Interim Baseline Report

Hunstanton Coastal Management Plan

60552153

January 2018

Borough Council of
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Quality information

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Revision History

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1. Introduction

1.1 Project Background

AECOM Infrastructure and Environment UK Limited have been appointed by the Borough Council of King's Lynn and West Norfolk (BCKLWN) to develop a Coastal Management Plan and where possible to seek funding to implement the preferred management policy for the Hunstanton frontage through an Outline Business Case (OBC).

1.2 Purpose of the Report

The purpose of this interim report is to summarise the works undertaken to date on the Hunstanton Coastal Management Plan. The works undertaken to date include:

- Reviewing available information;
- Review and summarise local coastal processes;
- Analysis of wave conditions;
- Analysis of beach profile data;
- Undertaking a Preliminary Environmental Assessment;
- Preliminary assessment of Hunstanton Cliffs – including failure mechanism and mitigation options;
- Updating the condition assessment of existing defence assets;
- Undertaking a baseline 'Do Nothing' economic assessment;
- Developing a long list of management options.

1.3 The Site and Strategic Policy

Hunstanton is a seaside town along the west facing coast of the Wash in Norfolk, approximately 21km north east of the town of King's Lynn (Figure 1-1). The study area comprises approximately 1.3km of undefended cliffs (Unit A) and approximately 1.5km of defended coastline (Unit B) that consists of seawalls, promenade, rear wave wall and beach management groynes. The entire coastline is fronted by a sandy/shingle beach of varying levels.

Hunstanton is a popular tourist area, particularly in the summer months. The promenade is a prominent amenity area with an array of attractions which are well trafficked by the public. There are numerous seasonal kiosks located along the promenade with a leisure centre, aquarium, small funfair and caravan park located just behind the rear wave wall.

Figure 1-1: Location of Hunstanton and study area (imagery ©2017 Google)

The Site is comprised of two management units as defined in the Wash East Coastal Management Strategy, 2015 (The Strategy): Unit A – Hunstanton Cliffs and Unit B – Hunstanton Town.

The agreed intent of The Wash Shoreline Management Plan Review, Environment Agency, 2010 (SMP2) is to continue to allow the cliffs to erode naturally and provide sediment to help maintain the beaches to the south, until the erosion starts to threaten cliff top properties and the cliff road. This is expected to occur in approximately 50 years (although there is a significant uncertainty in this date). From that time on, the SMP's intent is to prevent further cliff erosion to sustain the properties and the road in Unit A.

The Strategy concluded that the preferred approach to managing the erosion in Unit A in the future, should be to pilot a range of low cost options that reduce erosion caused by wave action at specific locations. This trial of options would determine their effectiveness in slowing erosion. Options identified in The Strategy were base netting, sand bags, gabions and a rock sill (rock revetment). The Strategy identified from the key Stakeholder Group that there was a clear consensus that it is not realistic or desirable to stop erosion, but options such as these to slow the erosion rate should be pursued.

In Unit B the preferred management approach of both the SMP2 and The Strategy is to 'Hold the Line' by maintaining the existing promenade, seawall and groyne defences and replacing these structures when required (predicted residual life of theses defences in the Strategy was 15-20 years).

It should be noted that Unit C to the south of the study area (Wolferton Creek to South Hunstanton) is managed by the Environment Agency and a Community Interest Company, work is currently being undertaken in this area and the Study should assess the opportunities for an integrated approach with this Unit.

2. Coastal Processes Analysis

2.1 Tidal Levels

Tide levels for Hunstanton extracted from the Admiralty Tide Tables (2016) are shown in Table 2-1.

Table 2-1. Tidal levels for Hunstanton extracted from the Admiralty Tide Tables (2016)

Tide State	Tide Level (mCD)(1)	Tide Level (mOD)(1)
HAT	**+8.20**	**+4.45**
MHWS	**+7.40**	**+3.65**
MHWN	**+5.60**	**+1.85**
MSL	**+3.88**	**+0.13**
MLWN	**+2.50**	**-1.25**
MLWS	**+0.90**	**-2.85**
LAT	**+0.20**(2)	**-3.55**(2)

Note (1): Chart Datum (CD) at Hunstanton lies 3.75m below Ordnance Datum (OD) (UKHO, 2016)

Note (2): Estimated using LAT at Immingham and subtracting Tide Level Difference at Hunstanton for MLWS

2.2 Extreme water levels

Tidal levels occur on a cyclical basis as a result of the interaction of the gravitational forces of the sun and moon and are highly predictable. However, water level variations can also be caused by a combination of climatic factors. Changes in atmospheric pressure and strong winds can combine to produce water levels different to those predicted by astronomical forcing; these variations are known as 'Storm Surges'. It is positive surges which tend to have the greatest effect with respect to coastal flood and erosion risk management, due to water levels increasing to unpredictable levels. Combinations of 'Storm Surge' and tidal levels can cause Extreme Water Levels, the magnitude of which is described by a Return Period. Return Periods relate the annual probability of occurrence to a frequency; e.g. 1 in 100 years, the level which will occur, on average, once in a hundred years. It should be noted that the definition 'Storm Surge' is often interpreted as having a sudden occurrence; however 'Storm Surges' generally exhibit a progressive increase to their peak level over several hours. An example of a 'Storm Surge' occurring in the local area is the event of 1953 in Kings Lynn, where a positive surge of nearly 3 metres was registered (SMP2, 2010).

Extreme water levels around the UK have been studied widely and the results are readily available. Extreme water levels for 2008 (the Base Year of the data) were obtained from the Environment Agency Coastal Flood Boundary conditions for UK Mainland and islands via the ESRI UK website. The closest extreme water level data is available at a location approximately 2 km offshore from Hunstanton (location is described as Spurn Head to Holme-next-to-Sea).

Table 2-2. Extreme Water Level extracted from EA Coastal Flood Boundary (base year 2008)

Return Period (years)	Annual Exceedance Probability (%)	Extreme Sea Levels mOD
1 in 1	100	4.36
1 in 2	50	4.48
1 in 5	20	4.63
1 in 10	10	4.75
1 in 20	5	4.88
1 in 25	4	4.92
1 in 50	2	5.05
1 in 75	1.3	5.12
1 in 100	1	5.17
1 in 150	0.7	5.25
1 in 200	0.5	5.31

2.3 Wave regime

Although The Wash is an area dominated by tidal conditions, wave effects and their interactions with the coastline are also present and important.

To analyse the wave climate wave data was obtained from the Channel Coastal Observatory (CCO) website. The data was collected from a wave rider buoy 'North Well' (Directional Waverider MKIII) situated at the entrance to The Wash at 053°03.494' N, 000° 28.503' E as seen in Figure 2-1 (yellow circle WWB1), operated since September 2006. The data covers a period of over 9 years (between September 2006 and December 2015). Figure 2-1, extracted from the Environment Agency Sea State report The Wash 2010, also shows the main channel 'The Well' running through the centre of The Wash (as indicated by the orange shaded contours).

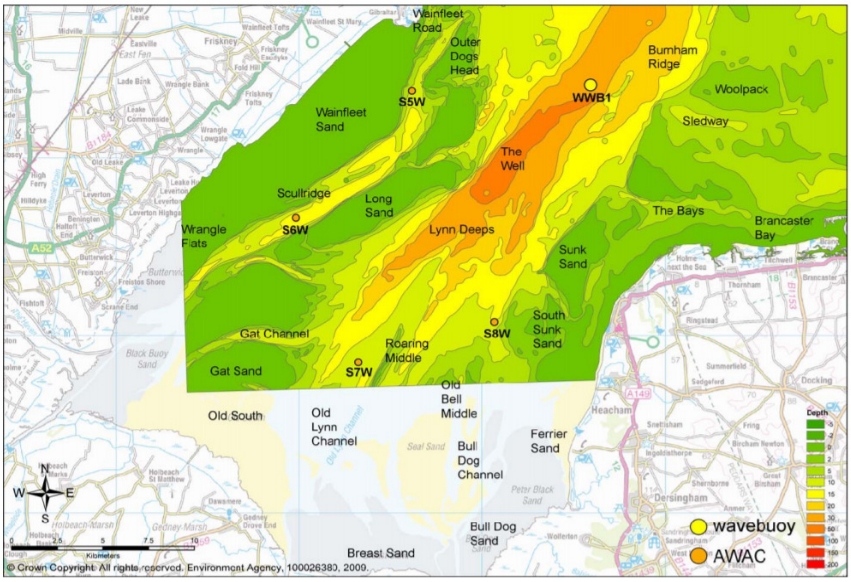

Figure 2-1 Plot showing offshore wave buoy location in yellow (extracted from Environment Agency Sea State Report 2010)

From this wave data the wave rose diagram, Figure 2-2, has been created. Based on this, it can be concluded that at the mouth of The Wash, the waves generated in or propagating from the North Sea approach from a narrow range of directions with the larger waves coming predominantly from the north-east sector. They travel along the length of the main channels before being dissipated by the shallow bed profiles and surface roughness of the inter-tidal sand and mud flats. Waves are also generated inside The Wash via strong winds combined with high water spring tides. These waves will generally have shorter periods than the ones coming from the North Sea.

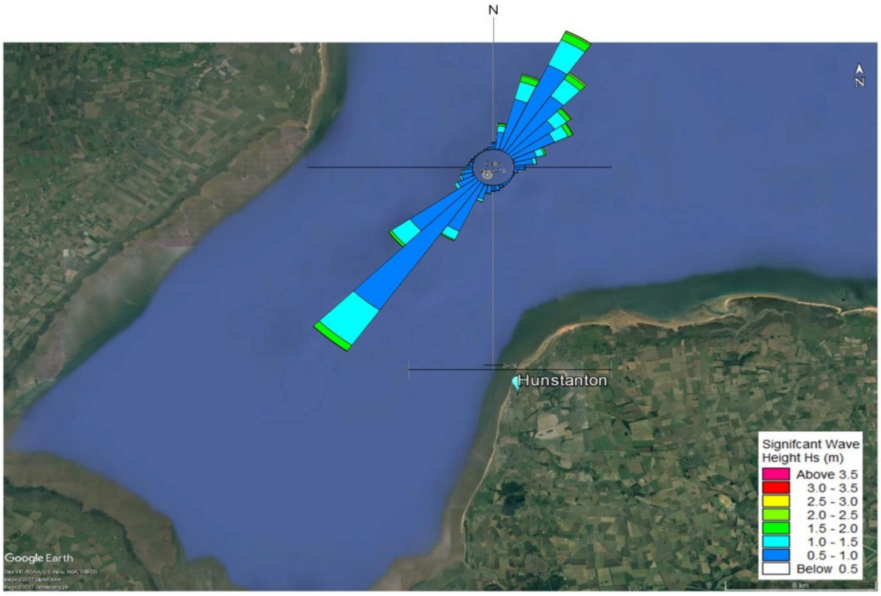

Figure 2-2 Wave rose diagram (imagery ©2017 Google)

2.3.1 Extreme Offshore Waves

Base year extreme wave heights from the CCO offshore wave data at North Well are derived from a Weibull extreme analysis. Note that the available offshore wave data covered a relatively short period, for extreme analysis, of 9 years. The short period of the record creates uncertainty in the extreme analysis for higher return period values, particularly return periods above 1 in 10 years.

Table 2-3 Extreme analysis for offshore wave

Return Period (years)	Annual Exceedance Probability (%)	Extreme Wave Height, H_s (m)
1 in 1	100	2.58
1 in 2	50	2.80
1 in 5	20	3.07
1 in 10	10	3.27
1 in 20	5	3.40
1 in 25	4	3.52
1 in 50	2	3.71
1 in 75	1.3	3.81
1 in 100	1	3.89
1 in 150	0.7	3.99
1 in 200	0.5	4.07

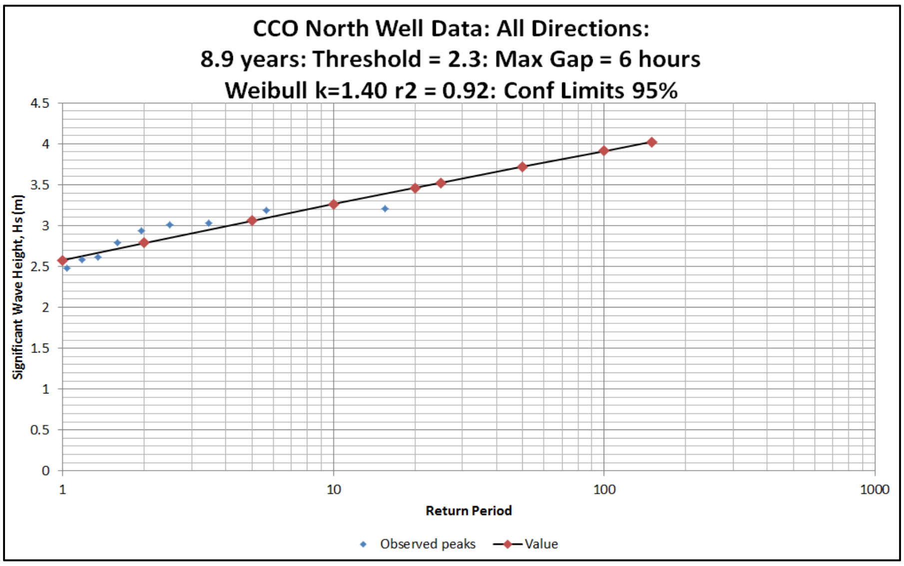

Figure 2-3 Extreme wave analysis - Weibull Distribution

2.3.2 Joint Probability

Joint probability refers to the chance of two or more conditions occurring at the same time. Joint probability analysis is an important aspect of coastal flood management as flood conditions are often caused by more than one environmental variable acting simultaneously. In this instance, regarding coastal flood and erosion risk, the coincidence of extreme waves and extreme water levels is of interest. In order to assess the probability of extreme waves and water levels combining to create an extreme event, a simplified joint probability analysis was undertaken.

The assessment was based on the guidance provided by DEFRA and Environment Agency joint publication; Use of Joint probability in Flood Management: A Guide of Best Practice – R&D Technical Report FD2308/TR2 (2005). The technique used follows that of the 'desk study approach' which involves the application of published EA dependence values between water levels and wave height. The published guidance suggests a "modest correlated" dependence value outside The Wash bay area. Although there is no site specific data available addressing the correlation between wave height and sea level, further analysis has been undertaken to examine the occurrence of peak wave events of the CCO data in relation to the water level. This analysis indicates that the peak wave events occurred during both high water and low water. Hence, it is appropriate to assume that wave height and sea level are modestly correlated in the area of interest.

Table 2-4: Joint probability of offshore waves and water levels

		Joint exceedance return period (years)							
		1	2	10	20	50	100	150	200
		Wave Height, Hs (m)							
Water Level (mOD)	**3.97**	1.88	2.14	2.75	3.00	3.30	3.55	3.69	3.78
	4.08	1.67	1.93	2.53	2.79	3.12	3.33	3.48	3.59
	4.34	1.17	1.43	2.04	2.30	2.64	2.90	3.05	3.15
	4.36	1.17	1.43	2.04	2.30	2.64	2.90	3.05	3.15
	4.48		1.22	1.82	2.08	2.43	2.69	2.84	2.94
	4.63			1.54	1.80	2.15	2.41	2.56	2.67
	4.75			1.33	1.59	1.93	2.19	2.35	2.45
	4.88				1.37	1.72	1.98	2.13	2.24
	4.92					1.65	1.91	2.06	2.17
	5.05					1.44	1.70	1.85	1.96
	5.12						1.57	1.72	1.83
	5.17						1.48	1.64	1.74
	5.25							1.51	1.62
	5.31								1.53

2.3.3 Nearshore Waves

The determination of nearshore wave extremes was conducted by transforming the CCO offshore wave climate data from the offshore wave buoy location (North Well) to nearshore (i.e. in front of the seawall) using the LITPACK software developed by DHI.

The main input parameters for the 1D wave transformation were bathymetric and topographic profiles, wave climate and water levels. Wave transformation was performed at 6 selected locations, using available bathymetry combined with the latest beach profiles provided by the Environment Agency. Joint probability combinations of water levels and wave heights were subsequently used for assessing the nearshore wave climate.

Wave refraction and wave growth are not taken into account in the 1D wave transformation model. For the purpose of this study, it is assumed that the direction of wave attack is perpendicular to the coastline. This may result in an overestimate of wave height, therefore providing a slightly conservative approach.

An examination of the CCO offshore wave data extracted from the North Well wave buoy indicated that the peak period associated with larger offshore wave heights are in the region of 7s. Therefore, a 7s peak period was selected for the wave transformation modelling. The offshore wave input parameters used for the model are summarised below:

- Significant wave height, H_s (m) and water level combinations – Table 2-4;
- Peak wave period, T_p (s) – 7s;
- Wave direction, W_{dir} – Perpendicular to the coast (285° for NH002, NH0012, NH016, NH020, 300° for NH028 and NH035 – for locations of the beach profiles used see Figure 2-5).

Wave transformation was performed on 6 beach profiles, using the latest beach profiles (summer 2017 profiles) provided by the Environment Agency. Nearshore waves were extracted at the 0m ODN contour. The highest nearshore wave heights were selected for each return period and tabulated in Table 2-5.

It should be noted this is a high level 1D wave transformation that aims at giving a reasonable estimate of the magnitude of potential wave climate associated with various return periods for use for the options appraisal process.

Table 2-5 Nearshore significant wave heights, H_s (m)

Return Period (years)	NH002	NH012	NH016	NH020	NH028	NH035
1	1.94	1.95	1.97	1.94	1.95	1.90
2	2.10	2.14	2.17	2.12	2.15	2.04
10	2.25	2.34	2.43	2.33	2.39	2.18
20	2.29	2.38	2.47	2.38	2.44	2.21
50	2.35	2.42	2.52	2.42	2.48	2.28
100	2.39	2.48	2.57	2.48	2.53	2.33
150	2.42	2.50	2.60	2.51	2.56	2.35
200	2.43	2.52	2.62	2.53	2.57	2.37

2.3.4 Predicted Sea Level Rise

In order to consider sea level rise and derive extreme levels for the future time epochs (2030, 2060, 2117), the base year (2008) extreme water levels have been factored with UCKP09 95th percentile medium emission scenario (including surge) sea level rise projections. The present and future predicted extreme water levels are presented in Table 2-6.

Table 2-6 Base year and future predicted extreme water levels due to climate change

Return Period (Years)	Extreme Water Level (mOD)	Water Level mOD under Medium Emissions Scenario (95%) + Surge		
	2008	2030	2060	2117
1	4.36	4.43	4.64	5.11
2	4.48	4.55	4.76	5.23
10	4.75	4.82	5.03	5.50
20	4.88	4.96	5.16	5.63
50	5.05	5.13	5.33	5.80
100	5.17	5.25	5.45	5.92
150	5.25	5.33	5.53	6.00
200	5.31	5.39	5.59	6.06

Predicted future climatic changes are also expected to cause increased storminess and consequently larger extreme waves. Although there is no general agreement on quantitative estimates of increases, the National Planning Policy Framework (NPPF) provides indicative allowances for extreme wave heights.

Table 2-7 Climate change allowance for extreme wave height

Parameter	1990 -2055	2056-2115
Extreme wave height allowance	5%	10%

Additional 1D wave transformation was carried out using the same approach to determine the effect of climate change on nearshore wave height. The wave model was applied using the joint probability wave/water levels including the effect of sea level rise and climate change. The assessment is undertaken for 3 future epochs, 2030, 2060 and 2117 and the results summarised in Table 2-8, Table 2-9 and Table 2-10.

Table 2-8 Effect of climate change on nearshore wave heights (m) in 2030

Return Period (years)	NH002	NH012	NH016	NH020	NH028	NH035
1	2.01	2.03	2.05	2.02	2.04	1.97
2	2.16	2.21	2.25	2.19	2.23	2.10
10	2.29	2.38	2.48	2.38	2.44	2.22
20	2.32	2.42	2.52	2.42	2.47	2.24
50	2.39	2.47	2.56	2.47	2.52	2.33
100	2.44	2.52	2.62	2.53	2.58	2.37
150	2.46	2.55	2.64	2.55	2.60	2.39
200	2.47	2.57	2.66	2.57	2.62	2.41

Table 2-9 Effect of climate change on nearshore wave heights (m) in 2060

Return Period (years)	NH002	NH012	NH016	NH020	NH028	NH035
1	2.12	2.15	2.17	2.14	2.15	2.08
2	2.26	2.31	2.36	2.32	2.34	2.20
10	2.38	2.47	2.55	2.50	2.52	2.31
20	2.41	2.51	2.61	2.55	2.57	2.34
50	2.48	2.57	2.66	2.61	2.62	2.42
100	2.52	2.61	2.71	2.66	2.67	2.46
150	2.54	2.63	2.73	2.68	2.68	2.48
200	2.56	2.65	2.75	2.70	2.70	2.50

Table 2-10 Effect of climate change on nearshore wave heights (m) in 2117

Return Period (years)	NH002	NH012	NH016	NH020	NH028	NH035
1	2.14	2.15	2.16	2.14	2.15	2.12
2	2.33	2.37	2.40	2.36	2.38	2.29
10	2.51	2.59	2.67	2.60	2.64	2.46
20	2.56	2.65	2.74	2.66	2.70	2.50
50	2.61	2.68	2.79	2.70	2.74	2.56
100	2.66	2.75	2.84	2.76	2.80	2.60
150	2.68	2.77	2.87	2.79	2.82	2.62
200	2.70	2.78	2.87	2.80	2.83	2.64

2.3.5 Comparison to Previous Studies

The findings from the AECOM, 2017 1D modelling vary from the results presented in the Royal Haskoning (RH) 2012 report (Appendix K1). This is mainly due to differences in the methodology, as explained later in this section of the report. There are two locations where nearshore wave climate from the two reports can be directly compared:

1. CH4034 from the RH, 2012 is comparable to NH012 from AECOM, 2017 and
2. CH4036 from RH, 2012 is comparable to NH028 from AECOM, 2017

A comparison of the results is presented in Table 2-11. Note that AECOM, 2017 results in Table 2-11 are different to the results previously presented in Table 2-5 as they are extracted at different locations. In the RH, 2012 report, nearshore waves are extracted at 0.5m ODN for RP below 50 and -1.1m ODN for RP above 50. For the purpose of comparison, wave heights tabulated in Table 2-11 are extracted at comparable locations.

Table 2-11 Nearshore wave height (m) comparison

	Nearshore wave height (m) Comparison 1		Nearshore wave height (m) Comparison 2	
	RH (2012)	**AECOM (2017)**	**RH (2012)**	**AECOM (2017)**
RP	**CH 4034**	**NH012**	**CH 4036**	**NH028**
1	1.95	1.95	1.64	1.94
2	2.00	2.10	1.68	2.16
10	2.03	2.26	1.79	2.46
20	2.12	2.30	1.83	2.51
50	2.98	2.52	2.24	2.64
100	3.02	2.56	2.28	2.66
200	3.06	2.61	2.36	2.71

Comparison 1 shows that the wave heights from AECOM 2017 are very similar to RH 2012 for RP below 50, whilst wave height values for RP above 50 are lower than the RH results. In Comparison 2, wave heights from AECOM 2017 are higher than RH 2012.

The West East Coastal Management Strategy – Task 1 a2 – Baseline Coastal Processes Report (RH, 2012) used wave data from RH, 2010 which assumed maximum deep wave heights/periods/directions for lower water levels up to 1:50 per year, and for extreme water levels above 1:50 per year (as below). Deep water waves are translated to nearshore waves using look-up tables based on the EurOtop method.

- Less severe than 1:50 – H_s= 2.5m, T_p = 6s, Direction 300°
- 1:50 and more severe – H_s= 3.5m, T_p = 8s, Direction 330°

The AECOM 2017 data presented in Table 2-5, Table 2-8, Table 2-9 and Table 2-10 are calculated using a different approach to previous studies using the latest wave data and beach profiles. It takes into account of joint probability where a range of water level and wave combinations associated with different return periods are assessed using the MIKE by DHI LITPACK modelling software.

As described previously, wave growth and other 2D effects i.e. complex bathymetry/wind-wave interactions are not included in the approach used. These effects could be significant as the distance to the CCO offshore wave point (North Well) is approximately 14km away from the shore. Wave growth due to wind could increase the wave heights. On the other hand, refraction due to complex bathymetry could decrease the wave heights. Despite these factors, the wave climate estimates are considered realistically conservative as Posford Duvivier, 1996 indicates that the significant wave heights at the entrance to the Wash of around 3m, reducing to around one metre further inshore. However, the application of a 2D wave model is recommended to account for the influence of wave growth and refraction if a more detailed assessment of the local wave climate is required in the future.

The extreme analysis for significant wave height is based on a 9 year dataset. It should be noted that this short period of records creates uncertainty in the extreme analysis for higher return period values. Additional wave data covering a longer period (i.e. UKMO data covering 37 years) can be purchased and used to confirm the validity of the extreme analysis in future studies.

2.4 Beach Data Review

Figure 2-4 below is extracted from the RH, 2012 report showing the sediment character in The Wash and Wash East Coastal Management Strategy frontage.

In the offshore areas of East Anglia, excluding The Wash, the seabed sediments are dominantly sands or gravelly sands. An important source of sand for this area is the Norfolk Cliff where erosion of Pleistocene sediments provides approximately 400,000m^3 of sand per year (BGS, 1988). Within The Wash itself, the central main channel has a relatively high percentage of gravel. This originates from the deposition of glacial till that was carried by the Devensian ice sheet. The material was deposited in the North Sea and northern parts of The Wash embayment as the ice melted and was then redistributed by rising sea levels.

Well sorted sand, which comprises the lower shore between Hunstanton and Heacham, is present throughout the intertidal and subtidal zones of The Wash. The sand fraction shows a coarsening trend towards the centre of The Wash. Mean grain sizes range between 0.250mm and 0.375mm on the sandbanks, and between 0.125mm and 0.180mm on the tidal flats (RH, 2012).

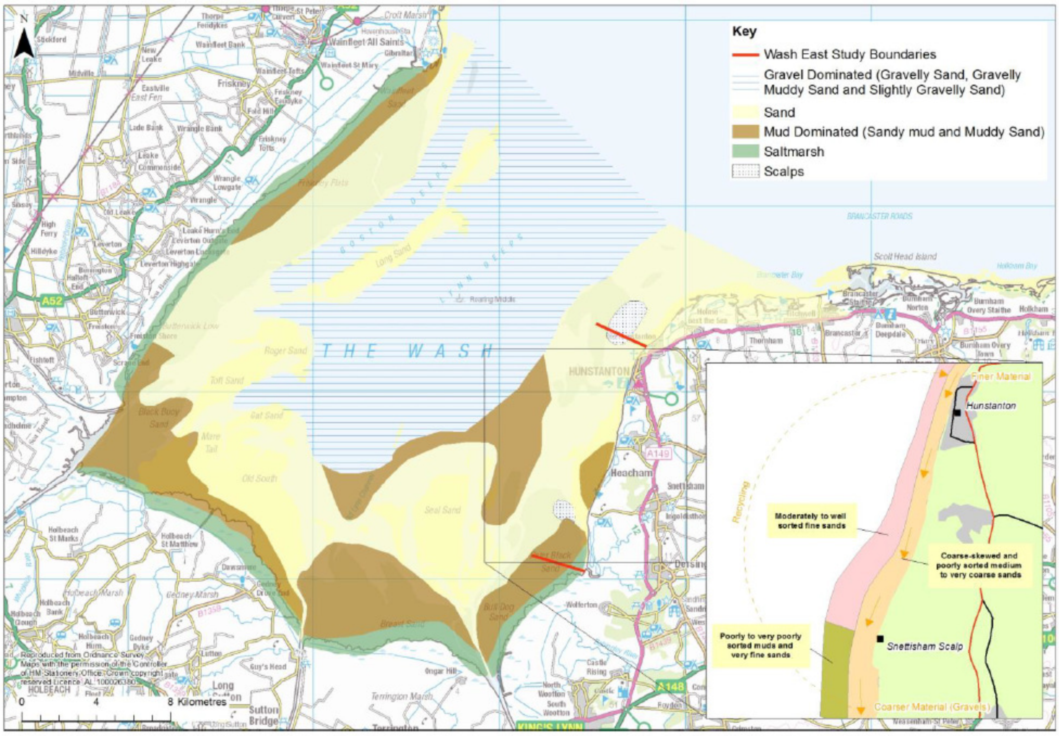

Figure 2-4: Figure extracted from RH, 2012 showing beach material within The Wash

2.5 Beach Profile Analysis

Beach profile data has been analysed in order to identify any trends in erosion and accretion. Beach profiles were provided by the Environment Agency for the frontage between 2010 and 2017. Generally two profiles at each location have been captured a year, in summer (April – September) and in winter (October – March). Figure 2-5 shows the locations of the surveyed beach profiles.

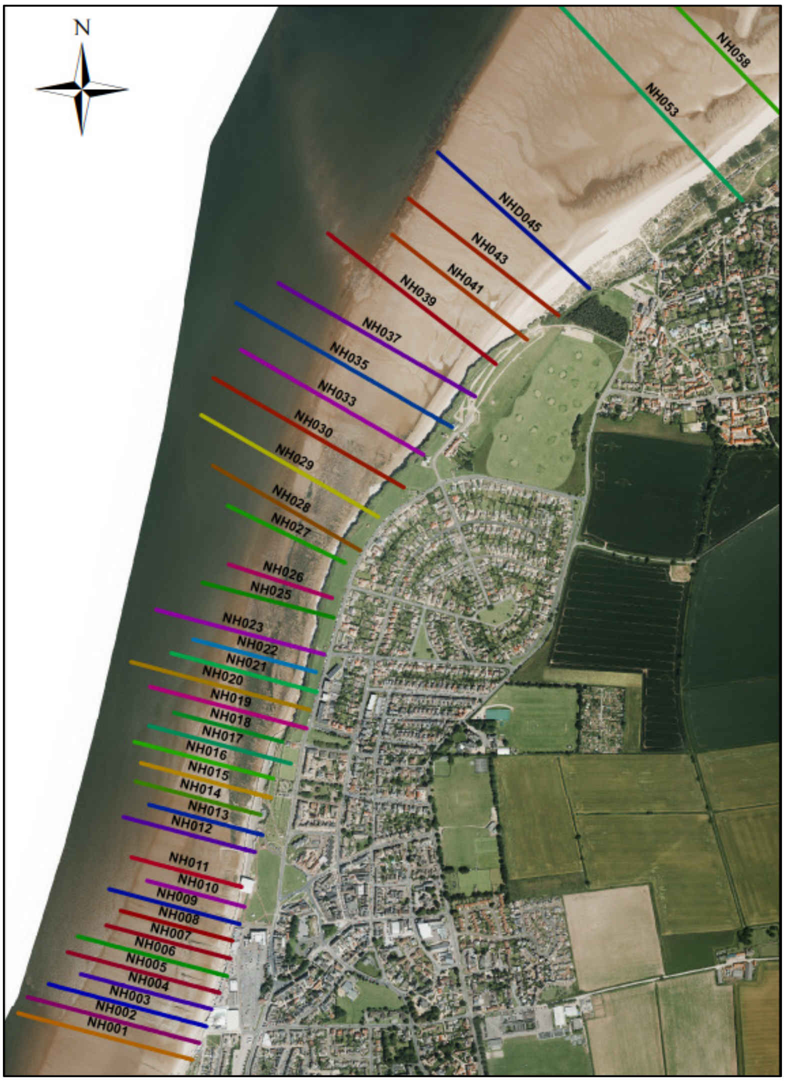

Figure 2-5: Map showing locations of beach profiles (map imagery © 2017 CCO)

To analyse the data 6 profiles were selected to represent the frontage: NH002, NH012, NH016, NH020, NH028 and NH035. The aims of the analysis were to quantify the variability of beach levels and to identify any trends in either accretion or erosion.

2.5.1 NH002 (Seawall)

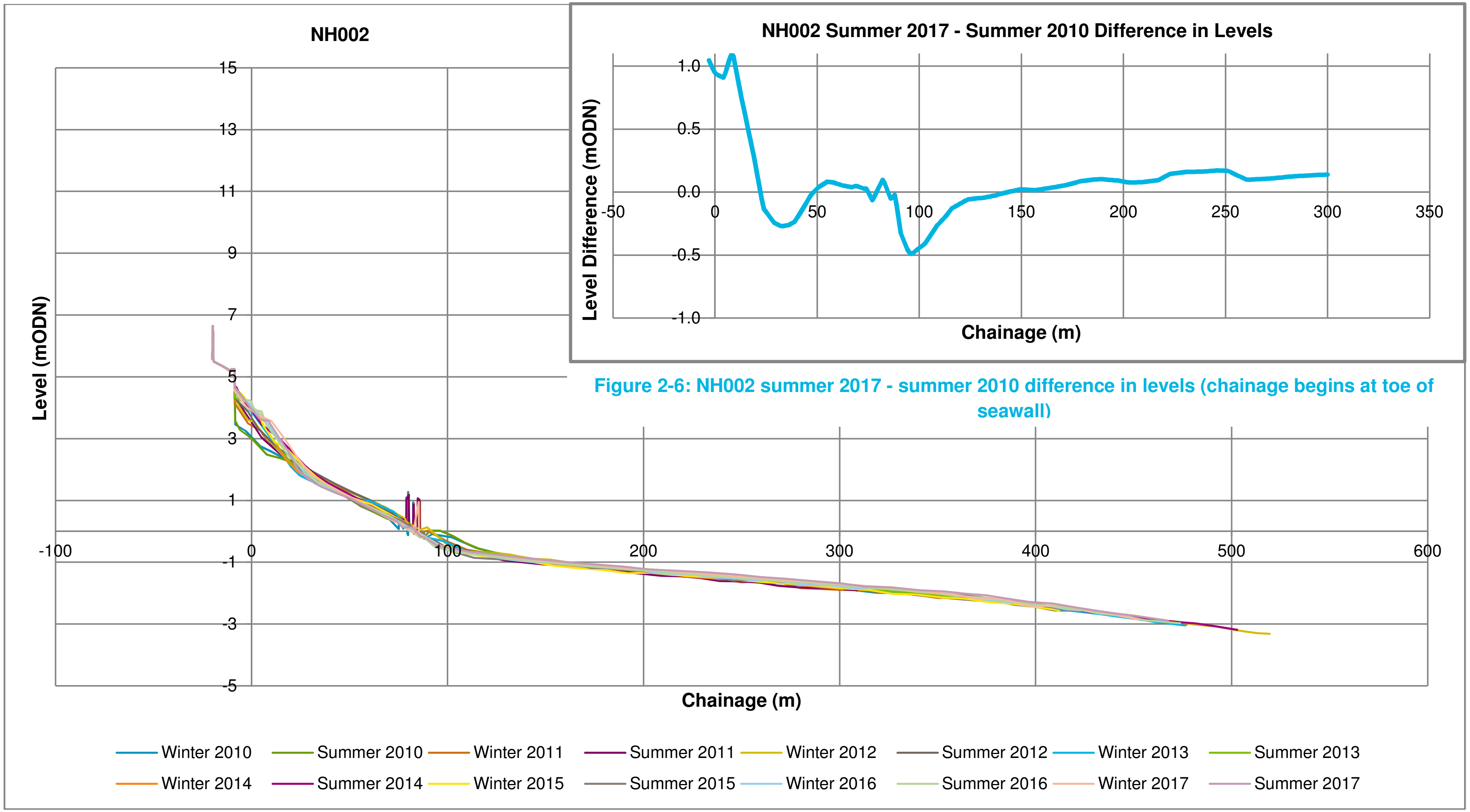

Figure 2-6: NH002 summer 2017 - summer 2010 difference in levels (chainage begins at toe of seawall)

Figure 2-7: NH002 beach profile levels

Figure 2-7 shows that maximum variation in beach levels has been less than 1.5m over the last 7 years. Figure 2-6 shows that the biggest difference between the latest profile and the earliest profile is found at the top of the beach where accretion has occurred to a maximum of approximately 1m. Below the upper 25m of beach the changes in levels are smaller, less than +/-0.5m, and demonstrate both erosion and accretion of material. It can be seen that whilst the upper 150m of beach has both erosion and accretion, in the lower 150m the levels have only increased. Overall, it has been observed that from the toe of the seawall to 300m offshore there appears to have been a net increase in beach volume over the last 7 years.

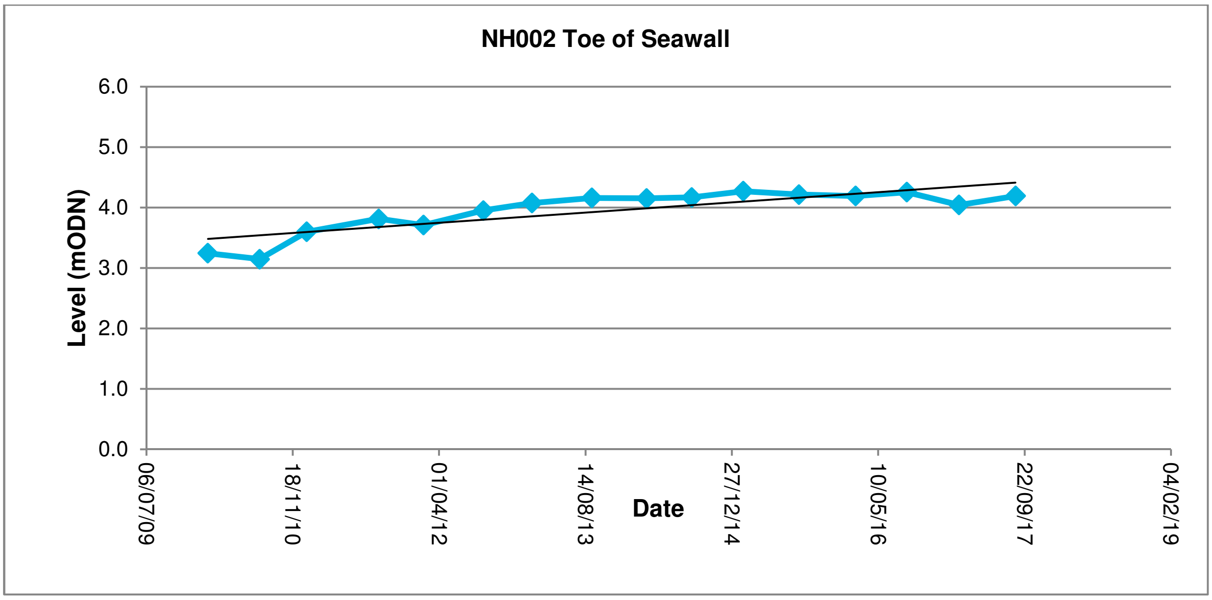

Figure 2-8: NH002 levels at toe of seawall

Figure 2-8 shows that at the toe of the seawall at NH002 the overall trend has been one of accretion of approximately 0.1m/year, although the level of beach material was higher in 2016 than 2017 which means this might not be representative of the long term trend. The beach level at the toe of the wall has varied by approximately 1.1m over the monitoring period.

2.5.2 NH0012 (Seawall)

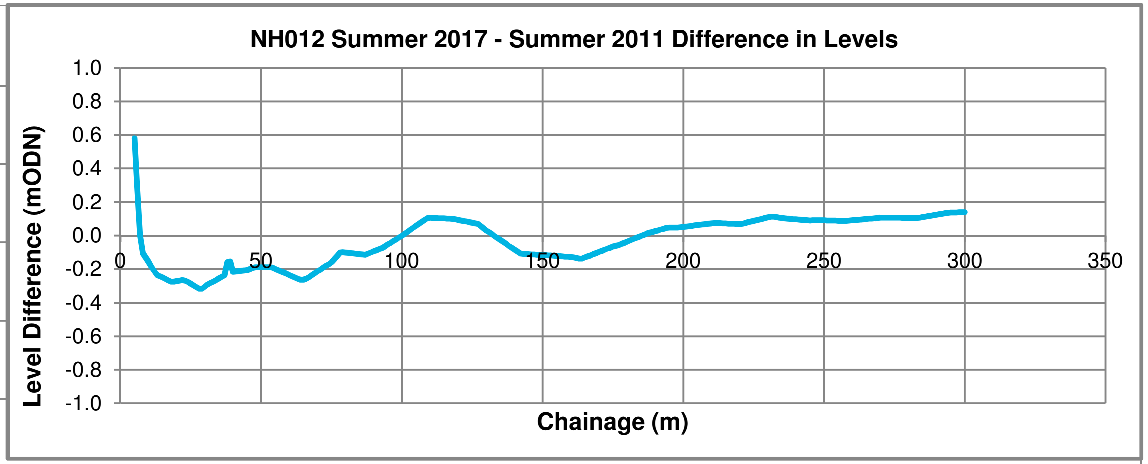

Figure 2-9: NH012 summer 2017 - summer 2011 difference in levels (chainage begins at toe of seawall)

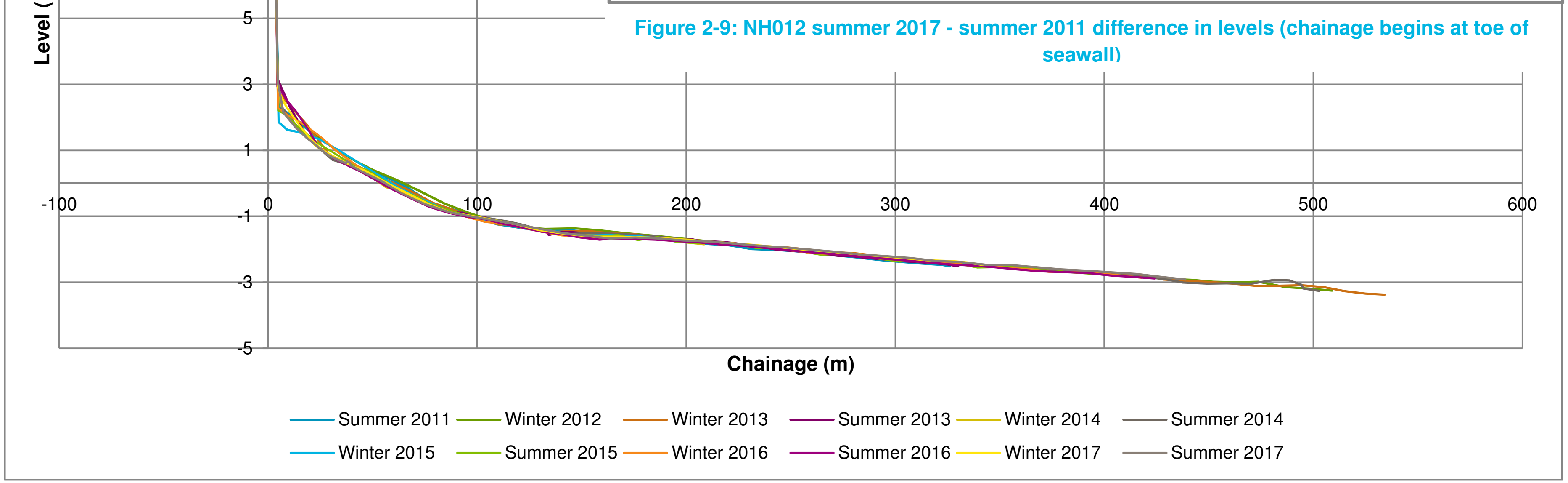

Figure 2-10: NH012 beach profile levels

Figure 2-10 shows that maximum variation in beach levels has been less than 1.5m over the last 6 years. Figure 2-9 shows that the biggest difference between the latest profile and the earliest profile is found at the top of the beach where accretion has occurred to a maximum of approximately 0.6m. Below the upper 10m of beach the changes in levels are smaller, less than +/-0.3m, and represent both erosion and accretion of material. It can be seen that whilst the upper 200m of beach has both erosion and accretion, in the lower 100m the levels have increased. Overall, it has been observed that from the toe of the seawall to 300m offshore there appears to have been a net reduction in beach volume over the last 6 years.

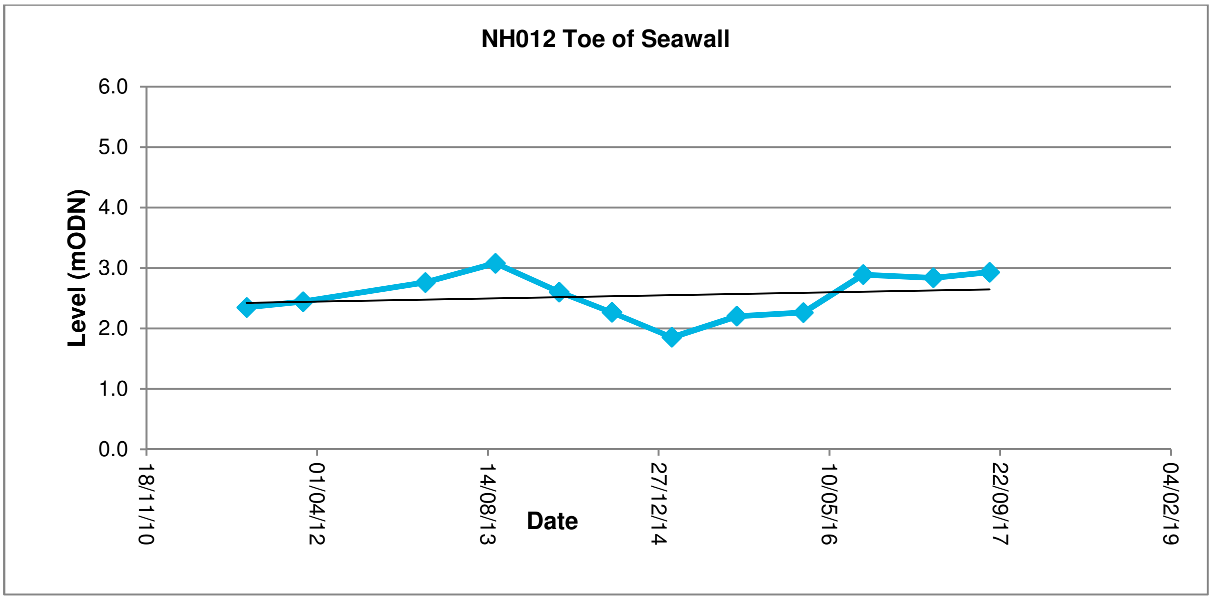

Figure 2-11: NH012 levels at toe of seawall

Figure 2-11 shows than at the toe of the seawall at NH012 the overall trend has been one of accretion of less than 0.1m/year. However, the trend is not well established with the highest level seen in 2013 and the lowest in 2015 indicating erosion of 1.2m between these years. The level at the toe of the wall has varied by approximately 1.2m over the monitoring period.

2.5.3 NH0016 (Seawall)

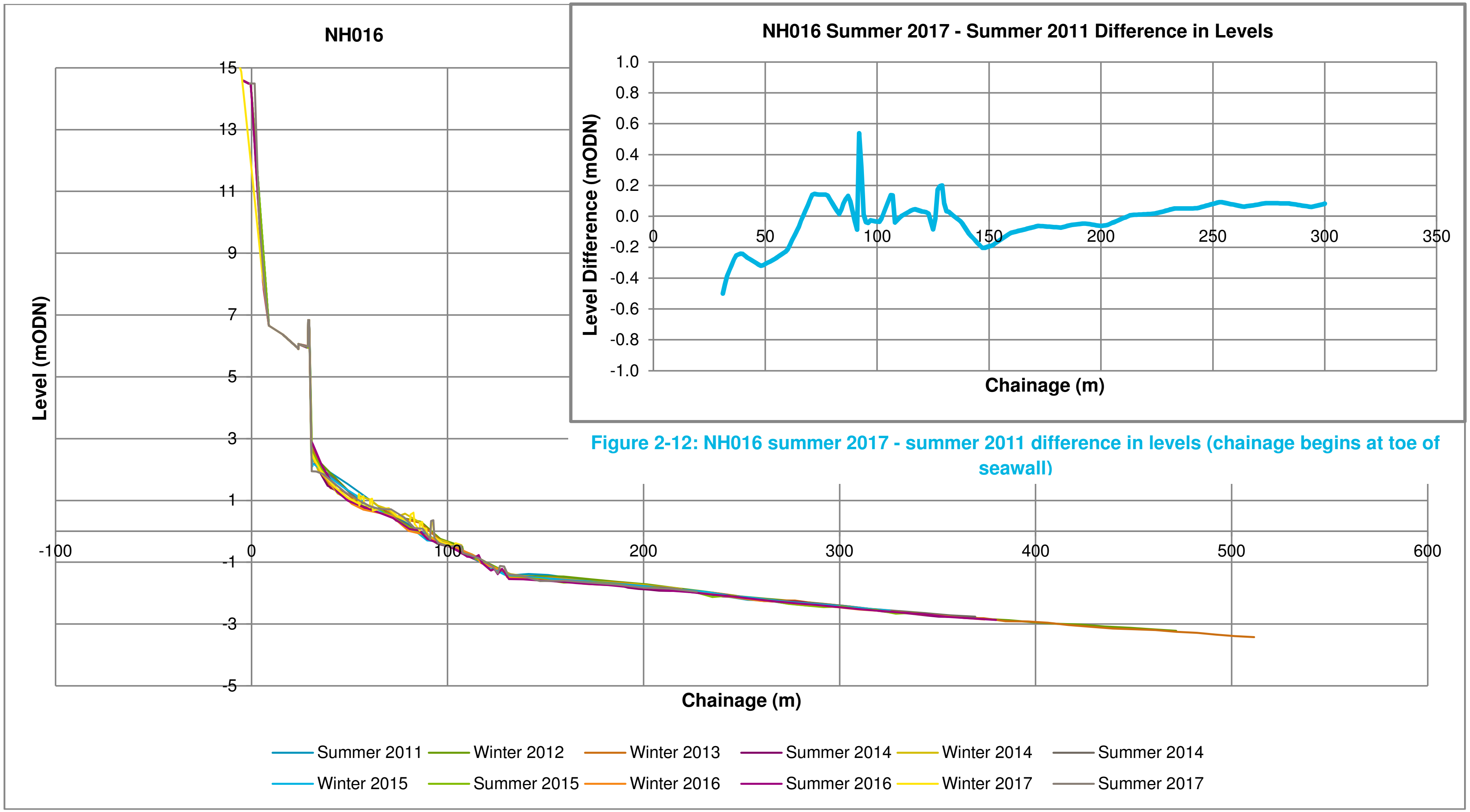

Figure 2-12: NH016 summer 2017 - summer 2011 difference in levels (chainage begins at toe of seawall)

Figure 2-13: NH016 beach profile levels

Figure 2-13 shows that maximum variation in beach levels has been less than 1m over the last 6 years. Figure 2-12 shows that the biggest variations between the latest profile and the earliest profile occur in the upper 150m of beach where there has been both areas of accretion and erosion. Below the upper 150m the variations are less than +/-0.2m indicating the beach has been more stable. Overall, it has been observed that from the toe of the seawall to 300m offshore there appears to have been a net reduction in beach volume over the last 6 years.

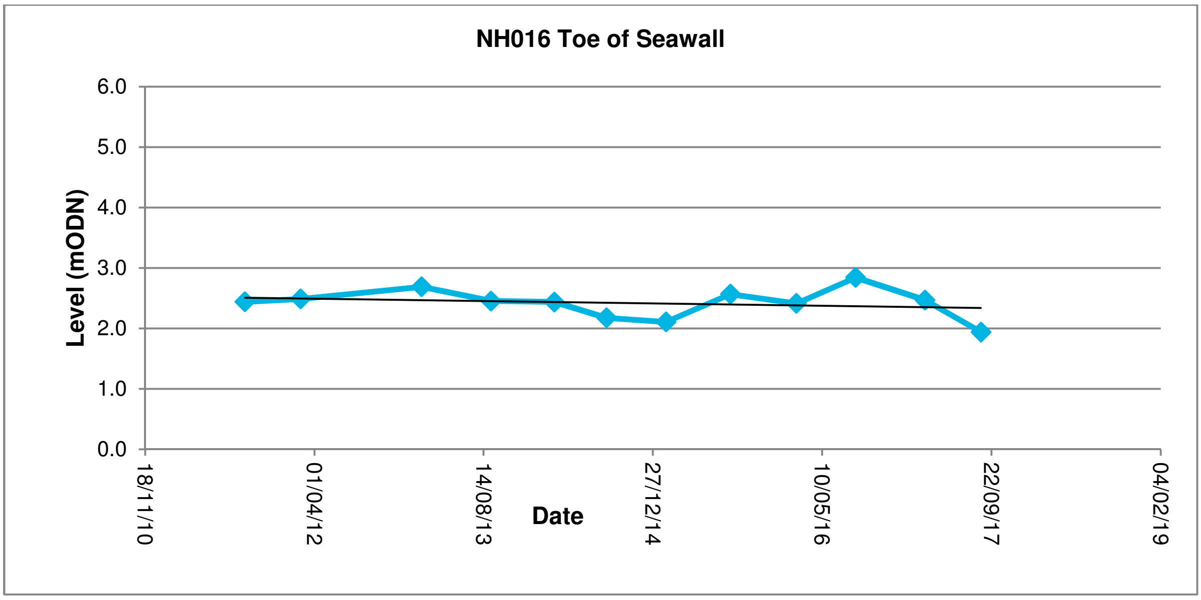

Figure 2-14: NH016 levels at toe of seawall

Figure 2-14 shows that at the toe of the seawall at NH0016 the overall trend has been one of erosion of less than 0.1m/year. However, this is not well established with sequent annual surveys showing accretion of material. The level at the toe of the wall has varied by approximately 0.9m over the monitoring period.

2.5.4 NH020 (Cliff)

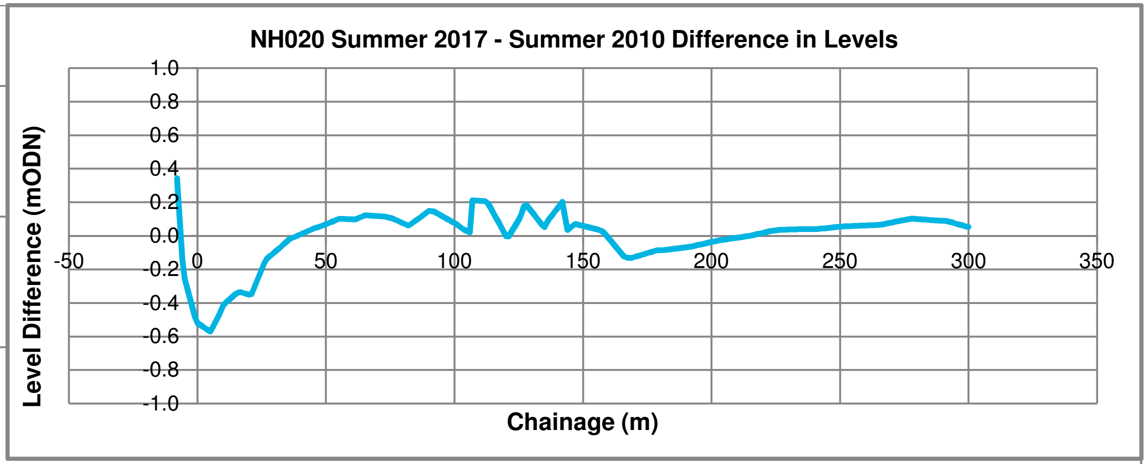

Figure 2-15: NH020 summer 2017 - summer 2010 difference in levels (chainage begins at toe of seawall)

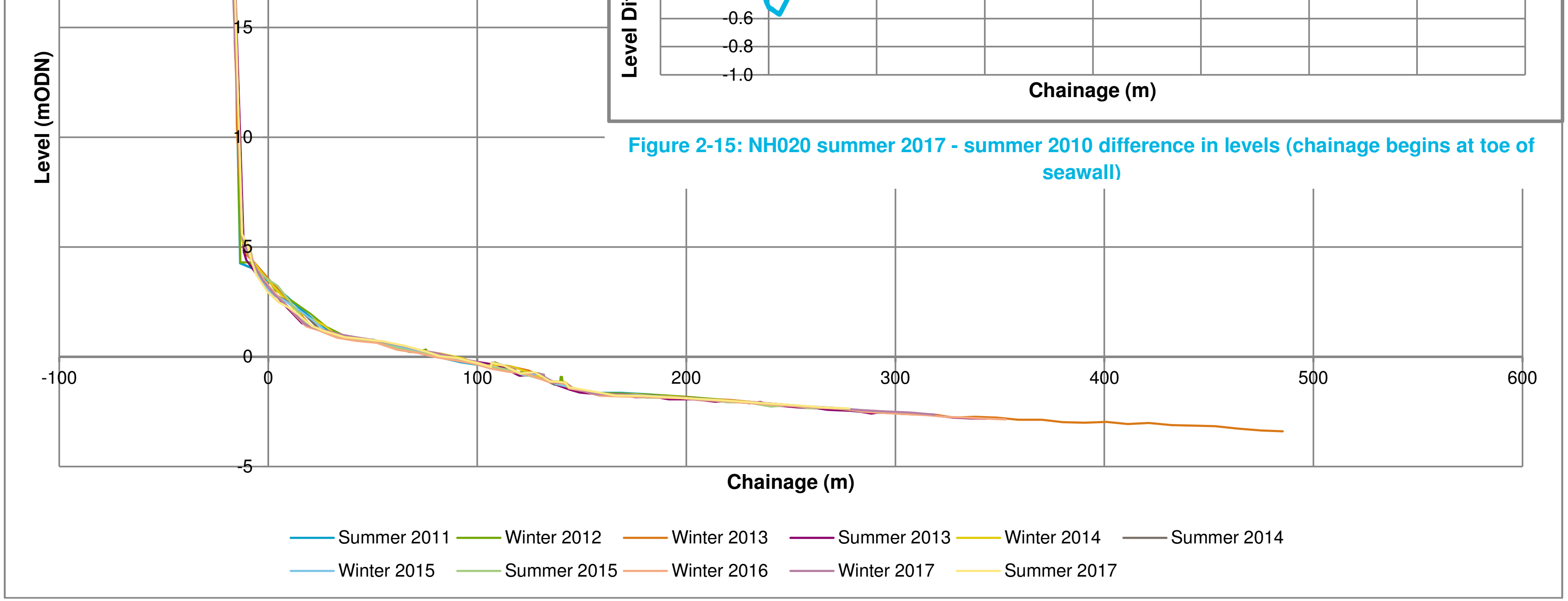

Figure 2-16: NH020 beach profile levels

Figure 2-16 shows that maximum variation in beach levels has been less than 1m over the last 6 years. Figure 2-15 shows that the biggest difference between the latest profile and the earliest profile is found at the top of the beach where there is accretion to a maximum of 0.4m and then in the next 25m there is erosion to a maximum of -0.6m. Below the upper 25m of beach the changes in levels are smaller, less than 0.2m, and indicate both erosion and accretion of material. Overall, it has been observed that from the toe of the seawall to 300m offshore there appears to have been a small net reduction of beach volume over the last 6 years.

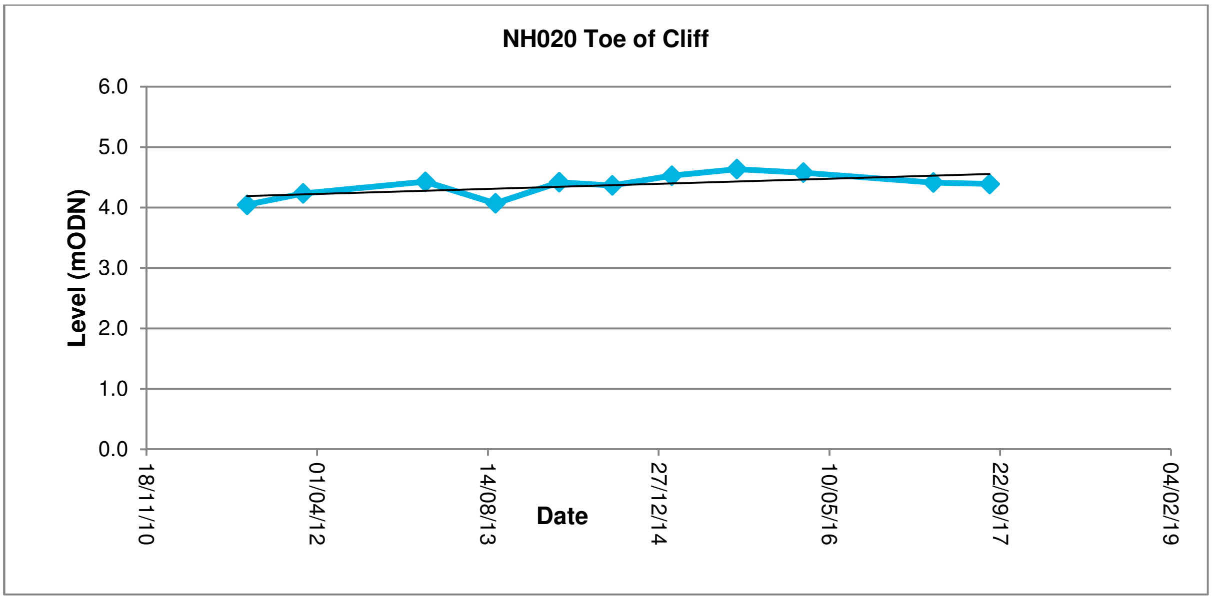

Figure 2-17: NH020 levels at toe of cliff

Figure 2-17 shows that at the toe of the cliff at NH020 the overall trend has been one of accretion of less than 0.1m/year, although this trend is not well established with the beach level lowering in the last 2 years. The level at the toe of the cliff has varied by approximately 0.6m over the monitoring period.

2.5.5 NH028 (Cliff)

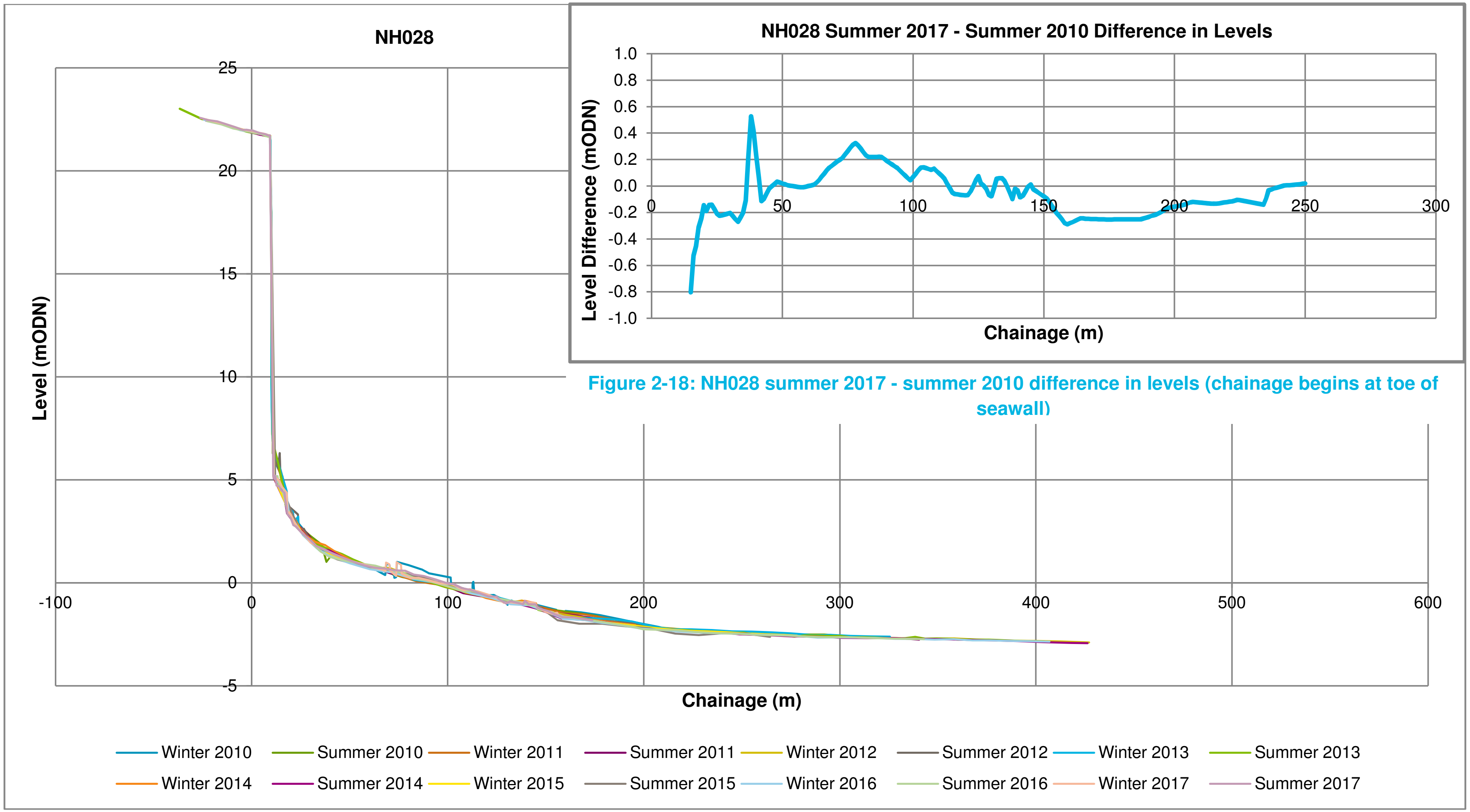

Figure 2-18: NH028 summer 2017 - summer 2010 difference in levels (chainage begins at toe of seawall)

Figure 2-19: NH028 beach profile levels

Figure 2-19 shows that maximum variation in beach levels has been less than 1.5m over the last 7 years. Figure 2-18 shows that the biggest difference between the latest profile and the earliest profile is found in the upper 100m of beach where there is both erosion and accretion to a maximum change of approximately 0.8m. Below the upper 100m of beach the changes in levels are smaller, less than +/-0.3m, and indicate the beach is more stable here. Overall, it has been observed that from the toe of the seawall to 300m offshore there appears to have been a net decrease in beach volume over the last 7 years.

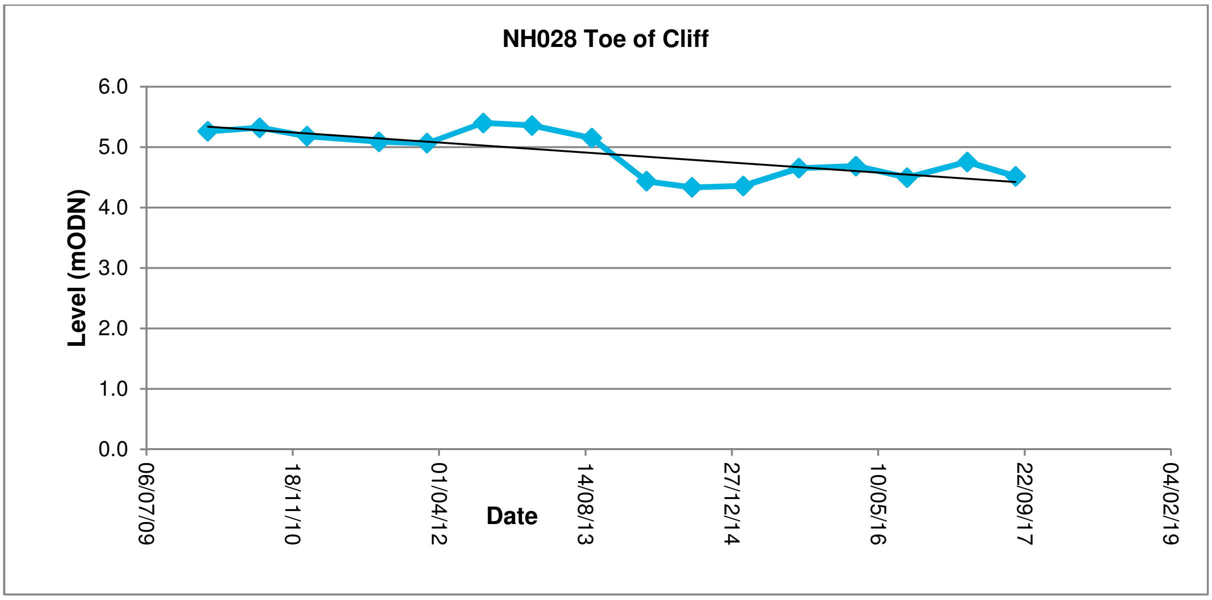

Figure 2-20: NH028 levels at toe of cliff

Figure 2-20 shows that at the toe of the cliff at NH028 the overall trend has been one of erosion of approximately 0.1m/year, although there have been consecutive annual surveys that have shown accretion of material. The level at the toe of the cliff has varied by approximately 1.0m over the monitoring period.

2.5.6 NH035 (Cliff)

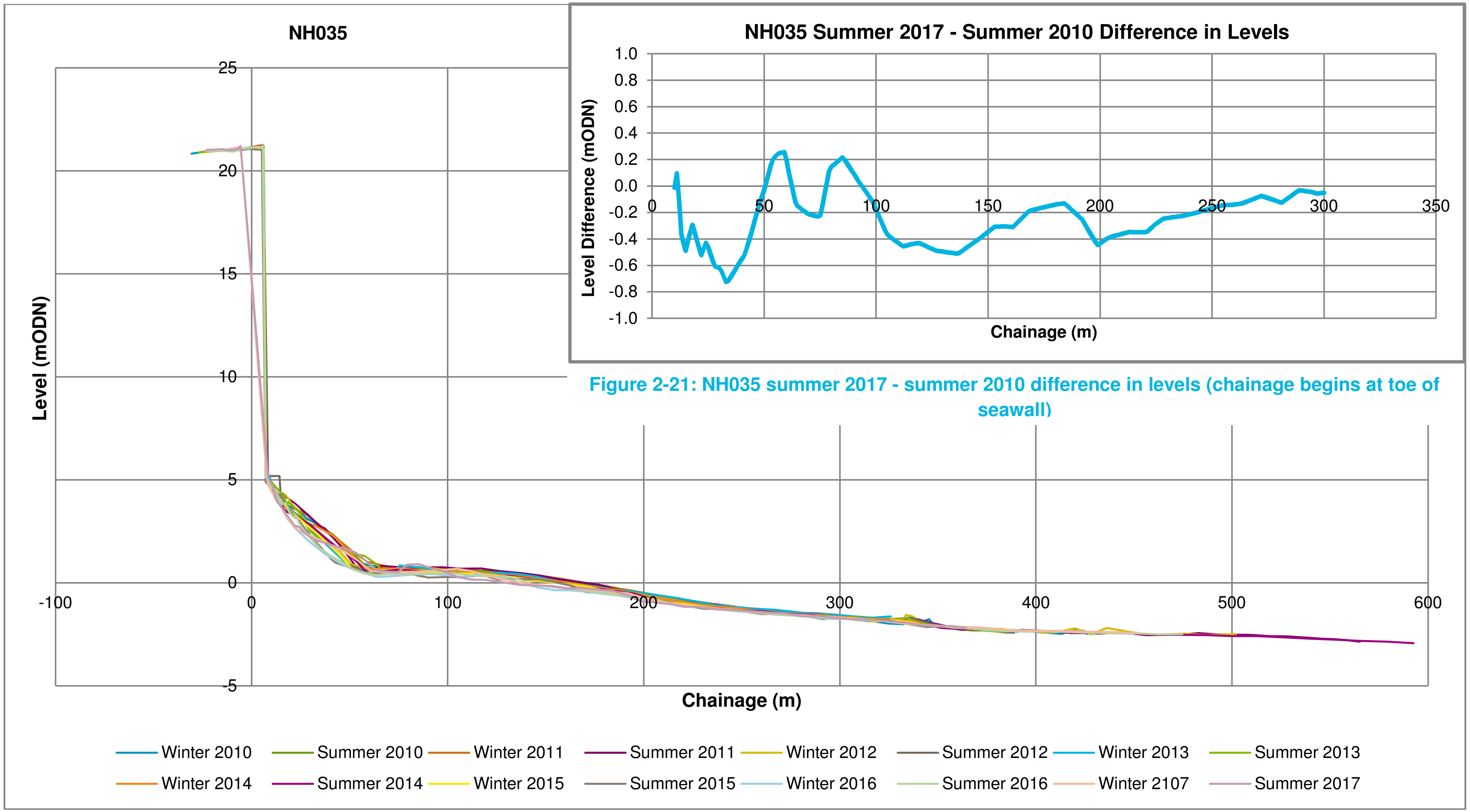

Figure 2-21: NH035 summer 2017 - summer 2010 difference in levels (chainage begins at toe of seawall)

Figure 2-22: NH035 beach profile levels

Figure 2-22 shows that maximum variation in beach levels has been less than 1.5m over the last 7 years. Figure 2-21 shows that the biggest difference between the latest profile and the earliest profile is to a maximum of +/- 0.7m with both erosion and accretion occurring across the chainage. Overall, it has been observed that from the toe of the seawall to 300m offshore there appears to have been a net decrease in beach volume over the last 7 years.

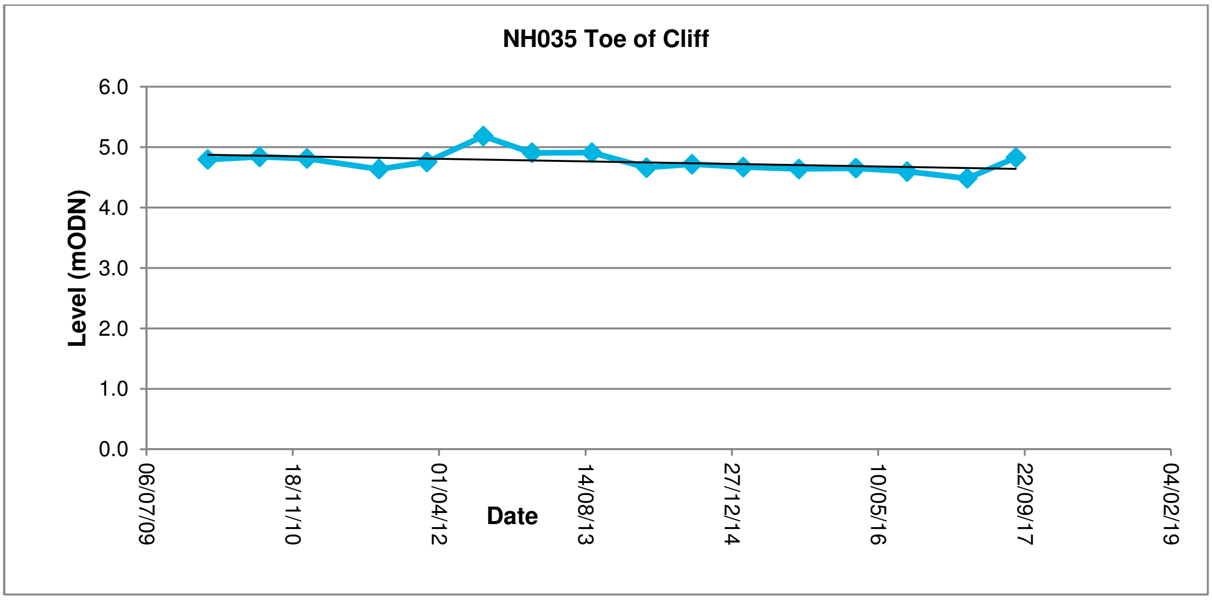

Figure 2-23: NH035 levels at toe of cliff

Figure 2-23 shows that at the toe of the cliff at NH035 the overall trend has been one of erosion of less than 0.1m/year, although there have been consecutive annual surveys that have shown accretion of material. The level at the toe of the cliff has varied by approximately 0.7m over the monitoring period.

2.6 LiDAR Data Analysis

Available LiDAR (Light Dectection And Ranging) data from the CCO website has been obtained for the Hunstanton frontage. The LiDAR data provides information covering the years 2011 (October), 2012 (November), 2013 (March) and 2014 (November). The plots in Figure 2-24 show the annual net changes in beach level. These annual net change plots show that the beach level along the Hunstanton frontage is mostly within +/- 0.6m per year. Areas between NH012 and NH028 that have seen drawdown in one year, seem to experience recovery to previous levels in the following years. Consequently, no specific trend or pattern of erosion and accretion can be determined within this area. An example of this is towards the end of the seawall (near NH020) where there was erosion between 2012 and 2013 followed by accretion in the next year.

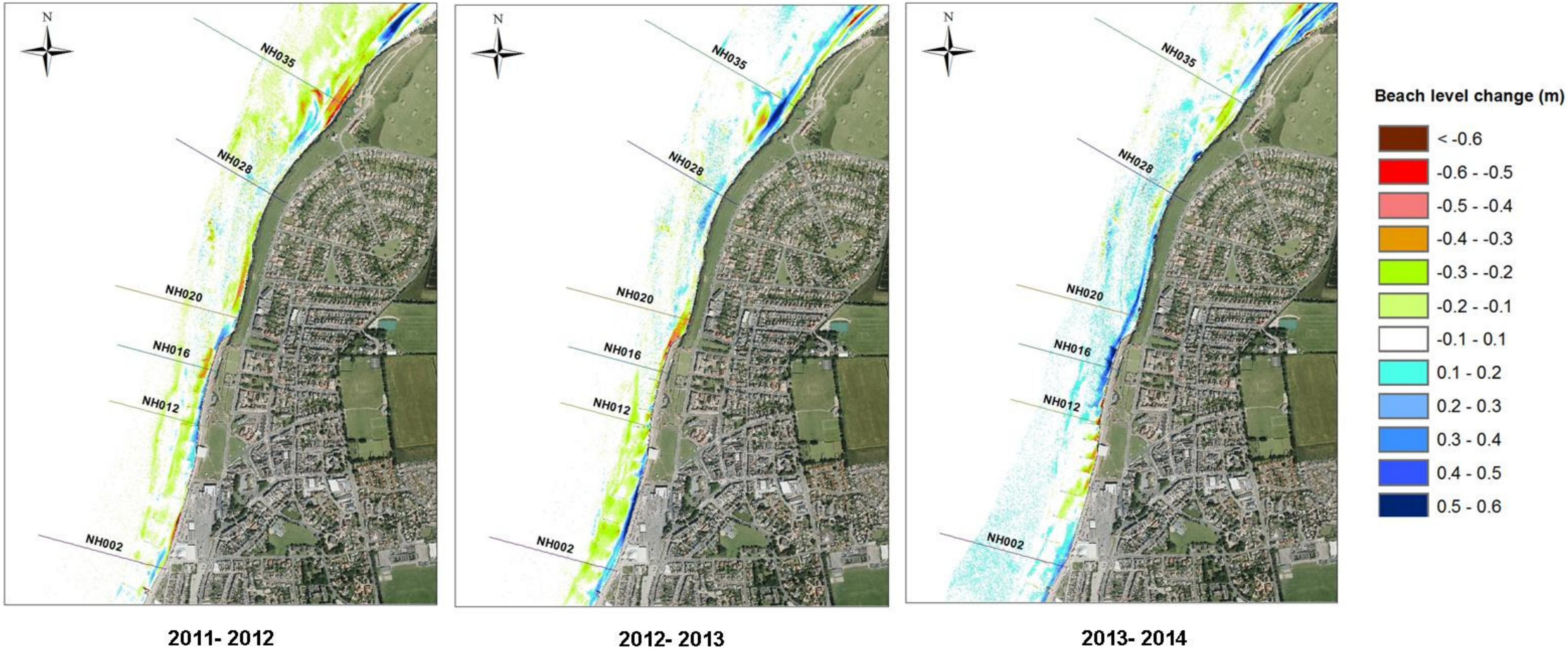

Figure 2-24: Annual net change in beach level

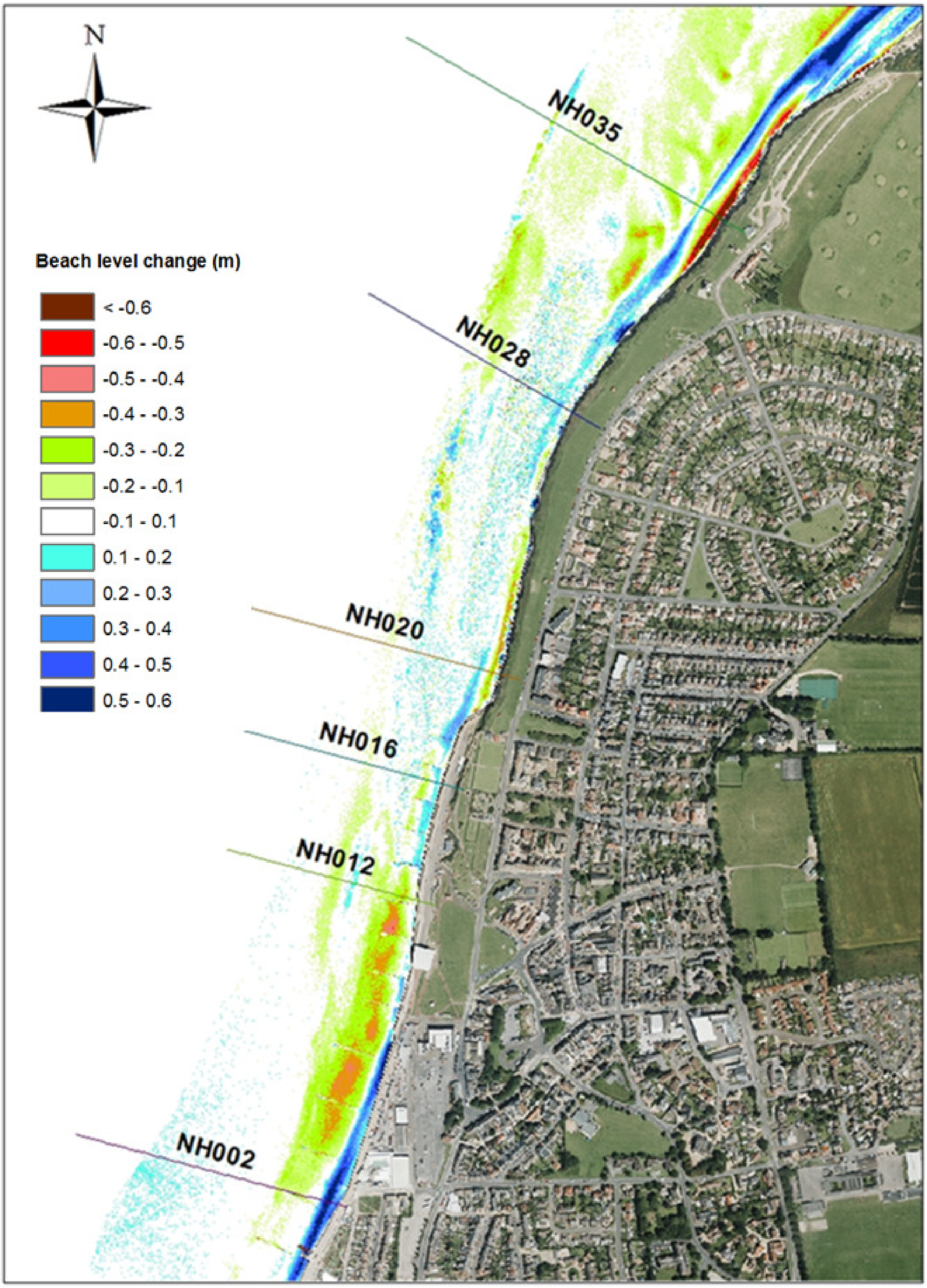

Figure 2-25 Total net change in beach level 2011 to 2014

The plot in Figure 2-25 shows the total net changes in beach level between 2011 and 2014. The figure shows a cumulative erosion of up to -0.5m between NH002 and NH012. The area immediately in front of the seawall at NH002 shows an accumulative accretion of up to 0.6m. The data also suggests that the area adjacent to the seawall between NH012 and NH020 has experienced accretion of up to 0.2m over the 3 years. The limited change in beach levels between NH020 and NH028 is due to this area being largely covered by the wave cut platform.

2.7 Discussion

The largest change in beach levels surveyed has been approximately 1.5m over the last 7 years. It has generally been observed that the level of the upper 100m of beach is more variable, with the lower beach being typically more stable. The only profile analysed that shows a trend of accretion over the 7 years was NH002. It is postulated that material could be accreting in this location because of changes to the coastline alignment here, as shown in Figure 2-26. The net transport is from north to south and as the alignment changes just north of NH002 the wave angle to the coast reduces the amount of down-drift material.

To confirm this additional analysis was undertaken for NH001 (located to the south of NH002), where it was found that there has also been a net increase in material over the last 6 years, similar to NH002 (as shown in Figure 2-27), this supports the theory that the change in alignment of the coastline is potentially the reason for more material accreting here. All other analysed profiles show that over the past 7 years there has been a net reduction in beach levels, although all profiles show a mixture of accretion and erosion.

Figure 2-26: Change in seawall alignment at NH002

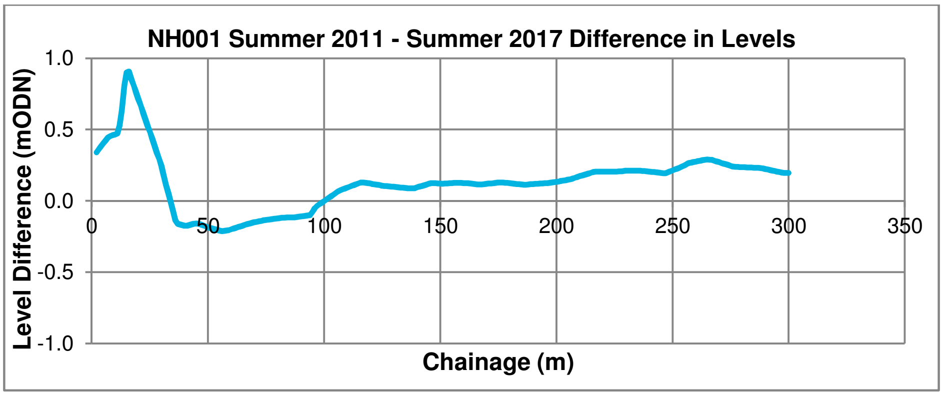

Figure 2-27: NH001 summer 2011 - summer 2017 difference in levels (chainage begins at toe of seawall)

Figure 2-28 illustrates how the beach level at the toe of the wall gradually increases moving from north to south towards NH002. The drift of material from north to south in the study area can also be observed by the difference in beach levels on either side of the groynes as shown in the image.

Figure 2-28: Looking south towards NH002, increasing beach levels observed

The LiDAR plot showing the difference between 2014 and 2011 levels shows a general trend of erosion occurring between NH002 and NH012, with some accretion of material occurring adjacent to the seawall. However, without additional years of LiDAR data available to analyse, this cannot be confirmed to be a long term trend.

Generally, along the toe of the seawall and cliff the beach levels have appeared quite stable, although some cyclic variation has been observed, longer term trends have been difficult to establish. The maximum variability of the beach levels along the toe of the seawall has been less than 1.1m over the last 7 years; this should be considered in the design of options along with previous analysis of beach levels carried out to date.

3. Preliminary Environmental Assessment

3.1 Introduction

This Preliminary Environmental Assessment (PEA) is a review of the environmental work undertaken to date relevant to the Hunstanton Coastal Management Plan. As the environmental work undertaken to date is extensive this review highlights only key environmental data and constraints that should be taken into account during the development of the Plan.

The review considers each of the following environmental aspects:

- Previous studies;
- Land use;
- Environmental designations;
- Historic environment;
- Water Framework Directive;
- Preferred Strategy option and the environment.

3.2 Previous Studies

The Wash Shoreline Management Plan (Royal Haskoning DHV, 2010) undertook a Strategic Environmental Assessment and a Water Framework Directive assessment to appraise the potential environmental consequences of the high-level decision-making and shape the selection of the preferred option.

Similarly, the Wash East Coastal Management Strategy (Royal Haskoning DHV, 2015) included a Strategic Environmental Assessment, Habitats Regulation Assessment and Water Framework Directive assessment.

3.3 Land Use

The Hunstanton Cliffs in Unit A are designated for their geological interest, which benefits from them being undefended. On the southern section the current cliff edge lies approximately 100 metres from the road and properties of Hunstanton. In the northern section the cliff is characterised by a large open space, a car park (used mainly by visitors to the cliffs and beach), tourist facilities (café and toilets) and the lighthouse.

Hunstanton town is a regional commercial centre and coastal resort. Unit B is characterised by the beach, promenade, seaside amenity area and numerous holiday parks. It provides year-round tourist accommodation and facilities.

The beach and cliffs along the entire frontage are popular for amenity use. Along the clifftop both the Peddars Way and Norfolk Coast Path (which will form part of the Hunstanton to Sutton Bridge stretch of the England Coast Path by 2020) are located, locally these paths starts in Hunstanton Town and then continue north along the coast eventually exiting Unit A.

3.4 Environmental Designations

Table 3-1: Table showing environmental designations located on frontage

Designation Type	Name	Units	Size (ha)	Description / Reason for Designation
International Designations				
Ramsar Site	The Wash	Units A and B	62,212	The Wash is the largest estuarine system in Britain. There are extensive saltmarshes, intertidal banks of sand and mud, shallow waters and deep channels. It is the most important staging post and over-wintering site for migrant wildfowl and wading birds in eastern England. It supports a valuable commercial fishery for shellfish and also an important nursery area for flatfish. There are species at levels of international importance present (for example Eurasian Oystercatcher, Common Redshank and the Pink Footed Goose). (JNCC, 2008)
Special Area of Conservation (SAC)	The Wash and North Norfolk Coast	Units A and B	107,718	Annex I habitats include sandbanks, mudflats, sandflats, shallow inlets and bays, reefs and coastal lagoons. Annex II species include the Harbour Seal and Otter. (JNCC, 2016)
Special Protection Area (SPA)	The Wash	Units A and B	62,212	The Wash provides habitat for a large number of bird species. The intertidal habitats contain important food sources for the large numbers of waterbirds dependent on the site. The Wash is of outstanding importance for a large number of geese, ducks and waders, both in spring and autumn migration periods, as well as through the winter. In the summer, the Wash is an important breeding area for Terns and as a feeding area for Marsh Harrier. (JNCC, 2017)
National Designations				
Site of Special Environmental Interest (SSSI)	Hunstanton Cliffs (land)	Unit A	4.5	The cliffs are of geological interest for the Red Chalk and the underlying Carstone. This is an important locality for the study of the sedimentology of these normally poorly exposed formations, in the area where the Carstone is thickly developed. Additionally biological interest is provided by a breeding colony of

				Fulmars on the cliff face. This is the largest colony on the east coast of England, south of Flamborough Head. (Natural England, 2017)
	The Wash (marine)	Units A and B	63,135	The whole area is of exceptional biological interest. The intertidal mudflats and saltmarshes represent one of Britain's most important winter feeding areas for waders and wildfowl outside of the breeding season. Enormous numbers of migrant birds, of international significance, are dependent on the rich supply of invertebrate food. The saltmarsh and shingle communities are of considerable botanical interest and the mature saltmarsh is a valuable bird breeding zone. In addition the Wash is also very important as a breeding ground for Common Seals. (Natural England, 2017)

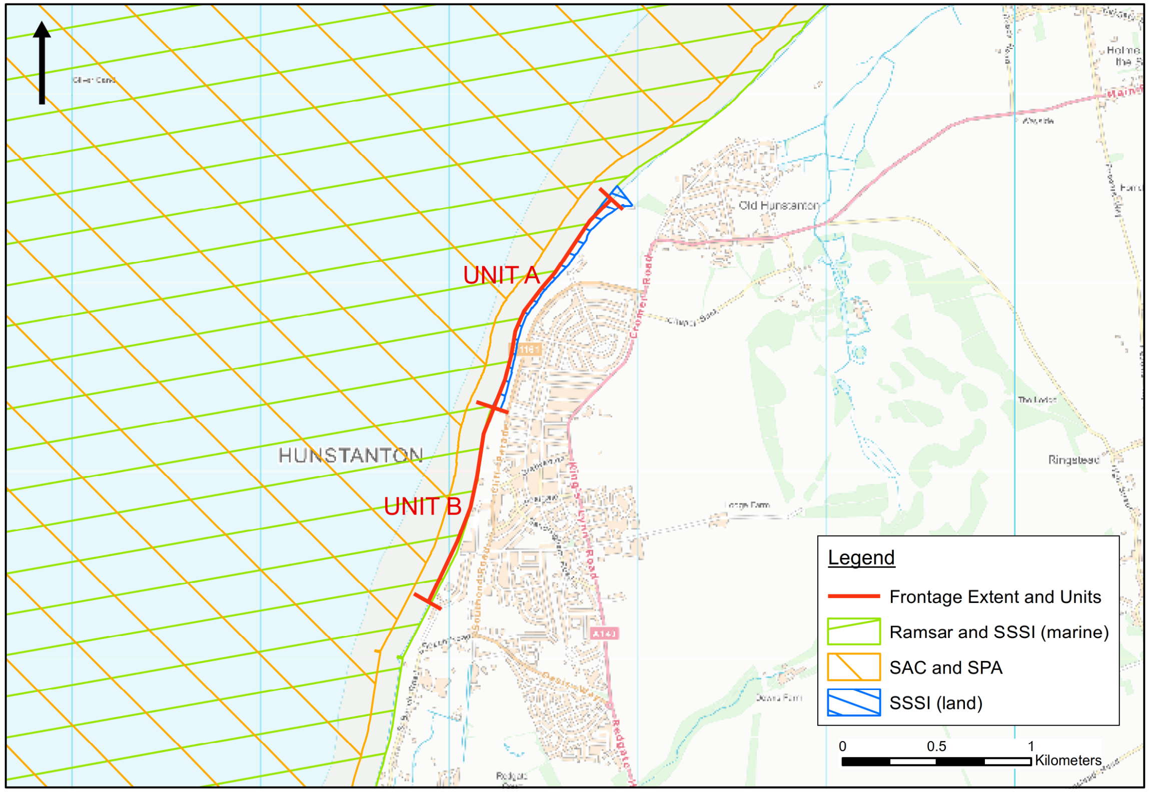

Figure 3-1: Map showing environmental designations on frontage (contains OS data © Crown copyright and database right 2017). Note: the SAC and SPA extend to Mean High Water, whilst the Ramsar Site and marine SSSI extend up to the toe of the seawall/cliff.

3.5 Historic Environment

The Historic England database of listed buildings has been reviewed for sites along the frontage.

There are important historic assets on the cliff top (Unit A), including two listed buildings. The Ruins of St Edmund's Chapel (set-back approximately 55 m from the cliff edge) and the Lighthouse (set-back approximately 30 m from the cliff edge). In Hunstanton Town (Unit B) the following listed assets are set-back approximately between 140-280 m from the seawall: Golden Lion Hotel, Town Hall, Church of St Edmund and a cross.

A section of the frontage is also in Hunstanton's Conservation Area which encompasses the main town and the Lighthouse (spans across Units A and B).

Figure 3-2: Locations of listed assets (© Historic England 2017)

3.6 Water Framework Directive

The Units are fronted by the Wash Outer coastal water body (below MHWS), part of the Anglian River Basin District. The hydromorphological designation of this water body is 'not designated artificial or heavily modified'.

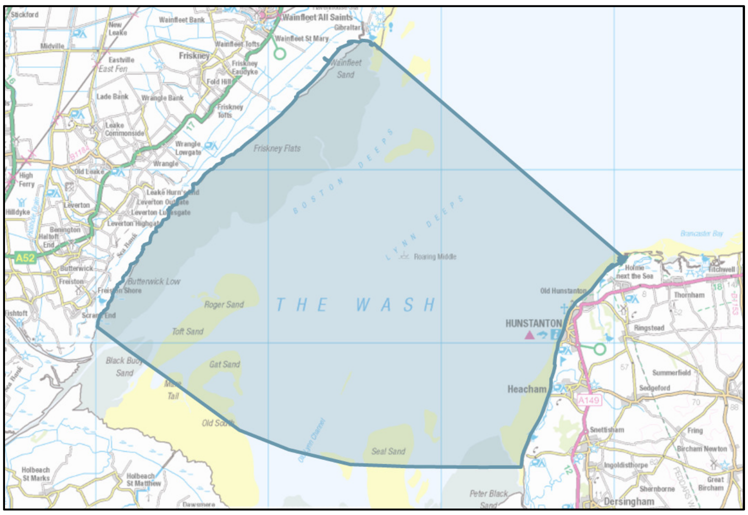

Figure 3-3: Location of the Wash Outer water body from Catchment Data Explorer (© Environment Agency 2017)

A summary of the condition of the water body from the Environment Agency Catchment Explorer is given in the table below.

Table 3-2: Wash Outer water body classification summary

	2009 Cycle 1	2016 Cycle 2	Predicted Outcome
Overall Water Body	Moderate	Moderate	Moderate by 2021
- Ecological	Moderate	Moderate	Moderate by 2021
- Chemical	Does not require assessment	Good	Good by 2021

3.7 Preferred Strategy Option and the Environment

The Strategy concluded that the preferred option for Unit A is unlikely to have any significant effect on any internationally designated sites. The monitoring programme that will accompany the piloting of defence measures will ensure that any impacts on the SSSI are identified and appropriate measures are put in place, both for the Fulmar colony and the geological interest of the cliffs. The WFD assessment concluded that the piloting is unlikely to cause a decline in water body condition or affect any future mitigation measures (Environment Agency, 2015).

For Unit B, any future works will be to existing defences, so it was determined that there would be no deterioration in the condition of any WFD water bodies or any internationally designated sites (Environment Agency, 2015).

4. Hunstanton Cliff Assessment

4.1 Introduction

A preliminary geotechnical assessment of the Hunstanton Cliff in Unit A has been undertaken in October 2017 by AECOM. A complete note from the inspection is included in Appendix A and summarised below.

The aim of the assessment was to:

- Assess the current condition of the cliff;
- Identify the failure and erosion mechanisms;
- Consider the suitability of options to slow down / reduce the rate of erosion including those recommended in the Strategy for a Pilot Study (Environment Agency, 2013).

4.2 Failure Mechanisms

The base of the cliff is formed of Carstone with Chalk above. Historic photos and maps show that the undefended cliff is regressing over time. Significant blockfalls were present along the whole length of cliff at the time of the visit and should be expected to continue to occur in the future at any point along the length of the cliff.

The failures at Hunstanton Cliff are the result of several different mechanisms:

- Erosion of the base of the cliff by wave action causing undercutting and subsequent blockfall from above;
- Erosion of the cliff face by groundwater percolating through joints in the rock;
- Erosion of the cliff face by surface run-off water;
- Erosion of the cliff face by water flowing from drainage pipes which daylight directly into the cliff face.

4.3 Options

The recommendations from the Strategy Pilot Study Appendix have had their suitability assessed. The options proposed for the piloting study in the Strategy were: base netting, sand bags, gabions and a rock sill (rock revetment).

In summary, it is considered that the creation of a rock sill would be the most suitable option, as it is a more resilient option than the others and would have a longer lifespan. The mechanism considered likely to be the cause of the majority of the instability of Hunstanton Cliff is wave action / erosion at the base of the cliff, which results in lack of support at the cliff base and subsequent collapse of the Carstone, leaving overhangs in the chalk to collapse at a later date. The creation of a rock sill would act to reduce wave action. The health and safety implications of undertaking construction works at the base of the cliffs must be considered in development of this option. Potentially a scaling exercise should be undertaken to remove loose blocks or masses of chalk ahead of the placement of the rock. It may also be possible to face the already eroded Carstone behind the rock sill with resin or sprayed concrete to further protect the existing material, although this should be considered alongside the restrictions set in place by the SSSI.

5. Condition Assessment Update

A visual inspection of the existing structures in the Study area has been carried out to provide residual lives of the existing structures to inform the economic assessment and the options appraisal. A full report is contained in Appendix B and the findings are summarised below.

The condition grades of the structures were determined using guidance from the Environment Agency (2006) Condition Assessment Manual. These grades were then converted into residual lives using the Environment Agency (2013) Condition Grade Deterioration Curves guidance. The results of previous surveys using non-visual investigation techniques (i.e. trial pits, beach level assessment, concrete cores and ground penetrating radar) were then used to provide additional information to predict the residual lives of the structures.

The predicted residual lives of the seawall structures which will inform the economic assessment are presented in Table 5-1.

Table 5-1: Predicted residual lives of Defence Sections (with low levels of maintenance)

Seawall Defence Section	Estimated Residual Life (years)
Section A	35
Section B	35
Section C	35
Section D	15
Section E	15
Section F	15
Section G	15

Please note that a copy of the draft Condition Survey Report is contained in Appendix B.

6. Economic Assessment Review

A brief review has taken place of the economic assessment work undertaken in the Wash East Coastal Management Strategy in order to ensure any recommendations from that work are taken into consideration and to provide a sense check on any new analysis.

The guidance and assumptions used in the Strategy development, taken from 'Appendix G - Economic Assessment' are listed below. The list is primarily focused on Units A and B as Unit C it outside of the Coastal Management Plan area.

- Options were assessed in accordance with the FCERM appraisal guidance over a 100 year appraisal period.
- Calculation of damages were undertaken in accordance with the approaches outlined in the Multi Coloured Handbook (2010).
- Property data was obtained from the National Receptors Dataset (NRD). Properties with an MCM code of 999 were inspected. Upper floor properties were removed from the flooding damages.
- Discount rates used were in accordance with the recommendation of the HM Treasury 'Green Book'. The economic base date used was December 2012.
- Market values of Residential properties were taken in December 2012. Values of Commercial properties were taken from 'Commercial and Industrial Floor Space and Rateable Value Statistics, 2008'.
- In Unit B the hard defences were considered to start failing in 10 to 20 years, with total failure by year 50. Following failure of these defences the cliff line would retreat to become aligned with the natural cliffs in Unit A.
- Flood damages were only considered to occur in Unit C (Unit A and B only affected by erosion).
- For the erosion damages properties were assumed to be uninhabitable 5 years prior to the date at which erosion would reach the property. This was justified as after this point it would not be safe due to the risk of sudden cliff collapse.
- Recreational damages were taken for Unit C only (where there is a large caravan park) for the loss of value of enjoyment of landscape, wildlife and natural amenities as well as for recreational activities.
- Tourism damages were also taken for Unit C only (where there is a large caravan park).
- No environmental damage was applied for the creation of habitat. This was because it was concluded that the uncertainties associated with climate change into the future are too great to provide a reliable quantification of the economic benefits of the habitat change.
- Agricultural losses associated with flooding were included in the Unit C damages.
- For the flooding damages in Unit C the costs of the emergency services were considered and the cost to human health.
- Road infrastructure damages were only applied in Unit C where disruption to the A149 was assessed.
- Utilities were identified as a potential benefit, but were not included in the assessment.
- Results:

  Unit A – 3 shelters, a café and a lighthouse at risk from erosion. Present Value (therefore discounted) 'Do Nothing' damages – £35,200.

  Unit B – 30 residential properties at risk from erosion and a variety of other non-residential buildings. Present Value 'Do Nothing' damages – £1,555,000.

7. Updated Economic Assessment

At this interim stage the only scenario which has been assessed is the ‘Do Nothing’ scenario, after the options have been developed other scenarios will be assessed. Below is a brief summary of the approach used and the results of the assessment. A stand-alone economic assessment report with full details of the approach taken is to follow the Interim Report.

7.1 Erosion Rates

The scenario was appraised over 3 time periods (also known as epochs) these were chosen to reflect the time periods used in the earlier Strategy work enabling previous information to be applied to this study:

- Short term: 2017 - 2030
- Medium term: 2030 - 2060
- Long term: 2060 – 2117

Erosion predictions have been based on the SCAPE (Soft Cliff and Platform Erosion) model that was constructed as part of the development of the Strategy. This model has been used for FCERM assessment purposes in the Strategy and has also previously been used for studies in other areas.

The model provides future recession rates for the 3 epochs used in the Strategy (present day to 2030, 2030 to 2060 and 2060 to 2110) for the different zones of Unit A. The predicted recession rates are shown in Table 7-1.

Table 7-1: Recession rates from SCAPE model extracted from Strategy Appendix K2

Zone	Epoch 1 NAI Recession Rate (m/year)	Epoch 2 NAI Recession Rate (m/year)	Epoch 3 NAI Recession Rate (m/year)
1.1	0.10	0.10	0.13
1.2	0.14	0.15	0.18
1.3	0.30	0.33	0.39
1.4	0.16	0.24	0.29

Figure 7-1: Output from SCAPE model for Unit A extracted from Strategy Appendix K2 (Cliff lines - green line 2030, yellow line 2060, red line 2110)

Unit B is a different situation because there are already existing defences. The SCAPE model considers that once the structures have failed, the cliffs would eventually 'step-back' to be in line with Unit A, whereas the coastline in Unit B is currently held further seaward by the defence structures. The model also assumes that the cliffs would have reached their equilibrium alignment at the end of epoch 2 (2060). This means an accelerated rate of erosion has been assumed from the time when the structures fail and 2060 as the cliff returns to the natural alignment, as shown in Figure 7-2.

Figure 7-2: Output from SCAPE model for Unit B extracted from Strategy Appendix K2

7.2 Properties at Risk

The erosion rates above were used to determine which properties were at risk and when they would be lost due to erosion. For Unit B where there are existing structures the residual lives of these structures were taken from the updated Condition Assessment Report. It was assumed that erosion in Unit B will only begin to occur once the existing structures reach the end of their residual lives (see Section 0).

The distances between the NRD property points and the frontage have been calculated using GIS. An adjustment has been made to reduce these distances by 5m to reflect the fact that the GIS points are generally in the centre of properties rather than at the edge nearest the frontage which is where the loss of the property would begin. In addition to this the distances have been reduced further to account for the danger of inhabiting a house at risk of imminent failure. Realistically houses will be abandoned before they are actually damaged due to erosion because of the risk of a large cliff failure event. The Strategy Baseline Coastal Processes Report (2012) states the estimated return period for a major failure of 3-5m depth of cliff is 10 to 20 years in the northern end of cliff and 5 to 10 years in the southern end of the cliff. Based on this it is thought that a reasonable reduction would be 5m, making the overall reduction in distances obtained through GIS to 10m (5m for the GIS point data being in the centre of properties and 5m for a property abandonment based on proximity to the cliff).

Note that at this stage of the economic assessment, sensitivity testing has also been carried out to show results for an assumed reduction of only 5m as well as 10m. This is provided as a check to see how much influence the above assumptions have on the property erosion damage values.

7.3 Flooding

7.3.1 Methodology

The prominent risk over the frontage is from erosion. Previous higher level studies have not considered the risk of flooding in Unit B because of its small risk and therefore limited the amount of damage. However, in this study it will be considered to reflect that in Unit B there have been previous high return period events that have caused flood damages, for example the December 2013 storm.

In Unit B there is a rear wave return wall along the landward side of the promenade which acts to remove much of the flood risk. This wall contains multiple gaps for access that in the event of a storm are blocked using flood gates. In a ‘Do Nothing’ scenario the FCERM guidance recommends that because manually operated flood gates are normally left open, it is pragmatic to assume they would be left open in this scenario (p.122, FCERM 2010).

Typically flood modelling is used to calculate flood damages in detailed economic assessments, but given the limited risk from lower return period events, no modelling has been undertaken at this site. Therefore, a high level approach using the Environment Agency Flood Map for Planning Risk has been used as a basis to estimate flood damages. Flood Zone 3 gives the flood extent for a 1 in 200 year or greater annual probability of flooding from the sea. The MCM provides guidance on the approach to use where only the number of properties that flood are known.

The Weighted Annual Average Damage (WAAD) approach for commercial properties (the only properties within Flood Zone 3 along the frontage are commercial) only requires the number of properties that flood in different return periods and the type of property to be known in order to calculate damages. The number of properties that flood in a 1 in 200 event has been found by using Flood Zone 3 and then after the table shown in Figure 7-3, extracted from the MCM, has been used to estimate the number of properties that flood in different events. Upper floor properties were excluded from the assessment. It should be noted that this approach is only recommended for use in outline studies; however with an absence of other data it is the only way to produce flood damages to reflect that there is a flood risk. The proportion of the damages obtained through this approach was compared with the other damages, and as the damage was a small part of the total damage, then it was considered appropriate to represent the occurrence of limited flooding.

Return Period	No. Of properties as % of 200 year No.
100	93
50	80
25	25
10	10
5	5

Figure 7-3: Estimate Proportions of Different Flood Events (extracted from MCM 2017)

Once the numbers of properties flooded in different return periods were calculated for the 1 in 200 year flood event the table shown in Figure 7-4, from the MCM, was used to estimate the monetary flood damages that occur based on floor area of the properties. As there is a mix of different commercial property types that flood, the average across all property types has been used (NRP sector average).

		Standard Of Protection						
MCM CODE	SECTOR TYPE	None	5	10	25	50	100	200
2	Retail	72.93	35.98	26.20	13.49	6.03	1.51	0.75
3	Offices	69.34	32.47	24.34	12.28	5.42	1.35	0.68
4	Warehouses	85.30	45.23	32.69	16.58	7.51	1.88	0.94
5	Leisure and sports	NOT APPLICABLE - CONSTITUENT CATEGORIES TOO DIVERSE						
51	Leisure	132.96	46.79	37.06	17.01	7.31	1.83	0.91
52	Sports	NOT APPLICABLE - CONSTITUENT CATEGORIES TOO DIVERSE						
521	Playing Field	0.93	0.42	0.32	0.16	0.07	0.02	0.01
523	Sports Centre	25.97	11.90	8.93	4.41	1.95	0.49	0.24
526	Marina	9.48	4.59	3.32	1.72	0.76	0.19	0.10
525	Sports Stadium	9.85	4.43	3.32	1.67	0.73	0.18	0.09
6	Public Buildings	34.36	16.54	12.29	6.21	2.76	0.69	0.34
8	Industry	13.82	7.05	5.13	2.63	1.18	0.30	0.15
9	Miscellaneous	NOT APPLICABLE - CONSTITUENT CATEGORIES TOO DIVERSE						
910	Car park	2.29	1.21	0.86	0.46	0.21	0.05	0.03
960	Sub Station	189.18	116.96	83.45	45.83	20.77	5.19	2.60
NRP sector average		68.12	36.03	26.36	14.00	6.41	1.70	0.85

Figure 7-4: Weighted Annual Average Damage by Standard of Protection (£/m^2) (extracted from MCM 2017)

7.3.2 Limitations

Whilst this method provides outline flood damages, there are some factors which area not considered by this method. Flood Zone 3 only shows the present day flood extent with sea level rise projections not included. This means that sea level rise has not been considered and the results are therefore not conservative in this respect.

Also property write-off has not been considered. According to FCERM guidance properties are defined as written off once flooded by an event of 1:3 year return period or less. Once written off the property value is taken as a damage and the properties accrue no more damages. A check was undertaken on the results and using the approximations of number of properties flooding given in Figure 7-3 it was not thought any properties would flood in a 1:3 year return period.

Similarly to write-off, once the properties erode they should no longer accrue flooding damages. This has been accounted for by taking the average erosion year of the properties which flood and then not counting flood damages after this time. Whilst it would be more precise to do this at the level of individual properties, with the flood approach taken, in the absence of detailed modelling, this approach is seen as the best way to cap flood damages after properties are eroded.

The guidance also requires that the property flood damages over the appraisal period for each property must not exceed the property value. Due to the limited number of flood damages expected to be taken it was not predicted that this will have an effect on the result, a check was undertaken on the results to confirm this.

7.4 Additional Damages (non-property)

7.4.1 Risk to Life

There is no official guidance associated with potential loss of life from cliff erosion events. The value of a loss of a life has been estimated at £1,898,000 based on data from the Rail Safety and Standards Board (RSSB, 2017). It was initially assumed that one loss of life will occur in the 100 year 'Do Nothing' appraisal period. This is based on the risks with the cliffs continuing to erode without any sort of fencing or signage to deter people from getting close to the top or bottom of the cliff and also the existing structures failing with no warning signs health and safety actions taken. For the 'Do Nothing' scenario an average discount factor for the appraisal period has been applied to the cash value. It has been estimated that the split of this damage across Unit A and B should be 75:25. In Unit A, there are high cliffs and therefore more risk, whilst in Unit B there are failing structures which are at a lower height.

The initial results showed that assuming one loss of life would occur in the appraisal period would mean that in Unit A the damages from loss of life were approximately 8x that of the property erosion damages. This is potentially problematic when developing a business case to potentially attract funding as there is a large amount of uncertainty of whether the loss of life damage will actually occur. Therefore, to reduce this risk an approach has been taken to carry out sensitivity testing on the risk to life additional damage and, at this interim stage of the economic assessment, provide additional results for there being a 10% and 50% probability that this loss of life actually occurs.

7.4.2 Visitor Numbers

It has been considered that if there was erosion to the promenade Hunstanton would become a less attractive place to visit due to the loss of the promenade. This would mean that there could potentially be a loss of people visiting and therefore an economic damage to the local economy. However, with indirect damages the loss at a national scale must be considered, rather than just local. MCM guidance states:

*"**National economic benefits and substitute sites.** If change to a particular coastal or river site simply transfer recreation from one site to another without any overall gains or losses in the value of recreational enjoyment, once travel costs have been taken into account, then no national gain or loss will be involved. The availability of substitute sites must therefore be considered when recreation benefits are being assessed."*

Hunstanton is located along a stretch of coastline where there are many other coastal resorts with cliffs and beaches. Under a 'Do Nothing' scenario it would be realistic to assume that visitors, which would have travelled to Hunstanton, would go elsewhere. Therefore, extra travel costs can be considered as damages. However, because of Hunstanton's location on the coast, and the road access to it, the alternative sites are actually no further to get to. Visitors from the south travelling from King's Lynn would pass Heacham and visitors travelling from the east would pass Sheringham and Cromer. Because visitor damages have to be considered at a national level, taking damages for this at Hunstanton cannot be justified following current guidance.

7.4.3 Utilities

The effect of allowing the coast to erode on the existing utilities potentially could increase the 'Do Nothing' damages. There is currently no information available on the locations or type of utilities. This is to be investigated further as the work on the economic assessment continues.

7.4.4 Road Erosion

Cliff Parade (B1161) will be at risk of erosion within the appraisal period in Unit A. When roads are at risk of erosion, damages can be derived based on either the length of diversions that would have to be taken or the cost of constructing a replacement road. However, in the case of Cliff Parade it has been assessed that no damages can be taken because it is not a major link road and if lost there is a diversion route along Belgrave Avenue that would take a similar duration and provide access to the same areas. Therefore no damages due to road erosion have been accounted for.

7.4.5 Property Access Erosion

The effect of erosion on property access for the properties directly landward of Cliff Parade was also considered. Whilst certain properties may not directly erode, the access route to the property may be lost, therefore making the property inaccessible and consequently uninhabitable. It was determined that if the access along Cliff Parade was lost, the properties directly landward would likely have to have already been abandoned due to their proximity to the cliff edge. However, for those properties on Cliff Parade not abandoned there is an alternate access available via Belgrade Avenue and the roads running perpendicular to it. Therefore no properties were considered to be lost due to the erosion of access routes.

7.4.6 Gross Value Added

The Gross Value Added (GVA) approach considers how loss or damage of businesses will affect the local economy through businesses closing temporarily, permanently or businesses relocating from the area. Whilst it cannot contribute to the overall FCERM damage it can help to achieve wider buy in to schemes and potentially contributions from local businesses or stakeholders. However, GVA impacts should only be considered up to 10 years into the future. This is because 10 years is considered adequate for businesses to respond to any risks and acknowledges in the longer term that many other factors will be involved in the behaviour of businesses. In this study area no properties are at risk of being lost in the next 10 years so the GVA approach has not been applied.

7.5 Results

Note that these results are reflective of the work carried out to date as described in this Interim Report and are not reflective of the final economics appraisal.

7.5.1 Erosion

The number of properties expected to be at risk from coastal erosion over the next 100 years are shown in Table 7-2.

Table 7-2: Properties at erosion risk in the next 100 years (assuming 10m property buffer)

Epoch	Residential Properties		Commercial Properties		Total	
	Unit A	Unit B	Unit A	Unit B	Unit A	Unit B
Short (2017-2030)	0	0	0	0	0	0
Medium (2030-2060)	0	14	2	24	2	38
Long (2060-2117)	0	23	2	9	2	32
All	0	37	4	33	4	70

This initial analysis indicates that the only properties expected to erode in Unit A throughout the appraisal period including the Lighthouse holiday accommodation building in year 95 and 3 shelters in years 15, 41 and 47 respectively. Figure 7-5 shows the locations of these properties in Unit A. It is also worth noting that several other properties (the coastguard cottages, the former coastguard lookout tower/Marconi Wireless station and the remains of St. Edmund's Chapel) although not predicted to be lost to erosion are expected to be placed at significantly greater risk.

Figure 7-5: Map showing properties in Unit A at risk of erosion in the next 100 years

In Unit B, 37 residential properties are at risk from erosion and 33 commercial properties. Figure 7-6 shows the locations of these properties and Figure 7-7 illustrates when the properties in Unit B are predicted to erode.

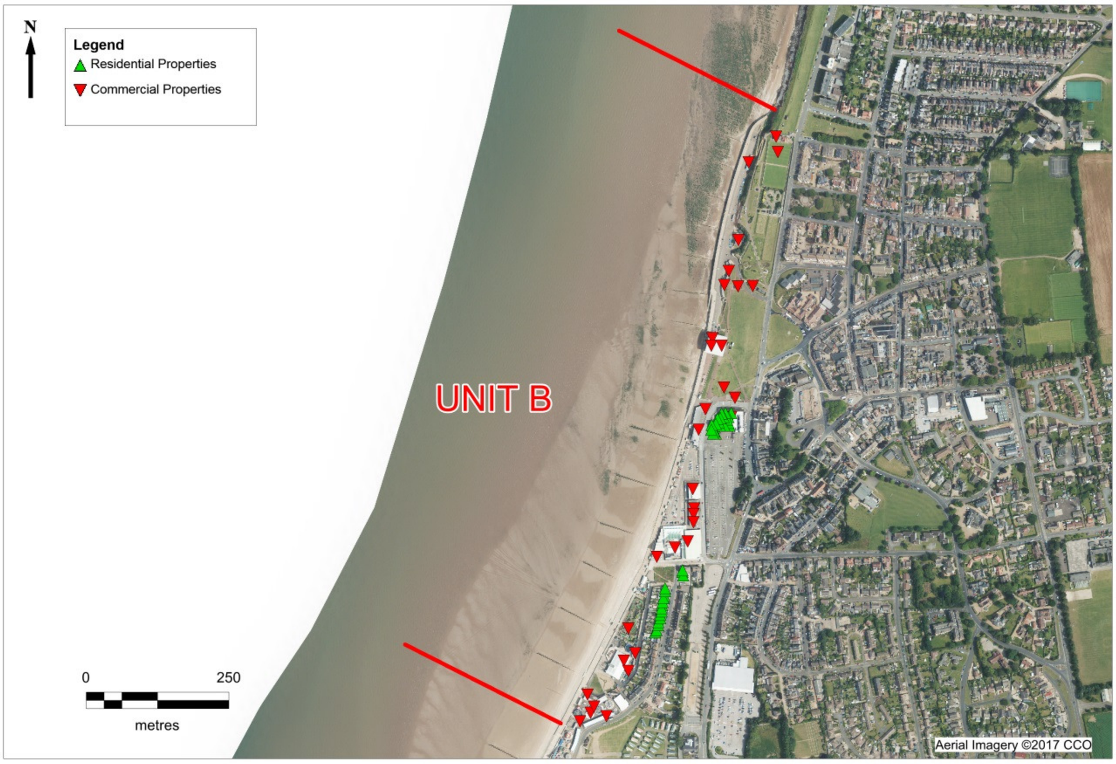

Figure 7-6: Map showing properties in Unit B at risk of erosion in the next 100 years

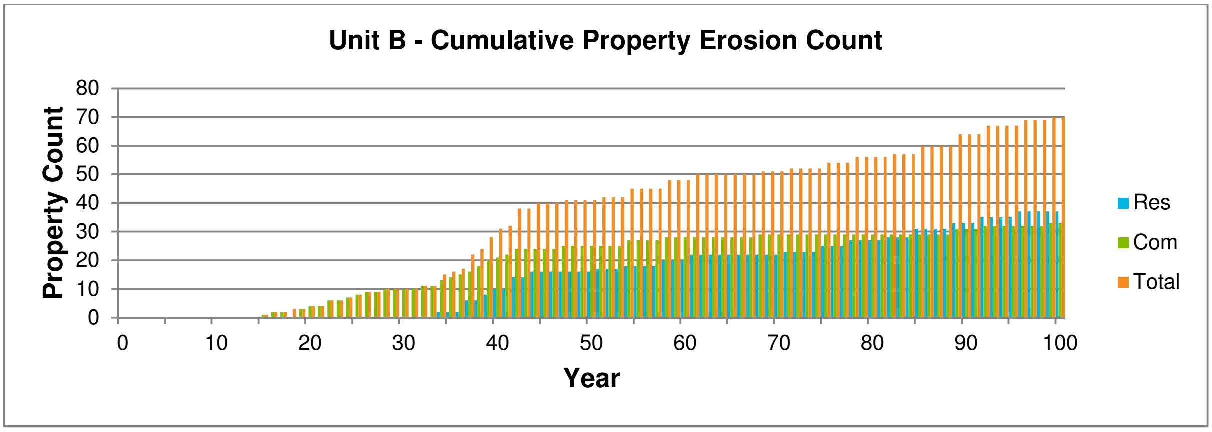

Figure 7-7: Cumulative count of properties in Unit B at erosion risk in the next 100 years

Figure 7-8 shows how the PV damages in Unit B are accrued over time.

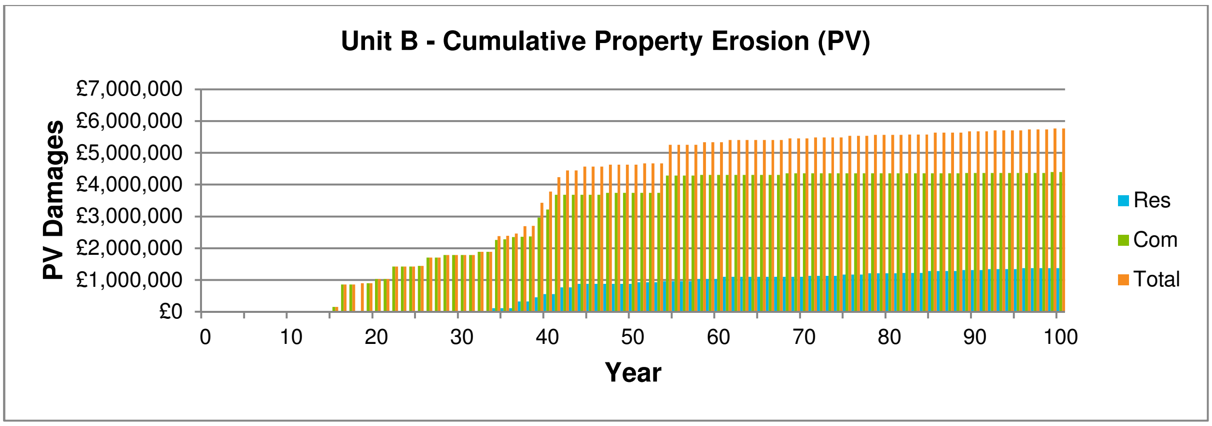

Figure 7-8: Cumulative PV damages of properties in Unit B at erosion risk in the next 100 years

Table 7-3 presents the PV and Cash damages associated with the properties affected by erosion in Units A and B using a 10m erosion buffer and Table 7.4 presents the results using a 5m buffer.

Table 7-3: Predicted damages caused by property erosion in the next 100 years (assuming 10m property buffer)

Epoch	Type	Residential Properties		Commercial Properties		Total	
		Unit A	Unit B	Unit A	Unit B	Unit A	Unit B
Short (2017-2030)	PV	£0	£0	£0	£0	£0	£0
	Cash	£0	£0	£0	£0	£0	£0
Medium (2030-2060)	PV	£0	£765,914	£18,865	£3,679,036	£18,865	£4,444,950
	Cash	£0	£2,783,982	£42,749	£10,324,137	£42,749	£13,108,119
Long (2060-2117)	PV	£0	£606,106	£17,600	£714,130	£17,600	£1,320,236
	Cash	£0	£5,433,277	£246,635	£4,647,731	£246,635	£10,081,008
All	PV	£0	£1,372,021	£36,465	£4,393,166	£36,465	£5,765,186
	Cash	£0	£8,217,259	£289,384	£14,971,868	£289,384	£23,189,127

Table 7-4: Predicted damages caused by property erosion in the next 100 years (assuming 5m property buffer)

Epoch	Type	Residential Properties		Commercial Properties		Total	
		Unit A	Unit B	Unit A	Unit B	Unit A	Unit B
Short (2017-2030)	PV	£0	£0	£0	£0	£0	£0
	Cash	£0	£0	£0	£0	£0	£0
Medium (2030-2060)	PV	£0	£420,885	£6,910	£3,197,509	£6,910	£3,618,395
	Cash	£0	£1,575,378	£23,157	£9,368,993	£23,157	£10,944,371
Long (2060-2117)	PV	£0	£521,311	£6,173	£615,862	£6,173	£1,137,173
	Cash	£0	£4,380,164	£41,227	£4,918,244	£41,227	£9,298,408
All	PV	£0	£942,197	£13,083	£3,813,371	£13,083	£4,755,568
	Cash	£0	£5,955,542	£64,384	£14,287,237	£64,384	£20,242,779

7.5.2 Flooding

The flooding assessment indicated that only commercial properties in Unit B are at risk of flooding. The damages associated with flooding are PV £48,981 and Cash £72,683. Figure 7-9 shows the locations of the properties at risk from up to a present day 1 in 200 year flood event.

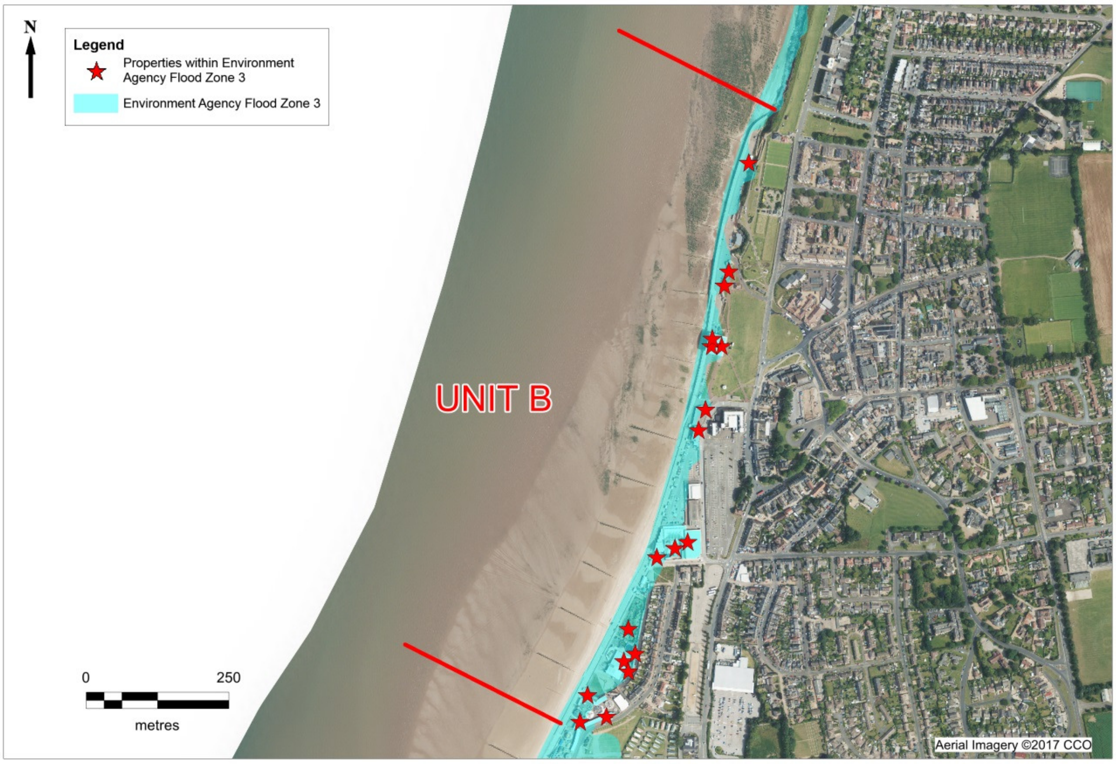

Figure 7-9: Map showing properties in Unit B at risk of flooding from up to a present day 1 in 200 year flood event in the next 100 years (all commercial)

7.5.3 Additional Damages (non-property)

The only additional damage applied is to reflect the predicted risk to life. Damages are shown in Table 7-5 below including a range of probability of loss of life occurring.

Table 7-5: Additional damages predicted in the next 100 years

Damages	Probability of 1 life lost over appraisal period	**Unit A**	**Unit B**
PV	100%	£424,382	£141,461
	50%	£212,191	£70,730
	10%	£42,438	£14,146
Cash		£1,423,500	£474,500

7.5.4 Total

Table 7-6: Total PV damages predicted in the next 100 years with variation of property buffer distance and probability of loss of life additional damage

Property erosion buffer distance	**Probability of loss of life occurring over appraisal period**		**Unit A**	**Unit B**
10m	**100%**	**PV**	£460,847	£5,955,353
	50%	**PV**	£248,656	£5,884,623
	10%	**PV**	£78,903	£5,828,039
5m	**100%**	**PV**	£437,464	£4,951,381
	50%	**PV**	£225,273	£4,880,650
	10%	**PV**	£55,521	£4,824,066

7.6 PF Calculator Results

Indicative Partnership Funding results are presented in this section from the Partnership Funding calculator. As no cost information is available at this Interim stage the indicative costs from the Strategy have been applied (to the nearest £100,000). These initial calculations are to indicate whether any Grant in Aid (GiA) could potentially be available to fund schemes.

One of the inputs for the Partnership Funding calculator is which deprivation category the households at risk are in. The Index of Multiple Deprivation (2010) was used to calculate that all the households at risk in the Hunstanton frontage are in the 21-40% most deprived areas.

The input data/assumptions and results from the Partnership Funding calculator are shown in the following sections. Please note for indication purposes the largest damage results have been used; i.e. taking results for a 100% probability of loss of life and using a 10m erosion buffer. The calculations have used an appraisal period of 100 years.

7.6.1 Unit A

It is assumed that the piloting of cliff toe protection will mean the 3 commercial properties currently at risk will not be lost and there will be no loss of life during the appraisal period.

Inputs	
PV whole-life benefits	£460,847
PV appraisal, design and construction costs	£500,000
PV post-construction costs	£1,000,000
Households better protected against coastal erosion	0
Results	
Raw Partnership Funding score	2%
External contribution required to achieve an adjusted score of 100%	£491,466
Assuming contribution to reach a score of 100%, GiA avialable towards the up-front costs of the scheme	£8,534

7.6.2 Unit B

It is assumed that the option of sustaining the sea wall and promenade will prevent erosion from occuring, however the flood risk will remain.

Inputs	
PV whole-life benefits	£5,955,353
PV appraisal, design and construction costs	£800,000
PV post-construction costs	£13,600,000
Households better protected against coastal erosion	37 (long-term)
Results	
Raw Partnership Funding score	5%
External contribution required to achieve an adjusted score of 100%	£763,859
Assuming contribution to reach a score of 100%, GiA avialable towards the up-front costs of the scheme	£36,141

8. Coastal Management Options

The options for coastal management in Hunstanton significantly vary between Units A and B, as Unit A is predominantly an undefended cliff frontage, whereas Unit B is currently protected by a comprehensive system of beach management and hard defence options. For this reason, the potential management options for Units A and B have been discussed separately below.

The long-lists of potential management options considered for both Units A and B are detailed below. It should be noted that this is not an exhaustive list of all potential options, but a list of various practicable options to open discussions with BCKLWN in order to develop a short-list of viable options to be taken forward for further appraisal.

8.1 Unit A – Long List Options

The management options considered for Unit A broadly form two distinct groups:

- ***No Active Intervention:*** where the cliff is allowed to continue to erode and no capital works are undertaken.
- ***New Defences:*** where capital works are undertaken to the existing frontage to reduce or remove its vulnerability to erosion caused by wave action.

No Active Intervention

1. Do nothing
2. Do minimum

New Defences

3. Cliff bolting
4. Netting to base of cliff
5. Rock revetment / Sill
6. Timber Revetments
7. Sand bags / Geotubes
8. Gabions
9. Cliff drainage
10. Seawall
11. Offshore breakwaters
12. Beach nourishment
13. Groynes (rock or timber)
14. Cliff stabilisation through re-grading
15. Relocation of key assets

Indicative sketches or example photographs of each of these long listed options will be presented at the Options Workshop.

It should be noted that some of these long listed options have previously been identified in The Strategy (2015) as potential options for a pilot scheme to trial erosion mitigation measure along this frontage.

Each of these options has been briefly described in the table below with some of the key advantages and disadvantages of the options listed.

Option	Description	Advantages	Disadvantages
Do Nothing	No future interventions.	• Zero cost option. • Compliant with SMP. • Allows natural coastal processes to take place.	• Health and safety risks to public at cliff top (regression) and cliff toe (rock falls). • No cliff erosion protection. Property and infrastructure will be lost to erosion. • Unlikely to be supported by community.
Do Minimum	Ensure health and safety compliance. Erect fencing and signage at the base and top of	• Low cost option. • Will provide health and safety measures to protect public.	• No cliff erosion protection. Property and infrastructure will eventually be lost to erosion. • Unlikely to be supported by

	the cliff.	• Compliant with SMP. • Allows natural coastal processes to take place.	community.
Cliff bolting	Bolts inserted into the cliff at regular intervals.	• Will support the tensile strength of the cliff material. • Will not have a footprint on the beach.	• Will not prevent wave action from undercutting the cliff therefore allowing erosion to continue. • Will change the aesthetic of the cliff – a place of geological interest. • Will impact on local ecology
Netting to base of cliff	Place a row of netting at the base of the cliff.	• Will retain the fallen cliff material and this will reduce the impact of waves. • Allowing continued erosion will maintain the geological features of the SSSI.	• Netting unlikely to be durable enough to withstand wave action. • Will require regular maintenance/replacement. • Will not prevent all erosion. • Associated safety issues with having a large volume of rock on the beach.
Rock revetment/ Sill	Protection of cliff toe with large rocks designed to be stable under waves installed at the base of the cliffs.	• Rocks will absorb wave energy, reducing the wave impacts at the cliff and erosion. • Can be repositioned if displaced or required elsewhere. • Requires little maintenance.	• Depending on wave climate and water levels a large amount of large rocks could be required leading to high cost. • The footprint of the structure on the beach will reduce access / amenity use. • Potentially health and safety risks of people climbing on the revetment. • Will not prevent all erosion. • Expensive to implement
Timber Revetments	Protection of the cliff with a timber revetment installed in front of the existing defences that will protect against wave action	• Effective at dissipating wave energy therefore reducing the amount of wave energy impacting the cliffs • In keeping with similar frontages throughout Norfolk	• The footprint of the structure on the beach will reduce access / amenity use. • Potentially health and safety risks of people climbing on the revetment. • On-going maintenance commitment • Will not prevent all erosion. • Will impact on the existing visual landscape
Sand bags / Geotubes	Sand filled geotextiles placed at the toe of the cliffs.	• Sand potentially can be taken from a local source. • Bags will absorb wave energy, reducing the wave impacts at the cliff and erosion.	• Not a proven technique in high energy wave environment. • Regular maintenance/ replacement would be required • The footprint of the structure on the beach will reduce access / amenity use. • Will not prevent all erosion. • Can be destroyed by vandalism.
Gabions	Rocks placed in steel wire cages and placed along cliff toe.	• Gabions will absorb wave energy, reducing the wave impacts at the cliff and erosion. • Will protect the toe of the cliff from scour. • Relatively cheap and easy to install.	• Wire mesh cages unlikely strong enough not to deform in wave conditions. Potentially could create a safety hazard. • The footprint of the structure on the beach will reduce access / amenity use. • Will not prevent all erosion. • Can be destroyed by vandalism.
Cliff drainage	Local improvement to cliff drainage through drilling holes and placing filters.	• Would slow down the groundwater induced erosion. • Will not have a footprint on the beach.	• Will not prevent wave action from undercutting the cliff, erosion will continue. • Will change the aesthetic of the cliff – a place of geological interest.

Seawall	A continuous impermeable structure along the toe of the cliffs. Likely to be reinforced concrete with steel pile toe protection.	• Will protect the toe of the cliff and prevent erosion from coastal processes. • Potentially a promenade could be built on the new seawall and increase amenity value of the frontage.	• Groundwater induced erosion will continue. • Very high cost option. • Would have to be paired with another option to remove the risks of falling debris from the cliffs, • Would interfere with the aesthetic of the cliff – a place of geological interest. • The footprint of the structure on the beach will reduce access / amenity use. • Environmentally intrusive. • Will prevent sediment from the cliff entering environment, potentially altering coastal processes.
Offshore breakwaters	Construction of large off-shore structures. Likely to be made of rock or pre-cast concrete units.	• Would absorb wave energy, reducing the wave impacts at the cliff and erosion. • Potentially creates off-shore habitat. • Potentially beach levels could increase. • Will not have a footprint on the beach.	• Very high cost option. • Complex offshore construction methods • Would interfere with the existing coastal and environmental processes along the frontage. • Environmentally intrusive. • Will not eliminate erosion, potentially will have to be combined with other beach management options. • Will potentially interfere with the amenity / recreational use of the frontage.
Beach nourishment	The placing of imported additional beach material.	• Increasing beach level will act to absorb wave energy, reducing the wave impacts at the cliff and erosion. • Would not change the aesthetic of the frontage. • Would be a benefit for down drift locations.	• The cliffs are currently providing material into the environment; however it is being transported away from the cliffs. • This option would have to paired with another option to keep the additional material at the cliffs such as groynes. • A high cost option • Likely to be required on multiple occasions throughout appraisal period. • Performance can be unpredictable due to the dynamic nature of sediment. • Will potentially impact on local ecology.
Groynes (Timber or Rock)	Long, narrow structures built perpendicular to the cliff. Likely to be made of timber or rock.	• Would help to retain material to this part of the coastline, increasing beach levels and reducing wave impacts at the cliff and erosion. • Will not change the aesthetic of the cliff – a place of geological interest.	• Retaining material to this part of the frontage would mean less material moves southwards towards Hunstanton Town. • Likely to need to be implemented in conjunction with beach re-nourishment • As the cliff retreats groynes would become less effective. • Groynes would not prevent waves impacting the cliffs and erosion would continue. • Performance can be unpredictable due to the dynamic nature of sediment. • Will impact on the landscape and amenity use of the frontage
Cliff Stabilisation through regrading	Re-grading the existing cliff resulting in a more stable slope.	• Would help limit erosion due to groundwater and weathering. • Avoids hard defences • Removes the H&S risks associated with cliff falls	• Would not prevent erosion due to wave action. • Would have to be implemented in conjunction with various other methods. • Would interfere with the

			aesthetic of the cliff – a place of geological interest. • Environmentally and ecologically intrusive. • Significant impact on landscape and public amenity spaces (on top of the cliff) • High cost option • Complex construction methodology
Relocation of key assets	Gradual adaption of communities and assets away from the erosion zone.	• Long term solution. • Will prevent the need to stop wave erosion and would avoid having to continuously maintain and replaced defences over time. • Would be a gradual approach which adapts to change. • Will not change the aesthetic of the cliff – a place of geological interest. • Will continue to allow material from cliffs to migrate on to neighbouring frontages	• Likely to be unpopular with the community. • Does not address public safety concerns • Not in line with long-term SMP policy • Difficulties in public funding for this type of scheme.

8.2 Unit B

The management options considered for Unit B, where the coastline is actively defended, broadly form into four distinct groups:

- ***No Active Intervention:*** where only minimal repairs for health and safety purposes are carried out and no other works are undertaken. The condition of the defences will decrease over time and eventually the existing defences will be allowed to fail.
- ***Maintain Existing Defences:*** where the existing defences are maintained through undertaking works to improve their residual lives. These options could range from low-scale patch and repair operations to large-scale planned defence refurbishment. Although the SoP offered by the defence will ultimately be reduced over time due to the impacts of predicted climate change.
- ***Sustain Existing Defences:*** where the existing level of protection offered by the defences is sustained by undertaking works to progressively enhance the defences in line with climate change projections.
- ***Enhance or Improve the Defences:*** where capital works are undertaken to either enhance the level of protection offered by the existing defences or replace the existing defences with new enhanced defences.

It should be noted that a potential marine lagoon is being considered by BCKLWN within Unit B. Whilst this could potentially have beneficial impacts on the coastal defences within this Unit, it has not been considered here as a potential long list option at this stage.

No Active Intervention

1. Do nothing
2. Do minimum

Maintain Existing Defences

3. Patch and repair maintenance of seawall, promenade and floodwall.
4. Re-facing of the seawall, promenade and floodwall
5. Repair/replacement of groynes
6. Eventual replacement of defences maintaining existing crest height.

Sustain Existing Defences

7. Raise existing seawall, promenade and floodwall in line with climate change
8. Re-facing and raise the seawall and promenade
9. Repair of groynes
10. Eventual replacement of defences elevating crest levels in line with climate change.

Enhance or Replace Existing Defences

11. Rock revetment

12. Sand bags / Geotubes
13. Gabions
14. Replacement seawall, promenade and floodwall
15. Offshore breakwater
16. Enhanced beach
17. Groyne replacement/enhancement
18. Timber revetments
19. Rock groynes

Indicative sketches or example photographs of each of these long listed options will be presented at the Options Workshop.

Each of these options has been briefly described in the table below with some of the key advantages and disadvantages of the options listed.

Type	Option	Description	Advantages	Disadvantages
No Active Intervention (NAI)	Do Nothing	No future interventions.	• Lowest cost option. • Allows natural processes to take place.	• Not compliant with the Hold the Line policy. • Health and safety risks as structures fail. • Property and infrastructure will be lost to erosion and flooding. • Unlikely to be supported by community. • Detrimental to local tourism and economy
	Do Minimum	Allow structures to fail over time whilst ensuring health and safety compliance. (effectively a delayed Do nothing option)	• Low cost option. • Will provide health and safety measures to protect public. • Allows natural processes to take place.	• Not compliant with the Hold the Line policy • Property and infrastructure will be lost to erosion and flooding • Unlikely to be supported by community. • Detrimental to local tourism and economy
Maintain	Patch repair maintenance of seawall, promenade and floodwall	Minor repair works and routine maintenance to existing structures as is currently being carried out.	• Will extend the residual lives of the existing structures in the short to medium term. • Low capital cost option.	• Will not extend the lives of the structures into the long term. • Repairs will become more expensive over time as condition of the structure deteriorates.
	Re-facing of the seawall, promenade and floodwall	Encase existing defence structures in layer of reinforced concrete.	• Will protect the existing structure and extend its residual life. • No significant change in footprint of structure.	• Works will disrupt public access to the promenade. • In-situ concrete works present an environmental risk in the tidal environment. • Fairly expensive to implement across the whole frontage
	Repair/ replacement of groynes	Carry out repairs to areas of the existing groynes in poor condition. Would involve the replacement of certain elements of the structures.	• Will extend the residual life of existing structures. • Potentially could act to trap more beach material on the frontage. • Construction could be staggered and different elements prioritised. • The existing groynes effectiveness is known from experience.	• Increasing the amount of sediment retained on this frontage will cause less sediment to be available in down drift locations. • Can be technically challenging to replace elements – with groynes partially hidden beneath the beach and because of corrosion of fixings it is often not possible to replace a single element. • Performance can be unpredictable due to the dynamic nature of sediment. • Will require ongoing maintenance commitments
	Eventual replacement of defences (to the same	Like for Like eventual replacement of defences	• Capital costs delayed into the future • Defences maintained	• Very expensive • SoP will deteriorate over time due to impacts of climate

	level)	at the end of their residual life (built to existing levels)	• Potential for erosion eliminated • Maintains the existing landscape and amenity area	change
Sustain	Raise existing seawall, promenade or floodwall, continuing on-going maintenance	Raise an element of existing defence to counter the impacts of climate change. Also continue minor repair works and routine maintenance to existing structures.	• Maintains existing SoP • Will extend the residual lives of the existing structures in the short to medium term • No significant change in footprint of structure.	• Will not enhance the level of protection offered. • Will not extend the lives of the existing structures into the long term. • Repairs will become more expensive over time as condition of the structure deteriorates. • Will impact on the visual landscape • Potentially have a detrimental impact on the promenade as an amenity space.
	Raising and re-facing of the seawall, promenade and floodwall	Raise and encase existing defence structures in layer of reinforced concrete.	• Will protect the existing structure and extend its residual life for the long term. • No significant change in footprint of structure. • Will maintain the existing SoP	• Will not enhance the level of protection offered. • Works will disrupt public access to the promenade. • In-situ concrete works present an environmental risk in the tidal environment. • Fairly expensive to implement across the whole frontage • Will impact on the visual landscape • Potentially have a detrimental impact on the promenade as an amenity space.
	Repair/replacement of groynes (same as maintain)	Carry out repairs to areas of the existing groynes in poor condition. Would involve the replacement of certain elements of the structures.	• Will extend the residual life of existing structures. • Potentially could act to trap more beach material on the frontage. • Construction could be staggered and different elements prioritised. • The existing groynes effectiveness is known from experience.	• Increasing the amount of sediment retained on this frontage will cause less sediment to be available in down drift locations. • Can be technically challenging to replace elements – with groynes partially hidden beneath the beach and because of corrosion of fixings it is often not possible to replace a single element. • Performance can be unpredictable due to the dynamic nature of sediment. • Will require ongoing maintenance commitments
	Eventual replacement of defences (to a raised level)	Eventual replacement of defences at the end of their residual life (built to a raised level in line with the impacts of climate change)	• Capital costs delayed into the future • Defences maintained • Potential for erosion eliminated • Will maintain the existing SoP	• Very expensive • Will not enhance the level of protection offered. • Will impact on the visual landscape • Potentially have a detrimental impact on the promenade as an amenity space.
Improve / Enhance	Rock revetment	Protection of seawall with large rocks designed to be stable under waves installed at the toe of the seawall's toe to protect against increased exposure due to erosion of the beach	• Effective at dissipating wave energy therefore reducing the amount of wave energy impacting the seawall. • Will protect the toe of the seawall from scour. • Rock is relatively easy to move around, can be repositioned if displaced or required elsewhere. • Requires little maintenance.	• Depending on wave climate and water levels a large amount of rocks could be required leading to high cost. • The footprint of the structure on the beach will reduce access / amenity use. • Potentially health and safety risks of people climbing on the revetment. • Will not enhance the level of flood protection offered by the defence. (Would have to be undertaken in conjunction

				with raising/replacing the existing defences)
	Sandbags /Geotubes	Sand filled geotextiles placed at the seawall's toe to protect against increased exposure due to erosion of the beach – generally placed below the existing beach level.	• Sand potentially can be taken from a local source. • Will protect the toe of the seawall from scour. • Bags can be used to raise beach levels and absorb wave energy, reducing the wave impacts at the seawall. • Relatively cheap and easy to install.	• Is not a proven technique in high energy wave environment. • The footprint of the structure on the beach will reduce access / amenity use. • Can be destroyed by vandalism. • Will not enhance the level of flood protection offered by the defence. (Would have to be undertaken in conjunction with raising/replacing the existing defences) • Will require ongoing maintenance commitments
	Gabions	Rocks placed in steel wire cages and placed along seawall's toe to protect against increased exposure due to erosion of the beach	• Gabions will absorb wave energy, reducing the wave impacts on the seawall. • Will protect the toe of the seawall from scour. • Relatively cheap and easy to install.	• Wire mesh cages are unlikely to withstand significant wave action. • The footprint of the structure on the beach will reduce access / amenity use. • Can be destroyed by vandalism. • Will not enhance the level of flood protection offered by the defence. (Would have to be undertaken in conjunction with raising/replacing the existing defences) • Will require ongoing maintenance commitments
	Replacement seawall, promenade and floodwall	Replace the existing seawall and promenade. Likely to be reinforced concrete with steel pile toe protection.	• Will provide a long term defence for the Unit. • Would provide an increased SoP. • Will eliminate the risk of erosion damage. • Could potentially enhance the promenade as an amenity space	• Very high cost option. • Will cause massive disruption to the frontage. • Will impact on the visual landscape. • Will not help maintain the beach levels
	Offshore breakwater	Construction of large off-shore structures. Likely to be made of rock or pre-cast concrete units.	• Would absorb wave energy, reducing the wave impacts at seawall. • Potentially creates off-shore habitat. • Could potentially assist beach levels to increase. • Will not have a footprint on the beach.	• Very high cost option. • Would interfere with the existing coastal and environmental processes along the frontage. • Environmentally intrusive. • Will not eliminate erosion, potentially will have to be combined with other beach management. • Potentially will interfere with the amenity / recreational use of the frontage. • Will not enhance the level of flood protection offered by the defence. (Would have to be undertaken in conjunction with raising/replacing the existing defences) • Completed construction involving offshore working.
	Enhanced beach	The placing of additional imported beach material.	• Increasing beach level will act to absorb wave energy reducing the wave energy at the seawall. • Would potentially improve the aesthetic and amenity use of the frontage. • Would potentially be a benefit for down drift locations.	• Will interfere with existing coastal and environmental processes. • This option would have to be paired with another option to improve its long term effectiveness. (i.e. groynes). • Likely to be required on multiple occasions throughout appraisal period. • Performance can be unpredictable due to the

				dynamic nature of sediment. • Will potentially impact on local ecology. • Will not enhance the level of flood protection offered by the defence. (Would have to be undertaken in conjunction with raising/replacing the existing defences)
	Groyne replacement	Carry out largescale replacement and enhancement of the existing groynes.	• Would enable the groynes to be redesigned potentially increasing the height and/or length. • Potentially could act to trap more beach material on the frontage and offer greater protection to the seawall. • Replacement could be staggered and different groynes prioritised. • Maintains the existing visual landscape. • Could potentially enhance the amenity value of the existing beach.	• Increasing the amount of sediment retained on this frontage will cause less sediment to be available in down drift locations. • Performance can be unpredictable due to the dynamic nature of sediment. • Will not enhance the level of flood protection offered by the defence. (Would have to be undertaken in conjunction with raising/replacing the existing defences) • May have to be implemented in conjunction with beach re-nourishment to ensure effectiveness. • Will require a long term maintenance commitment with on-going costs. • Enhanced groynes will potentially impact on both existing coastal and environmental processes.
	Timber Revetments	Protection of seawall with a timber revetment installed in front of the existing defences that will protect against wave action	• Effective at dissipating wave energy therefore reducing the amount of wave energy impacting the seawall. • In keeping with similar frontages throughout Norfolk	• The footprint of the structure on the beach will reduce access / amenity use. • Potentially health and safety risks of people climbing on the revetment. • Will not enhance the level of flood protection offered by the defence. (Would have to be undertaken in conjunction with raising/replacing the existing defences) • On-going maintenance commitment • Will impact on the existing visual landscape
	Rock groynes	Replace the existing groyne field with a series of large rock groyne structures	• Would act to trap more beach material on the frontage and offer greater protection to the seawall. • Removes the need for ongoing maintenance of timber groynes • Could potentially enhance the amenity value of the existing beach. • Potentially improve the visual landscape of the frontage. • Rock is relatively easy to move around, can be repositioned if displaced or required elsewhere. • Requires little maintenance. • Will potentially create a new environmental habitat	• Increasing the amount of sediment retained on this frontage will cause less sediment to be available in down drift locations. • Performance can be unpredictable due to the dynamic nature of sediment. • Will not enhance the level of flood protection offered by the defence. (Would have to be undertaken in conjunction with raising/replacing the existing defences) • May have to be implemented in conjunction with beach re-nourishment to ensure effectiveness. • Rock groynes will potentially impact on both existing coastal and environmental processes • Expensive to install. • Potential public safety issues related to people climbing on the structures

8.3 Preliminary Option Assessment

8.3.1 Preliminary Assessment Criteria

Initial Assessment Parameters

Each of the long-list options has been initially assessed against the following nine key parameters:

- Erosion risk
- SMP compliance
- Technical feasibility
- Maintenance
- Environmental impacts
- Cost (comparative)
- Health and safety
- Option life
- Public acceptance.

In each category the option was ranked with a colour code: red, amber or green. The following table outlines the classification system used for each category:

Category	Red	Amber	Green
Erosion risk	Increases erosion risk or has no / negligible impact on erosion risk	Potential to address or partially reduce erosion risk	Potential to significantly reduce or remove erosion risk
SMP compliance	Does not facilitate SMP policy	Partially supports / general support but localised change	Fully facilitates SMP policy
Technical feasibility	Option is technically very challenging or difficult to implement/construct	Option presents some technical challenges to implement/construct	No significant technical challenges to implement/construct
Maintenance	Requires a significant level of ongoing maintenance	Some scheduled maintenance is required	Maintenance free/minimal maintenance
Environmental impacts	Environmentally detrimental	Environmental benefits, but also drawbacks or no significant change	Potential for environmental enhancement
Cost (in relation to other options)	Significant cost	Moderate cost	Low cost
Health and safety	Fails to address or mitigate risk or makes risks worse including construction risks	Partially mitigates against health and safety risks or results in limited risks including construction risks	Potential to significantly reduce health and safety risks and low construction risks
Option life	Short term (<20 years) with further interventions required	Medium term (20-50 years)	Long term (50+ years)
Public acceptance	Potential for major objections or goes against feedback received	Likely public will be for and against or meets some feedback received	Will be supported by majority of public and addresses main concerns

Assessment Criteria

In addition to the red, amber or green colour assessment, where an option is prohibitively negative in any one category (e.g. prohibitively expensive, dangerous or ineffective) a black classification can be used.

Classification	Definition
Black	**Prohibitive**

<u>Please note that preliminary option assessment detailed below is only indicative at this stage and will be updated following both stakeholder and public consultation.</u>

8.3.2 Preliminary Assessment Matrix - Unit A

Option	**Category**								
	Erosion risk	**SMP compliance**	**Technical feasibility**	**Maintenance**	**Environmental impacts**	**Comparative Cost**	**Health and safety**	**Option life**	**Public acceptance**
Do nothing								n/a	
Do minimum								n/a	
Cliff bolting									
Netting to base of cliff									
Rock revetment / Sill									
Timber revetment									
Sand bags / Geotubes									
Gabions									
Cliff drainage									
Seawall									
Offshore breakwaters									
Beach nourishment									
Groynes (rock or timber)									
Cliff stabilisation through re-grading									
Relocation of key assets								n/a	

Unit A – High-level Assessment Matrix

8.3.3 Preliminary Assessment Matrix - Unit B

Type	Option	Category: Erosion risk	SMP compliance	Technical feasibility	Maintenance	Environmental impacts	Comparative Cost	Health and safety	Option life	Public acceptance
No Active Intervention	Do nothing	Red	Red	Green	Green	Green	Green	Red	n/a	Red
	Do minimum	Red	Red	Green	Green	Green	Green	Green	n/a	Red
Maintain	Patch and repair maintenance of seawall and promenade	Green	Green	Green	Red	Amber	Green	Green	Amber	Green
	Re-facing of the seawall and promenade	Green	Green	Green	Green	Amber	Amber	Amber	Green	Green
	Repair / replace groynes	Amber	Green	Amber	Red	Amber	Green	Amber	Red	Green
	Eventual replacement of defences (maintaining existing crest level)	Green	Green	Green	Amber	Amber	Red	Amber	Red	Green
Sustain	Raise existing defences (on-going maintenance)	Amber	Green	Amber	Red	Amber	Amber	Amber	Red	Amber
	Raising and re-facing of the seawall and promenade	Amber	Green	Amber	Red	Amber	Amber	Amber	Red	Amber
	Repair / replace groynes	Amber	Green	Amber	Red	Amber	Green	Amber	Red	Green
	Eventual replacement of defences (to a raised crest level)	Green	Green	Green	Amber	Amber	Red	Amber	Green	Amber
Enhance/ Improve	Rock revetment	Green	Green	Green	Amber	Amber	Amber	Amber	Amber	Amber
	Sand bags / Geotubes	Amber	Green	Black	Amber	Amber	Green	Amber	Red	Amber
	Gabions	Amber	Green	Black	Red	Amber	Green	Amber	Red	Amber
	Replacement seawall, promenade and floodwall	Green	Green	Green	Amber	Amber	Black	Amber	Green	Amber
	Offshore breakwaters	Amber	Green	Amber	Green	Red	Black	Amber	Green	Green
	Enhanced Beach	Amber	Green	Amber	Red	Red	Red	Green	Red	Green
	Groyne replacement/enhancement	Amber	Green	Amber	Red	Amber	Green	Amber	Red	Green
	Timber revetments	Amber	Green	Amber	Red	Amber	Amber	Amber	Red	Green
	Rock groynes	Amber	Green	Amber	Green	Amber	Red	Amber	Green	Green

Unit B – High-level Assessment Matrix

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Appendix A – Site Note: Hunstanton Cliffs Preliminary Assessment