell No. 23470

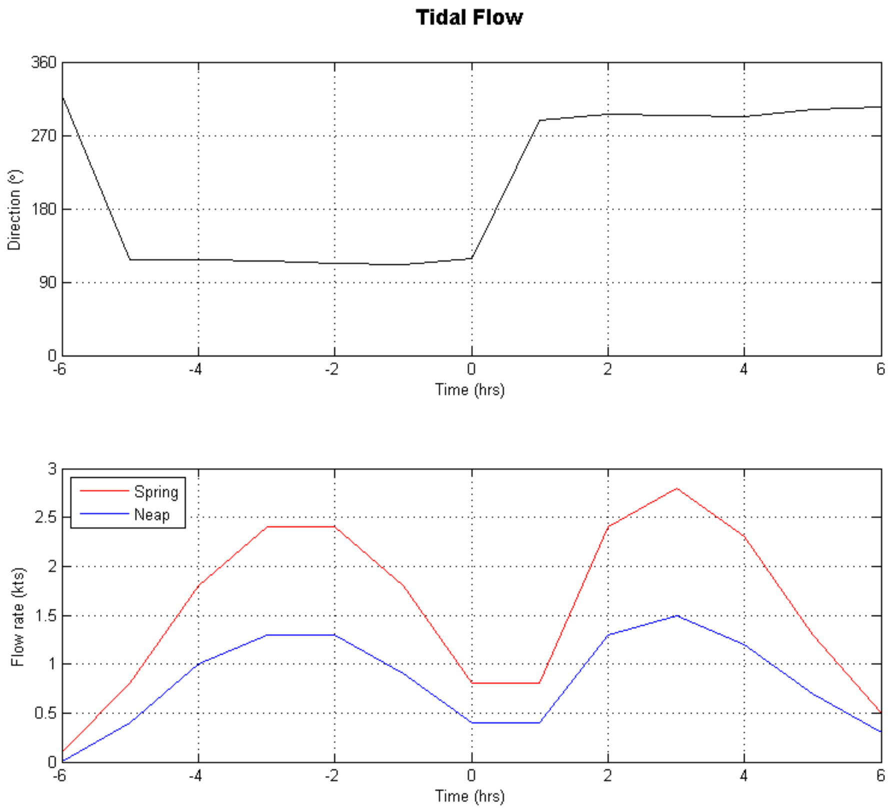
A general increase in RSL may result in a number of effects, such as, displacing the high water mark towards the shoreline, enabling wave energy to move further towards the coast (exposing the shoreline to greater periods of wave and tidal energy) and therefore creating increased potential for flood risk. The magnitude of these effects will vary depending upon the rate of predicted sea level rise and the timing relative to the 18.6 year lunar nodal cycle variations (which will impart a larger positive and negative variation in amplitude over shorter timescales).

3.5 Currents

3.5.1 Tidal currents

The tidal regime within the Bristol Channel is characterised by strong tidal flows, on an east-west axis, as a result of the large tidal range and channel morphology. The current speeds vary spatially both along and across the coastline in line with channels, sandbanks and intertidal flats. In proximity to Porthcawl, information on Admiralty charts (Figure 13) indicates strong near easterly and westerly flows on the flood and ebb respectively of around 2.5 knots (approximately 1.25 m/s) on spring tides.

[1] http://gov.wales/docs/desh/publications/111231floodingclimatechangeen.pdf



Source: UKHO, 1999

Figure 13. Tidal stream data approximately 3 km due south of Porthcawl

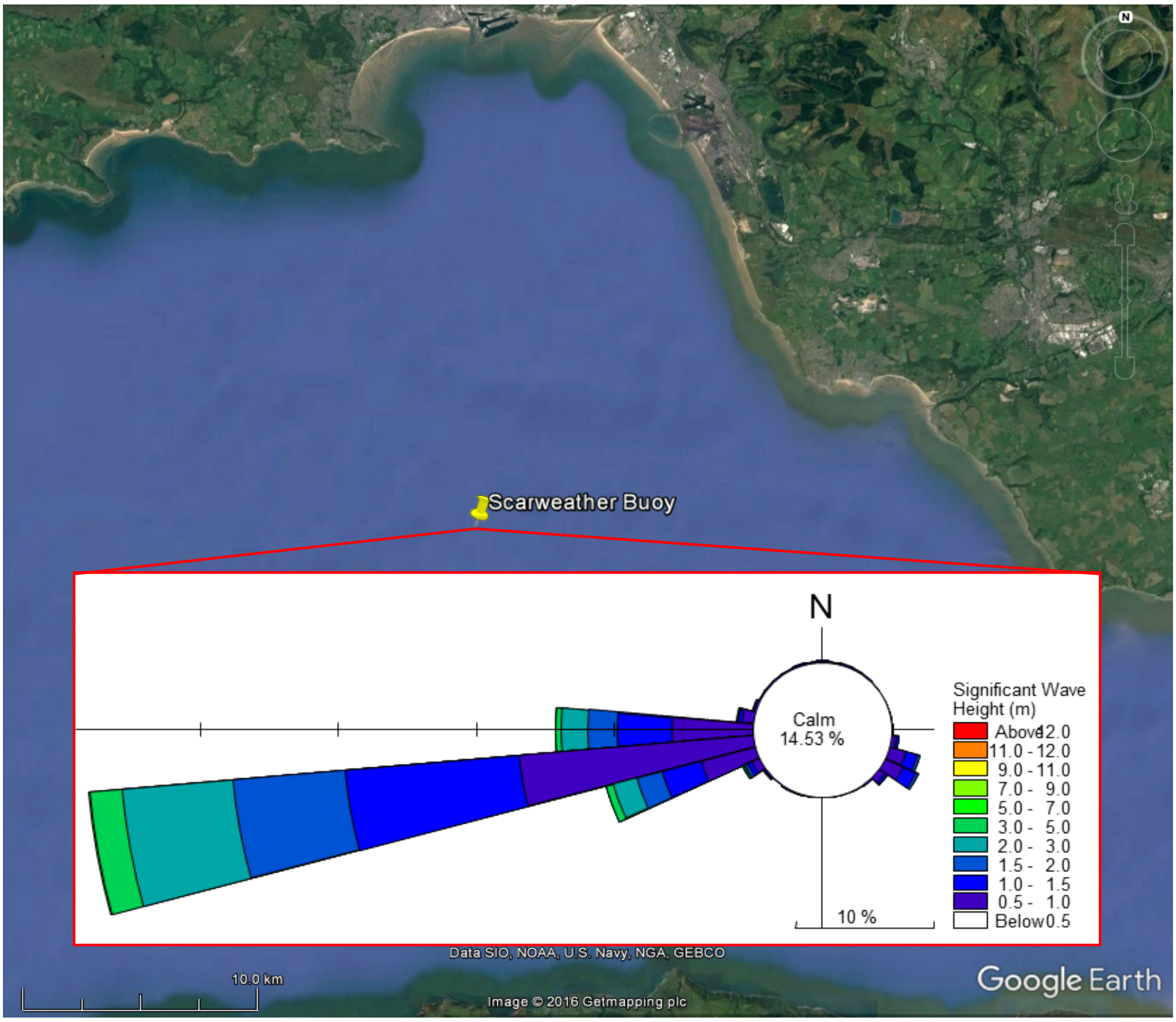
Peak current speeds generally increase in an easterly direction as the tidal range increases. Within the Bristol Channel however, the westerly ebb flow is stronger, generating a residual in this direction, despite the marginally longer but weaker easterly flood flow (Mackie *et al*., 2006; James *et al*., 2004; Posford Duvivier & ABP Research & Consultancy, 2000; Collins, 1987). The large tidal range within the Bristol Channel influences the extent to which waves interact with the seabed and are able to supply additional forcing to the tidal current regime.

3.6 Waves

3.6.1 Regional wave climate

The Bristol Channel is exposed to both long period swell waves generated in the Atlantic and shorter period wind-waves generated locally, which are limited by wind speed and fetch length. The largest and most frequent waves which approach the study area are from a WSW direction. During periods of low water and neap tides waves are modified by the local topography, as are long period westerly waves in water depths less than 20 m.

Data from the Scarweather WaveNet buoy located further west of Porthcawl in the Outer Bristol Channel (Latitude 51° 25'.99N, Longitude 003° 55'.99W, Figure 14) in 35 m water depth is used to inform the offshore wave climate. At the buoy an average significant wave height (Hs) of 1.2 m and average peak wave period (Tp) of 8.6 seconds was observed for the period between July 2005 and November 2015. The time series suggests a dominant wave approach from WSW direction for nearly 50% of the time, with significant wave heights of up to 7 m (Figure 14).



Map data ©2016 Google. Image © 2016 Terrametrics. Data © SIO, NOAA, U.S. Navy, NGA, GEBCO.

Figure 14. Significant wave height at the Scarweather WaveNet buoy between July 2005 and November 2015

The largest recorded significant wave height in the time series is 11.11 m on the 10 May 2014. This significant event is of similar magnitude of extreme offshore wave conditions published by Halcrow (2005) which analysed wave records between 1990 and 2000. The associated offshore extreme water levels are provided in Table 5 which show a 1:100 return period from the 240 degree sector of 11.13 m.

Table 5. Extreme offshore wave conditions (Halcrow, 2005)

Return Period (years)	Wave Height (m)	Wave Period (s)	Wave Height (m)	Wave Period (s)	Wave Height (m)	Wave Period (s)	Wave Height (m)	Wave Period (s)	Wave Height (m)	Wave Period (s)
	210°		240°		270°		300°		330°	
1:1	5.82	11.8	8.31	14.1	7.48	13.3	4.72	10.6	3.67	9.3
1:2	6.20	12.2	8.78	14.5	8.01	13.8	5.03	10.9	3.93	9.7
1:3	6.42	12.4	9.04	14.7	8.31	14.1	5.20	11.1	4.08	9.9
1:5	6.68	12.6	9.36	14.9	8.68	14.4	5.41	11.4	4.26	10.1
1:10	7.02	12.9	9.79	15.3	9.17	14.8	5.68	11.6	4.48	10.3
1:20	7.34	13.2	10.20	15.6	9.64	15.2	5.93	11.9	4.70	10.6
1:30	7.53	13.4	10.44	15.8	9.92	15.4	6.07	12.0	4.82	10.7
1:50	7.76	13.6	10.74	16.0	10.26	15.6	6.25	12.2	4.97	10.9
1:100	8.05	13.8	11.13	16.3	10.72	16.0	6.48	12.4	5.16	11.1
Numbers refer to 3 hourly wave records										

The Environment Agency assessment of extreme wave conditions, derived from a gridded model cell in close proximity to Sandy Bay (outside of the effects of the Western Breakwater), indicate much lower wave heights of around 3-3.5 m for different return periods (Table 6 and Table 7) from the south west. However, although reported here for completeness, concerns have been raised about this dataset and should be treated with caution. It is recommended that the data in Table 5 should be used.

Table 6. Environment Agency extreme swell waves (m) for cell GL2396

Wave Approach Direction	Return periods (years)					
	1:1	1:10	1:20	1:50	1:100	1:200
Southwest	3.0	3.3	3.4	3.4	3.5	3.5
Northwest	2.3	2.8	2.9	3.0	3.1	3.2

Table 7. Environment Agency extreme swell wave period (seconds) for cell GL2396

Significant Wave Height (Hs, m)	Zero-crossing wave period (Tz, seconds)					
	<8	8 - 10	10 - 12	12 - 14	14 - 16	>16
<1	0.53	0.24	0.13	0.08	0.02	N/A
1-2	0.43	0.28	0.16	0.09	0.03	N/A
2-3	0.42	0.41	0.15	0.02	N/A	N/A
3-4	0.67	0.22	0.11	N/A	N/A	N/A
4-5	N/A	N/A	N/A	N/A	N/A	N/A
Measures relate to percentage occurrence in each wave height/period zone						

3.6.2 Local wave climate

More locally to Sandy Bay waves are either limited in their fetch length (easterly) or are likely to be dissipated via the presence of offshore sandbanks (Scarweather to the west and Tusker Rock/West Nash to the south) particularly during a 2-4 hour window surrounding LW depending on the stage of the spring/neap tidal cycle.

Due to the short period data used in both the Halcrow (2005), Environment Agency (2011) CFBD waves and the Atkins (2012) study it was considered these data did not reflect the complete wave climate of the area for use of deriving wave overtopping. For this study ABPmer has used the SEASTATES database of hindcast offshore data (ABPmer 2013, 2016). SEASTATES is a fully spectral wave model which covers the North Atlantic and European shelf seas, and is driven by the spatially and temporally varying CFSR (Climate Forecast System Reanalysis) wind fields developed by NOAA (National [American] Oceanic and Atmospheric Administration). The SEASTATES hindcast has been previously validated against 28 buoys within UK and European waters. 37 years of hindcast wave conditions are coupled with 37 years of modelled water levels to represent the complexities of the wave climate in the immediate nearshore (Figure 15). This method allows for all wind, wave and water level conditions to be incorporated in the wave overtopping calculations. Further details of the methodology along with the overtopping results are reported separately.

The results of the analysis, deriving the local wave climate is provided below in Figure 15 and Table 8 and show that the defences around the Bay are subject to a sheltered wave climate. The intertidal zone surrounding Porthcawl containing a raised shore platform has a refraction effect on waves entering the nearshore, with waves in front of the Western Breakwater initially backing to a SSW direction from the more westerly directions seen offshore at Scarweather. Dissipation of these waves is also apparent over the intertidal area of the Bay, with a reduction in average significant wave height to less than 1 m. Further sheltering and refraction effects as a result of the Western Breakwater are witnessed, with consistently smaller Hs values of less than 0.4 m at the frontage toe locations within the Bay. Average significant wave heights increase in value west (0.07 m) to east (0.35 m) throughout the frontage locations in the Bay. This is combined with a rotation in wave direction to that immediately parallel to the bathymetric contours (Figure 3, Figure 11).

The raised shore platform at Rhych Point appears to enhance refraction of waves entering the eastern sections of Sandy Bay following initial diffraction around the Western Breakwater.

Table 8. Average wave statistics at the toe of the Western Breakwater and throughout Sandy Bay.

Toe Frontage ID	Average Significant Wave Height Hs (m)	Average Peak Wave Period Tp (s)	Average Wave Direction (°)
1	0.16	8.5	147
2	0.16	7.9	147
3	0.29	7.0	185
4	0.31	6.9	208
5	0.75	8.7	197
6	0.35	7.3	225
7	0.07	7.7	142

Locations are shown within Figure 15.

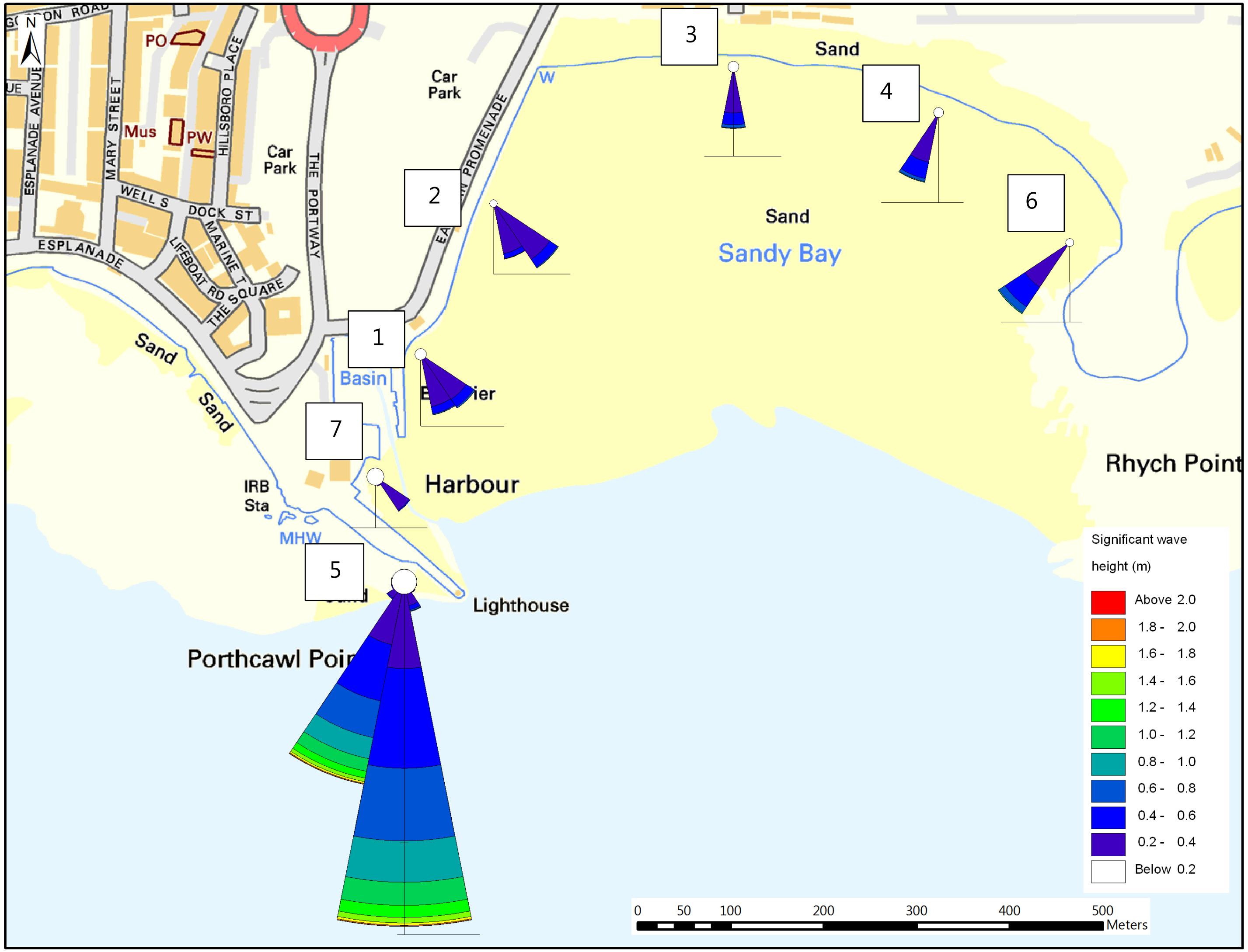


Figure 15. SEASTATES significant wave heights and mean wave directions for the nearshore within Sandy Bay and at Porthcawl Western Breakwater

3.6.3 Extreme waves

The period between mid-December 2013 and mid-February 2014 according to the Met Office, was the stormiest period of weather that the UK had seen for at least 20 years, with the storms during early and mid-February being particularly severe. Subsequent analysis (Haigh *et al*. 2016) has identified that this winter season contains the largest number of extreme sea level events in any season in the last 100 years. At the Scarweather buoy, on 12 February 2014 (which coincided with a neap tidal period), a significant wave height (Hs) of 8.2 m was recorded, associated with peak wave period (Tp) of nearly 12 seconds (and zero-crossing wave period Tz of 10.3 seconds), approaching from the west-southwest. Although it is likely that waves of a smaller magnitude will have reached the nearshore during this period, significant wave overtopping along Western Breakwater occurred (Figure 16).

Source: ITV, 2017[2]

Figure 16. Wave overtopping at the Western Breakwater during a storm event on 12 February 2014

Extreme wave modelling for Porthcawl Harbour was undertaken and extreme values from the study are presented in Table 6 (Halcrow 2005). It is important to note that conditions from the southwest and northwest were not considered due to the sheltering effects of the Western Breakwater and lack of wave impacts within the Porthcawl Harbour.

Extreme overtopping predictions for the defences across Sandy Bay in association with this study have been reported separately presented in ABPmer (2017). This analysis provides wave overtopping information for locations at the defence frontage, taking account of the refraction and partial diffraction effects around the Western Breakwater, as well as wave shoaling, wave refraction and wave breaking within the intertidal area of the Bay.

2 http://www.itv.com/news/update/2014-02-12/huge-waves-crash-into-wales-seafront/

Table 9. Extreme nearshore locally generated wind wave conditions (south east directions only)

Direction	120°		150°		180°	
Return Period (years)	Wave height (m)	Wave Period (s)	Wave height (m)	Wave Period (s)	Wave height (m)	Wave Period (s)
1	1.66	4.9	2.02	5.4	1.95	5.3
5	1.96	5.3	2.25	5.7	2.15	5.6
20	2.19	5.6	2.42	5.9	2.31	5.8
100	2.44	5.9	2.60	6.1	2.48	6.0

Source: Halcrow, 2005.

4 Conceptual Understanding

A combination of the nearshore morphological properties within the intertidal area of Sandy Bay and the existing defence frontages (including the main Western Breakwater) significantly modify wave properties entering Porthcawl. Prior to entering the nearshore waves are filtered in direction and height by a series of offshore sandbanks (mainly Nash and Scarweather) located to the south and west. Upon entering the nearshore, dissipation and refraction occur over the rock raised shore platform and then around the Western Breakwater at the west side of the Bay, with further dissipation and refraction occurring throughout the raised shore platform at Rhych Point. This occurs during both normal and extreme conditions. As a consequence the west side of the Bay is relatively sheltered from the most extreme wave activity, sufficient to allow sand to deposit in the Western Breakwater lee off the entranced to Porthcawl harbour. Around the rest of the Bay the shallow gradient intertidal zone causes refraction so that waves tend to approach the Sandy Bay defences and fronting sand dunes approximately perpendicular. Diffraction around the end of the Western Breakwater will radiate the waves towards the north-west corner of the Bay, causing waves to impact at an angle to the Eastern Promenade. Under certain circumstances waves would have the potential to run along the sea defence into the corner of the Bay. This corner will be disturbed with incident and reflected waves interacting at the highest water levels creating wave breaking and the potential for water splash if not direct wave overtopping.

Sediment transport throughout Sandy Bay is limited, with a slight west-to-east accretion of beach levels in recent years. This is likely due to a combination of the east-west axis of tidal flow, and the predominantly westerly and south-westerly direction of wave conditions both offshore and within the nearshore. The large tidal range also varies the level of beach exposure to waves temporally, with approximately 300 m of cross-shore exposure change between MHWS and MLWN level. Beach levels at the toe of the central frontage are considered to be stable from the information available, with no significant pattern of erosion or accretion over the longer term. However erosion is likely to occur throughout storm and surge events (not extensively monitored at the site), and therefore under benign conditions the intertidal zone has the ability to recover its former profile. As a consequence beach draw-down is considered to be limited in the longer term and therefore any level variations at the frontage which could affect wave overtopping around the Bay are likely to only be a function of the change in tidal events with SLR, rather than the greater combined effect should draw-down be an ongoing process.

Effects of future climate change particularly in the longer term will increase the general water depths within the Bay. As a consequence there is greater potential for higher waves to reach the defences at increased frequency, and hence an increased wave overtopping, flood risk and potential sea wall damage. As noted above, beach draw-down and sea defence by erosion is limited and therefore an 'undercutting' of the sea defence and dune system is not considered to be a high risk, particularly if toe protection of the structures are provided and dune stabilisation is continued. In general it is suggested that beach erosion is not a problem at the site, however the frequency of scarping events (and consequent sediment removal from eastern sections of the Bay) is likely to increase with sea level rise.

The above analysis is based on the continuing presence of the Western Breakwater. Should this be allowed to decay, then significant additional exposure to the dominant SSW waves will occur; particularly on the eastern side of the Bay. The wide intertidal zone and large tidal range will still create depth limited wave conditions, but there would be greater potential for wave overtopping (hence flood risk and additional impact on the defences), increasing the potential for structural failure and the need for greater maintenance.

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6 Abbreviations/Acronyms

BCBC	Bridgend County Borough Council
CFBD	Coastal flood boundary dataset
CFSR	Climate Forecast System Reanalysis
EA	Environment Agency
FRA	Flood Risk Assessment
HAT	Highest Astronomical Tide
Hs	Significant wave height
LAT	Lowest Astronomical Tide
LW	Low Water
mCD	Metres relative to Chart Datum
mODN	Metres relative to Ordnance Datum Newlyn
MHWN	Mean High Water Neap
MHWS	Mean High Water Spring
MLWN	Mean Low Water Neap
MLWS	Mean Low Water Spring
MSL	Mean Sea Level
NTSLF	National Tide and Sea Level Facility
PAR	Project Appraisal Report
RSL	Relative Sea Level
SLR	Sea Level Rise
SMP	Shoreline Management Plan
Tp	Peak wave period
Tz	Peak zero crossing period
UK	United Kingdom
UKCP09	UK Climate Projections 09

Cardinal points/directions are used unless otherwise stated.

SI units are used unless otherwise stated.

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