Hastings Borough Council

Coastal Adaptation Pathfinder
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CANTERBURY CITY COUNCIL

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1.0 Introduction

Shingle beaches provide a vital element of the flood and coastal erosion defences along the Hastings frontage. The monitoring and management of this asset is therefore crucial to the successful and sustainable delivery of flood and coastal erosion protection.

The Hastings shoreline and its fronting beach have been heavily modified and engineered over time. Remedial works at the harbour between 1970 and 1980 improved an area known as the ‘Stade’, at the eastern end of the study area. These maintenance works restricted the movement of shingle eastwards; thus, to the west of the harbour arm shingle accreted (Halcrow, 2006). Recently the gradient of the shingle bank within the harbour, which is used to store a beach-launched fishing fleet, has become exceptionally steep. This is contributing to significant problems for safe landing and launching of fishing boats. This study has been initiated in order to investigate the reasons for and impacts of coastal change upon the movement of shingle within and around the Harbour, which has had a direct impact on the unique resource of the fishing industry at Hastings.

The aim of Stage 1 of the study is to carry out a detailed investigation into the past, present and anticipated future condition of the beach at Hastings Harbour and its impact on harbour users. This will involve analysing the environmental influences, including coastal processes and factors of climate change and their varying effects on the coastline and beaches. This will then allow the project to move to Stage 2, which will be a more detailed analysis of the future scenario together with recommendations for what may be possible to reduce the impact of sediment transport and climate change on the fishing community.

2.0 Background Information

The following is a literature review of available documents evaluating the historical changes and responses to the harbour and the surrounding coastline. Brief details of recent engineering works that have impacted upon the study site are listed. A selection of aerial photographs from the Environment Agency's Aerial Beach Management Survey (ABMS) photo set have also been compiled in order to provide a pictorial record of change since the 1970s.

2.1 Previous Studies and Strategies

The ***Shoreline Management Plan (SMP)*** for this coastline is the South Foreland to Beachy Head SMP First Review 2007. This frontage is designated in the SMP as Policy Unit 24 – Hastings, with a recommendation to "hold the line of the existing defences for the next 100 years". Under the SMP Action Plan there is a high priority action for the maintenance of existing structures and improvement to groynes and harbour structures. This is to ensure an adequate beach is maintained to provide protection to the town and to retain its amenity value.

The ***Cooden to Cliff End Coastal Defence Strategy Plan (2004)*** specifically identified urgent works of beach recharge and construction of additional groynes around the White Rock/Carlisle Parade junction location and the need for attention to the terminal groyne at the east end of the frontage**.** A detailed study was undertaken in 2006 by Halcrow to examine the best way to take forward the urgent works.

The ***Hastings Harbour Arm Structural Review (2008)*** reviews the structural condition of the harbour arm and considers its strategic importance as a sea defence structure; to retain the beach to the west and protect the harbour on the east side from the prevailing south westerly wave activity. The report provides recommendations and estimated costs for future work.

Construction of the harbour arm was between 1895 and 1899, but was never fully completed. Subsequent failures and a mix of remedial measures have resulted in a general appearance of dilapidation. The report proposes a rock groyne together with beach feeding for this location in order to improve the sea defence.

In 2009, Canterbury City Council proposed an application for urgent works to be carried out ***(Hastings Coastal Defence Works, 2009)*** to maintain the existing defences along the Hastings frontage. The objective of the project was to carry out do minimum works to reduce the risk of seawall failure in the short term whilst the coastal defence strategy plan is reviewed and long term measures assessed. The works comprised beach recycling to restore the beach at the seawall and a small rock groyne to contain the beach, plus refurbishment to the concrete terminal groyne structure.

Three do minimum options were examined, all of which included the works to the terminal groyne and beach recycling. The options were for retaining the beach by a rock groyne (preferred option) or by a timber groyne, plus the option of annual beach recycling with no new groyne. The rock groyne option was chosen on economic grounds and because it would be more likely to fit in with likely long-term proposals.

2.2 Coastal Defence Works

Hastings 2009 Recycling Scheme

This area has a historical trend of critically low beach levels, as a result of which a coast protection scheme was submitted to DEFRA, although this was subsequently turned down in December 2006. However, a resubmitted scheme was approved by the Environment Agency in January 2009. There are a number of components to the scheme, which are outlined below, and in Figures 2.1 & 2.2 (Canterbury City Council, 2009);

1. Refurbishment of the concrete terminal groyne structure at the east end of Rock-a-Nore Road. This is a concrete structure with stone pitching where sections of the east side are in very poor condition and crumbling away. Concrete refacing to the exposed parts of the structure is considered to be the only viable option. It is thought that this would prolong the life of the structure by at least 20 years. After that time, further refurbishment may be required.

2. Restacking of the existing precast concrete stabits that have settled at the harbour arm to improve the protection to that concrete groyne structure. This is an inexpensive operation that will help to maintain the effectiveness of the harbour arm as a main groyne retaining the beach in front of Carlisle Parade to the west. The restacking of the stabits will increase short-term protection whilst a study into the condition of the harbour arm is carried out during 2009.

3. Adjustment to the planking on the three timber groynes (Groynes 21A, 22A, 23A) between the pier and the main site of works. Detailed surveys of the groynes has revealed that adding planking to some of the groynes and removing planking from others, mainly along the upper part, would improve the general beach situation. This allows a small increase in transport to the east but ensures sufficient planking to maintain the required beach profile across the groyne bays.

4. The construction of one new small rock groyne at Carlisle Parade and beach recycling. The size of the new rock groyne is the minimum to provide adequate beach retention at the Carlisle Parade location over the next five years. Its design is such that it can easily be raised and extended in the future. It is 53m long, comprising 1,500 tonnes of 3-6 tonne armour rock laid on heavy-duty geotextile. At a placed density in the order of 1.7 tonnes per cubic metre the volume of rock is in the order of 880m^3. The groyne is at level +5.0m OD at the seawall sloping down to the foreshore where it is toed in. The rock was delivered by sea direct to the site of the groyne using small self-discharging vessels. The rock is carboniferous limestone from Boulogne, which has been used successfully for many coastal defence structures in the past.

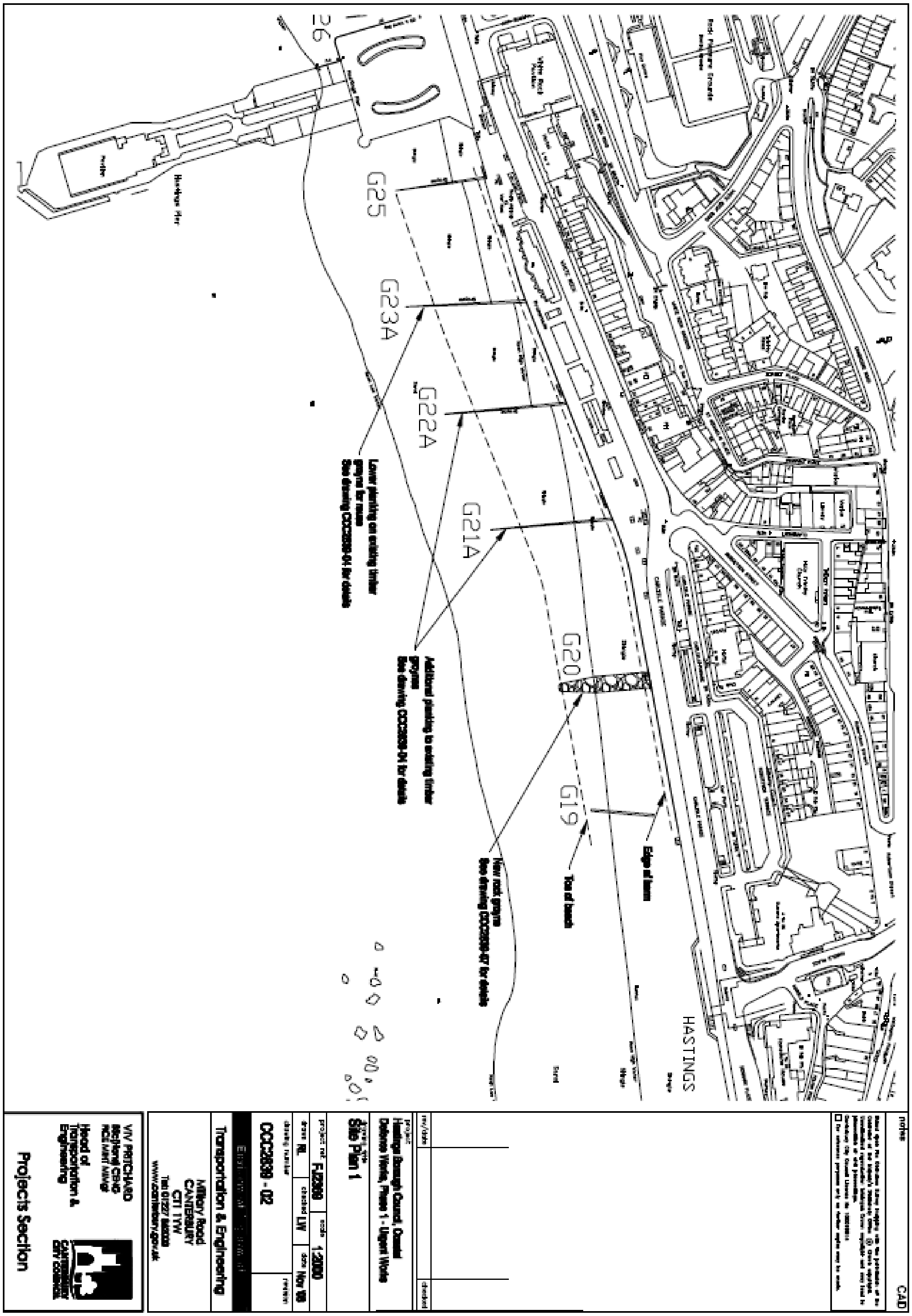


Figure 2.1: Hastings Recycling Scheme Site Plan 1

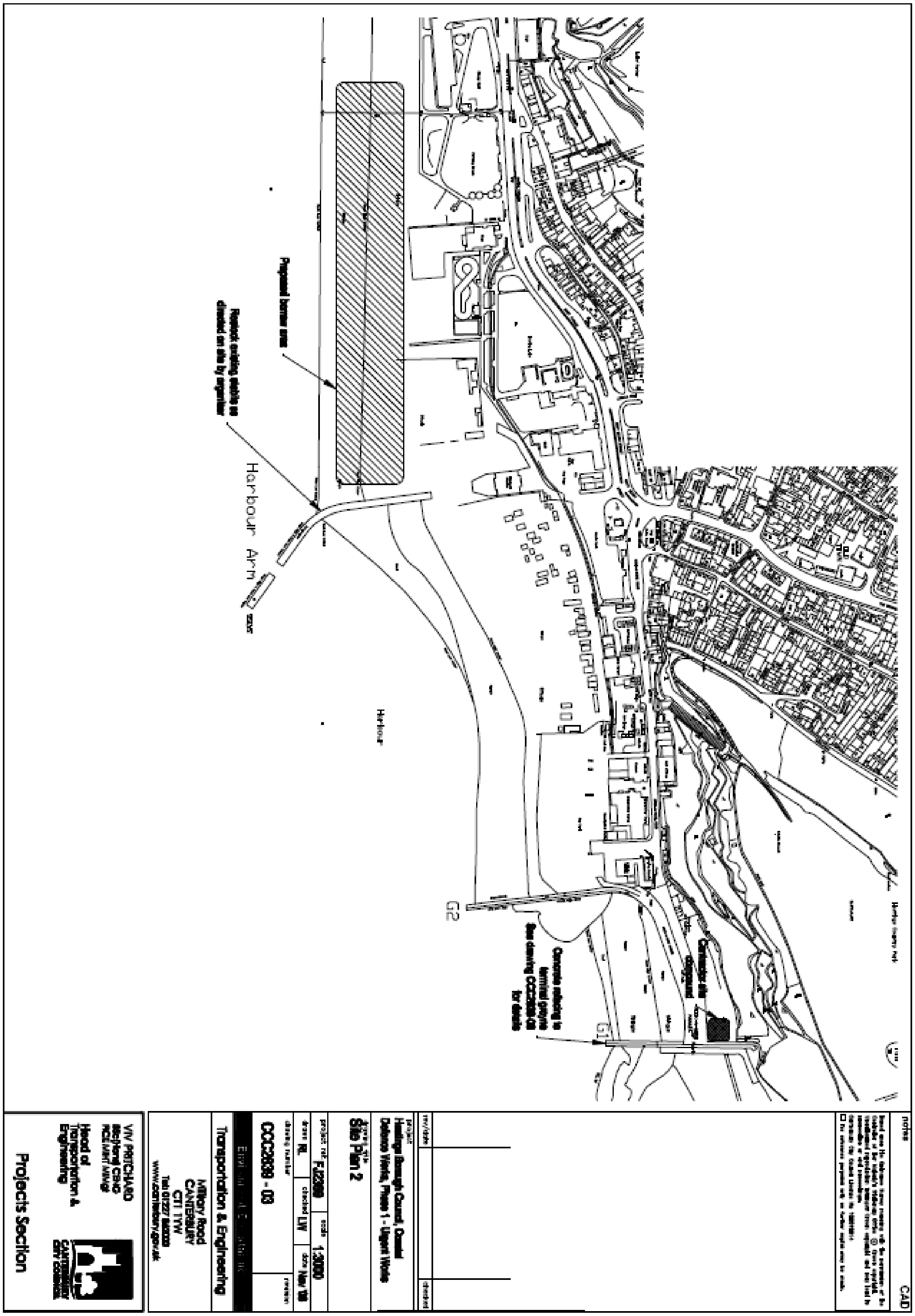


Figure 2.2: Hastings Recycling Scheme Site Plan 2

Following construction, the beach in the depleted area of White Rock was recharged using shingle recycled from a borrow area at Marine Parade just to the east. The depleted beach over about a 400m length east of Groyne 21A (Figure 2.1) was brought up to minimum level +4.5m OD at the seawall, with a level berm of 5m and slope of about 1 in 8 down to the foreshore. This required in the order of 15,000 m^3 of shingle.

Further beach recycling was carried out in April 2010 utilising the same extraction and deposition areas. As part of the scheme the harbour beach was also regraded; a temporary measure which reduced the gradient of the beach face to a 1 in 7 slope.

Bulverhythe Sea Defences Project

The Bulverhythe coastline is managed by the Environment Agency who maintains the frontage as a ‘hold the line’ policy in line with the recommendations of the Shoreline Management Plan (SMP), in order to protect the rail/road infrastructure and settlements. In 2006 the Bulverhythe Sea Defences project was completed for the Environment Agency. The project consisted of:

- The removal of 36 ineffective and dilapidated timber groynes ,
- The construction of 9 rock groynes and 700m of rock revetment,
- A capital recharge of 94,500m^3.

Again in late summer 2009, seven loads of shingle totalling 5,044m^3 were deposited west of the outfall.

2.3 Historical Aerial Photographs

As part of the Environment Agency’s Aerial Beach Management Survey (ABMS) the entire Sussex coastline has been photographed on an annual basis since the late 1970s. Aerial photographs from 2008, 2000, 1990 and 1980 are displayed in Figures 2.3-2.6.

Although the beach has noticeably increased in width naturally through accreting shingle over the years, the fishing fleet is strongly evident in all the aerial photographs with what appears to be a similar number of vessels.

Figure 2.3: Hastings Harbour Aerial (2008)

Figure 2.4: Hastings Harbour Aerial (2000)

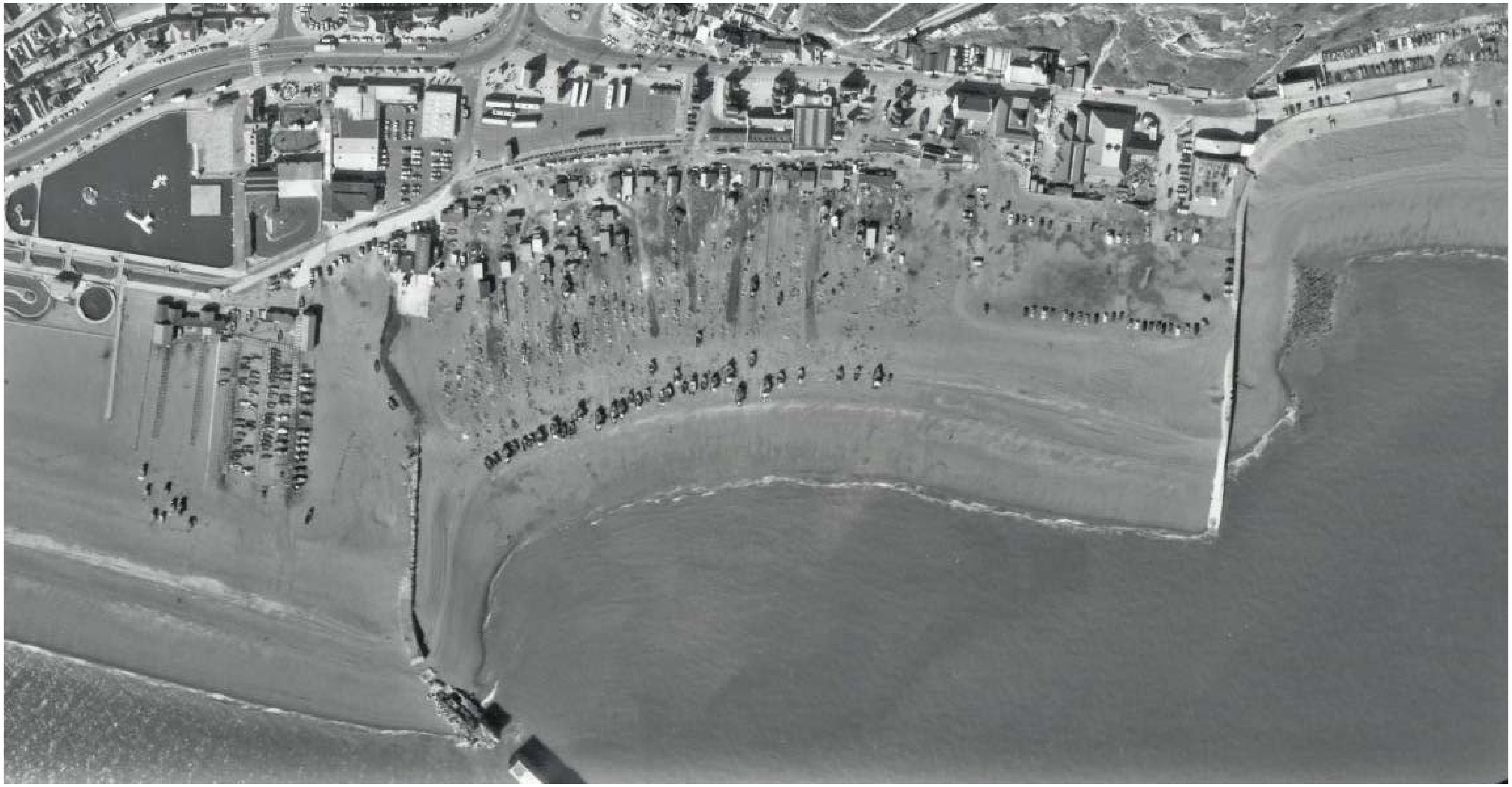


Figure 2.5: Hastings Harbour Aerial (1990)

Figure 2.6: Hastings Harbour Aerial (1980)

3.0 Hydrodynamics

A hydraulic appraisal has been conducted for the Hastings beach using all available data from previous studies and recent monitoring of the adjacent coast. The hydrodynamic climate is the driving force behind sediment transport and dictates the natural appearance of the beach both in terms of topography and sediment composition. Primarily maintained as a crucial part of the sea defences it also has significant amenity value and is linked to a number of commercial activities, not least the Hastings fishing fleet.

A suitable shingle beach can dissipate wave energy, reduce overtopping and prevent damage to the seawall. As a consequence of the dynamic nature of shingle, the hydrodynamic characteristics result in sediment transport and dictate the beach face gradient and orientation of the berm. Without suitable controlling structures this can lead to erosion of the beach and failure to maintain an adequate defence. The 2009 remedial works were designed to rectify such a problem east of Hastings Pier (Figure 3.1). Refurbishment of existing groynes, combined with the construction of a new rock groyne, and recycling of beach material acting to create a larger stable beach.

Figure 3.1: Impact of a Recent Storm Event at Hastings Prior to Remedial Works in 2009

3.1 Water Level Data

Variation in tidal levels is a function of astrological geometry and the Earth's topography. Harmonic analysis validated with actual measurements means these are well established and distributed by the United Kingdom Hydrographic Office (UKHO) (Table 3.1).

Table 3.1: Hastings Tidal Data

Admiralty Tidal Information (m ODN*)							
Port	**MHWS**	**MHW**	**MHWN**	**MSL**	**MLWN**	**MLW**	**MLWS**
Hastings	3.80	2.90	2.00	0.05	-1.60	-2.25	-2.90

**Conversion from CD to OD is -3.80 at Hastings.*

For illustrative purposes these levels are shown in contrast to a profile at the western end of the harbour beach (Figure 3.2). At present the beach crest is over two metres higher than the mean high water spring tide level providing a good standard of protection to the fleet and hinterland.

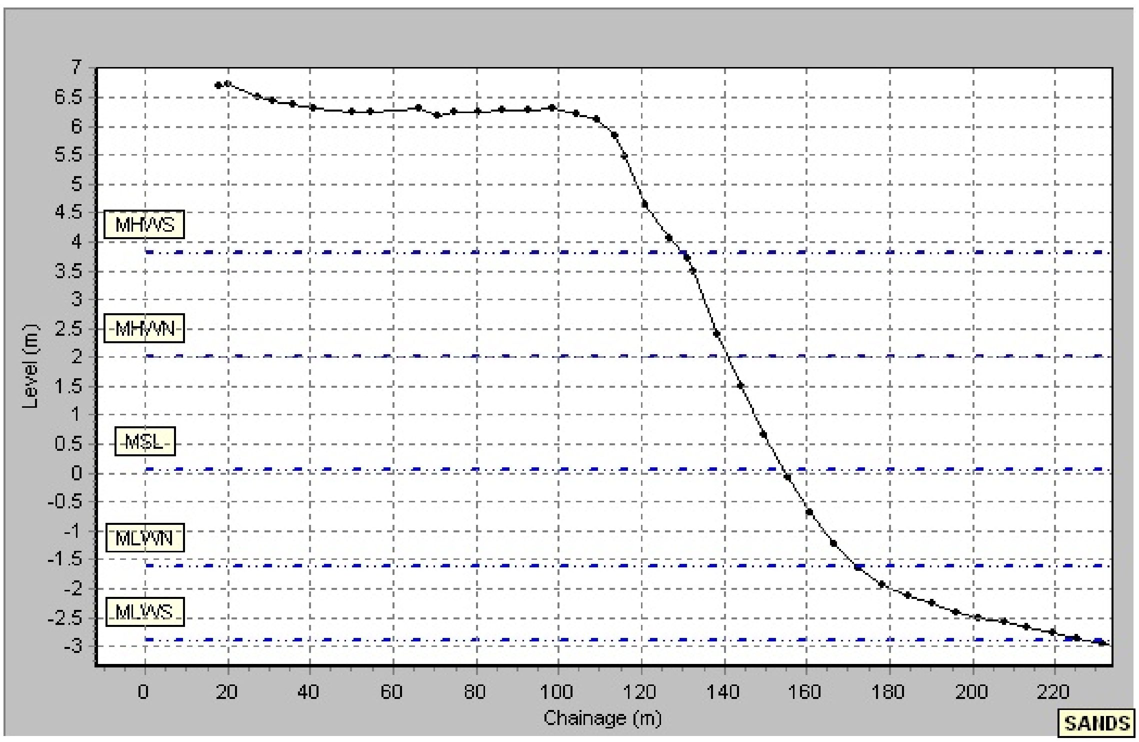


Figure 3.2: Tidal levels Superimposed on a Profile Surveyed in Spring 2010 at the Western End of the Harbour Beach

Currently there is no instrumentation to monitor water levels in the immediate vicinity of Hastings. The locations of the nearest active tide gauges are shown in Figure 3.3.

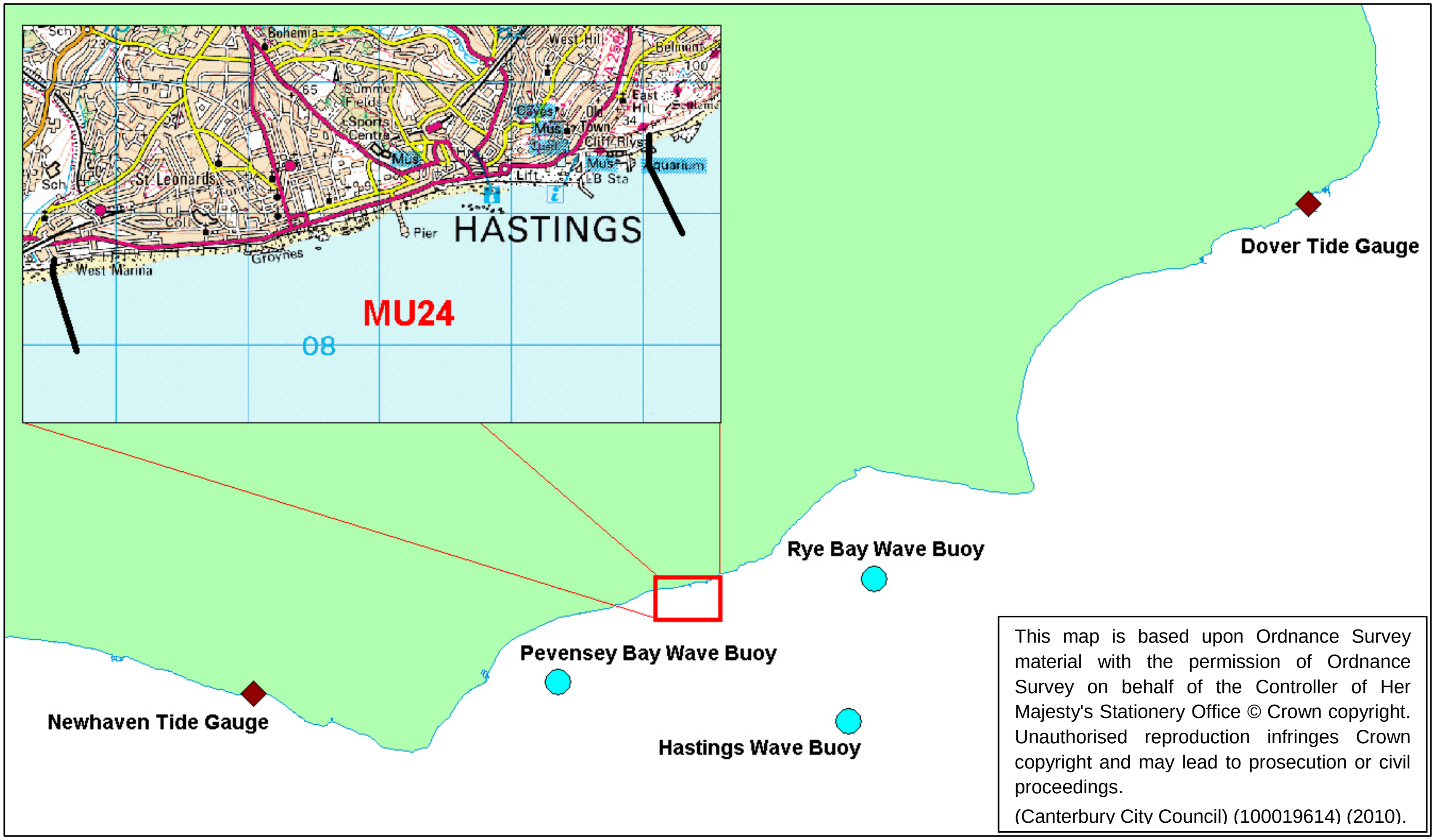


Figure 3.3: Site Location and Wave/Tide Gauges

Storm surges frequently result in water levels exceeding the predicted astronomical tidal level. These are primarily caused by high winds and low pressure systems, associated with storm events, causing water to pile up higher than the ordinary sea level. Table 3.2 and 3.3 show the highest recorded surges at the two nearest tide gauges.

Table 3.2: Dover Top 10 Positive Surges

Date	Surge (m)
1989/02/14 10:00	1.84
1926/10/10 09:00	1.71
1993/02/21 07:30	1.61
1983/02/01 22:00	1.55
1990/12/12 14:00	1.53
2007/11/09 03:30	1.52
1924/12/28 10:00	1.50
1995/01/10 09:30	1.45
1964/12/03 20:00	1.42
1965/12/10 09:00	1.38

Table 3.3: Newhaven Top 10 Positive Surges

Date and Time	Surge (m)
1987/10/16 04:00	1.27
1993/02/21 10:45	1.02
2000/10/30 10:30	0.98
2002/11/14 06:30	0.97
2000/12/08 05:30	0.94
1998/01/04 16:15	0.91
1983/02/02 00:00	0.91
2007/01/18 08:15	0.91
1995/01/10 11:15	0.90
1984/01/14 08:00	0.89

* Data obtained courtesy of the National Tidal and Sea Level Facility (**http://www.pol.ac.uk**)

Surges of such magnitude can have serious impacts on the coastal environment, especially when they combine with a high tide. Even today these events can only be predicted in the short term, consequently it is important to know the probability and potential size of these events in order to assess the suitability of the current defences. To this end Hydraulics Research (HR) Wallingford, as part of the UK south coast shingle study (Hague R, 1992), produced a joint probability analysis of wave heights and water levels at Pevensey Bay. The resulting return periods are given in Table 3.4.

Table 3.4: Extreme Water level Conditions for Pevensey Bay (Hague R., 1992)

Return Period (Years)	Water level (mODN) by Direction Sector (deg N)			
	0-360	70-130	130-190	190-255
0.1	4.06	3.66	3.47	3.98
1	4.38	4.02	3.95	4.35
10	4.62	4.24	4.21	4.62
50	4.77	4.35	4.34	4.77
100	4.83	4.39	4.39	4.83
500	4.95	4.48	4.5	4.95

As these figures were produced in 1992 they have been updated using current DEFRA guidance on sea level rise to reflect present day conditions (for a full explanation see climate change chapter) in Table 3.5.

Table 3.5: Extreme Water level Conditions for Pevensey Bay (2010)

Return Period (Years)	Water level (mODN) by Direction Sector (deg N)			
	0-360	70-130	130-190	190-255
0.1	4.1	3.7	3.51	4.02
1	4.42	4.06	3.99	4.39
10	4.66	4.28	4.25	4.66
50	4.81	4.39	4.38	4.81
100	4.87	4.43	4.43	4.87
500	4.99	4.52	4.54	4.99

It is worth noting that the highest risk is from storms from a south westerly direction and a water level that is expected to occur on average once every fifty years is a full metre above the spring mean high water level.

3.2 Wave Data

At any given time the wave climate is primarily a function of the wind speed, direction, duration and fetch length. Wave heights are intrinsically linked to water depth and reduce with shallow water effects as they approach the shoreline. As a consequence the size of waves that reach the beach are a function of offshore wave height, nearshore bathymetry and current tide/water levels.

Three wave buoys currently record wave data off the coast of Hastings (Table 3.6). Two Datawell Directional WaveRider Mk **III** buoys collect data as part of the Strategic Regional Coastal Monitoring Project, and another wave buoy positioned further offshore from Hastings as part of the CEFAS Wavenet programme. Their relative positions are shown in Figure 3.3.

Table 3.6: Wave Bouy Location Information

Wave Buoy Name	Operating Authority	Lattitude	Longitude	Approximate Water Depth	First Deployed
Pevensey Bay WaveRider	Channel Coast Observatory	50°46.966'N	00°24.974'E	9.8m CD	08/07/2003
Rye Bay WaveRider	Channel Coast Observatory	50°51.083'N	00°47.433'E	10m CD	27/08/2008
Hastings WaveNet*	CEFAS	50°44.770'N	00°45.220'E	40m CD	15/06/2003

* Data obtained courtesy of CEFAS (http://www.cefas.co.uk/data/wavenet.aspx)

For each year the most significant storms have been extracted and are included for reference in Table 3.7. These show that the most aggressive storm waves are generated from winds originating from the SW quarter. At Pevensey Bay the highest observed significant wave height is 4.23m from records between 2003 and 2009. Records from the Hastings WaveNet site show a similar trend but with slightly elevated wave heights reflecting its position offshore and deeper water. The largest observed significant average height is 5.25m over the same period. Results from monitoring at Rye Bay are consistent with observations at the Pevensey buoy.

Figure 3.4 graphically illustrates the incidence of storms recorded at Pevensey Bay since deployment in 2003. The 13th December 2008 saw the largest storm event of the most recent reporting period (July 2008 – Jun 2009), characterised by a maximum significant wave height (H_s) of 3.97m with a southerly wave approach. This was a significant event, not only at this location, but also at other sites further west along the Channel Coast.

The current reporting year has seen a pattern of storms comparable to the previous two years both in terms of frequency and magnitude of storms, in contrast to the relatively quiescent years of 2003/04, 2004/05 and 2005/06. The particularly rough winter months observed since 2006/07, which include nearly twice as many storms as the calmer winters of 2003-2006, are almost certainly a result of natural annual variation, rather than a response to climate change.

Table 3.7: Highest Storm Events 2003–2009

Date	Significant wave height Hs (m)			Direction	Water level (m OD) *
	Pevensey Bay WaveRider	Hastings CEFAS	Rye Bay WaveRider		
18 Jan 2009	3.36	3.67	3.42	SSW	0.83
22 Jan 2009	3.48	3.53	3.49	S	1.89
15 Jan 2008	3.96	-	-	SSW	2.45
31 Jan 2008	3.79	-	-	SW	0.45
10 Mar 2008	3.89	5.25	-	SSW	2.03
09 Nov 2008	3.35	3.53	3.27	SW	-0.42
04 Dec 2008	3.35	3.80	3.19	SSW	-0.37
13 Dec 2008	3.97	3.80	3.50	S	3.04
11 Jan 2007	3.60	4.24	-	SW	0.77
18 Jan 2007	4.23	5.06	-	SW	2.42
03 Mar 2007	3.09	4.24	-	SW	-0.12
06 Mar 2007	3.32	4.24	-	SSW	-2.12
02 Dec 2007	3.14	4.55	-	SW	0.46
03 Dec 2006	4.10	4.55	-	SSW	2.82
07 Dec 2006	3.34	4.55	-	SW	-2.20
11 Dec 2006	3.59	3.67	-	SW	1.08
30 Dec 2006	3.59	4.09	-	SSW	1.68
08 Jan 2005	3.53	-	-	SW	2.61
03 Dec 2005	3.55	3.67	-	SSW	3.15
30 Dec 2005	3.55	3.80	-	S	1.25
31 Jan 2004	3.92	-	-	-	1.37
19 Mar 2004	2.94	3.53	-	-	0.84
23 Jun 2004	3.76	4.39	-	SW	2.31
14 Oct 2004	3.03	-	-	SSW	-0.85
02 Nov 2003	4.18	3.80	-	SW	-
03 Nov 2003	2.75	3.40	-	SWW	-
25 Nov 2003	2.69	2.82	-	SW	-
26 Nov 2003	3.11	3.40	-	SW	-
29 Nov 2003	3.45	3.53	-	S	-

* Data from Pevensey Bay Directional Wave Rider Buoy. Tide levels from nearest tide gauge at Newhaven. Records courtesy of Channel Coastal Observatory and the Centre for Environment, Fisheries and Aquaculture Science.

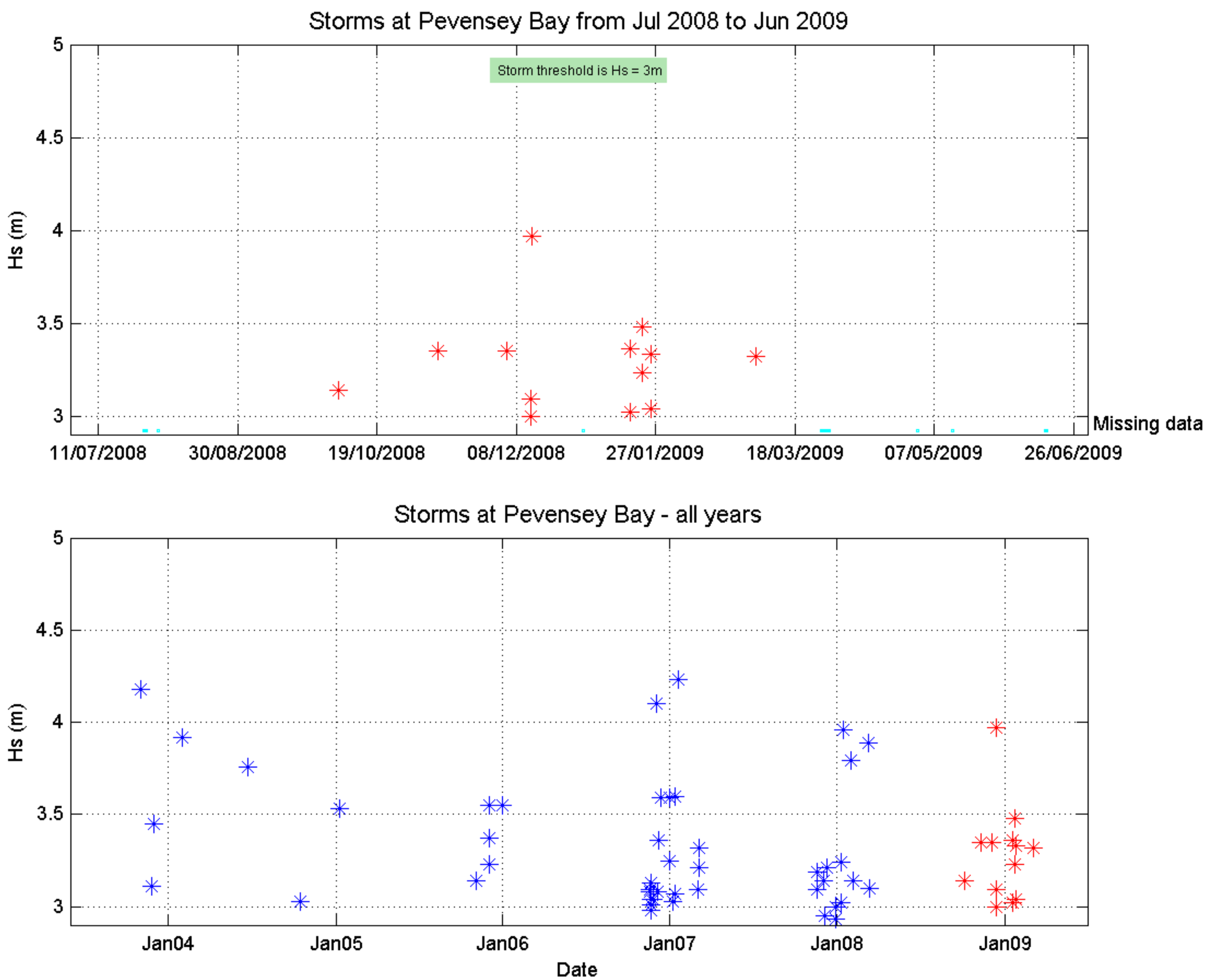


Figure 3.4: Incidence of storms during (a) most recent reporting period and (b) since deployment

Directional analysis of the Pevensey Bay data (Figure 3.5) demonstrates the predominance of south westerly waves, not only for large storm events but also for more regular waves. Although shingle and sand moves both east and west dependant on the current wave direction, this characteristic drives the net easterly sediment transport.

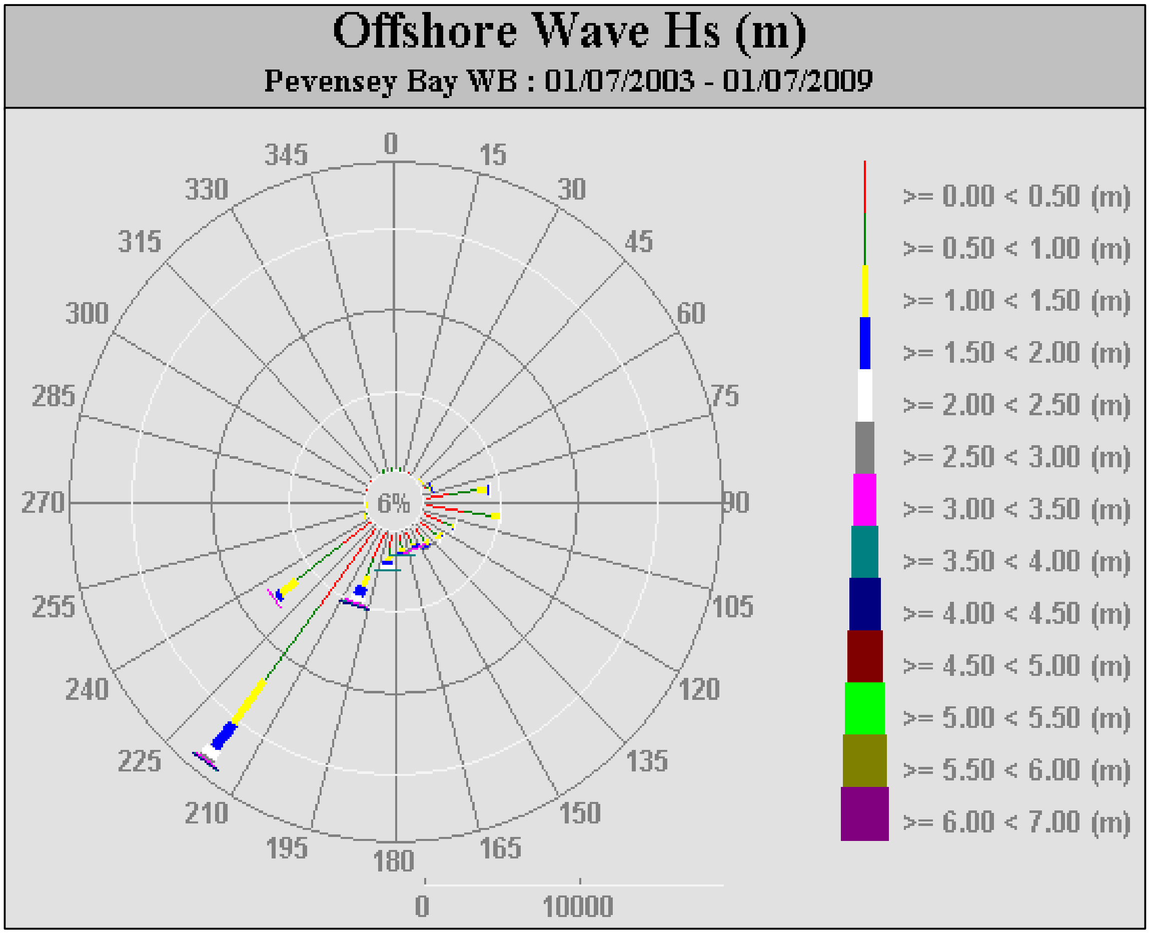


Figure 3.5: Percentage of occurrence of Direction vs. Offshore Wave Height (Hs) for July 2003 to July 2009

As part of the UK south coast shingle study wave heights were modelled for the Pevensey Bay site using local wind records up to 1990 (Table 3.8). The return periods and comparably large waves generated from the south west quarter are consistent with the measured data from the Pevensey wave buoy over the last seven years. It does however add weight to the argument that the last three reporting years have witnessed significantly more storms than an average year. The joint probability study produced a figure of 2.78m for the 0.1 year return period (occurs ten times a year on average), but the last three years have recorded over twice the number of these events.

Table 3.8: Extreme Wave Conditions for Pevensey (HR Wallingford, 1992)

Return Period (Years)	Hs (m) by Direction Sector (deg N)			
	0-360	70-130	130-190	190-255
0.1	2.78	1.29	1.74	2.77
1	3.70	1.75	2.55	3.67
10	4.50	2.13	3.12	4.39
50	5.02	2.36	3.44	4.84
100	5.23	2.45	3.57	5.02
500	5.71	2.65	3.84	5.41

From the 6 years worth of measurements, there is now sufficient evidence to suggest that this site seldom experiences the long period Atlantic swell which is regularly measured at the wave sites further west (including Rustington), and hence wave conditions at Pevensey Bay are dominated by in situ, wind-driven waves associated with the passage of low pressure systems.

4.0 Strategic Monitoring

Conceived in 2002 the Strategic Regional Coastal Monitoring Programme aims to provide a standard, repeatable and cost effective method of monitoring the coastal environment. Canterbury City Council are responsible for managing the project, and collecting data, for the coastline between Beachy Head and the Isle of Grain at the mouth of the Thames Estuary. All data collected by the Monitoring Programme are archived at the Channel Coast Observatory in Southampton.

As part of the Strategic Regional Coastal Monitoring Programme, the beach at Hastings has been surveyed three times a year since the summer of 2003, using land based GPS techniques. These consist of bi-annual profile surveys and a complete beach plan survey every year. If required, post storm surveys are also carried out after a storm event to detect the extent of any damage that may have been caused by storm waves. In addition to this, bathymetric surveys of the adjacent seabed were conducted in 2003 and 2006, and a network of tide and wave gauges has been set up in the southeast region. The location of the nearest wave buoys and tide gauges are shown in Figure 3.3.

4.1 Difference Models

To establish a 'long-term' review of trends in erosion and accretion along the Hastings frontage in terms of beach material volume changes, the most recently available complete Digital Ground Model (DGM) from spring 2010 has been compared to the earliest available baseline data (summer 2003) to create a difference model showing overall material gains and losses.

By overlaying and subtracting the 2003 DGM from the 2010 DGM, comparative volumetric analysis can be undertaken to determine change over the given period. Through the use of three-dimensional ground models and ortho-rectified aerial photography, it is possible to create a visual interpretation of the volumetric change that has occurred during each analysis period. This is shown in Figures 4.1-4.3, which indicate areas of net erosion or accretion (N.B. a 0.25m difference in elevation is considered as "no change") and the location of any extraction/deposition sites.

Sections of beach highlighted in red represent erosion that has occurred between 2003 and 2010, and the areas highlighted blue indicate accretion. Whilst these figures show an overall change in beach volume within each discrete section, it should be recognised that the data is based on the BMP survey, which is undertaken once each year. It is therefore only a snapshot of one moment in time, and the particular dynamics of each frontage need to be taken into account. This ensures that the information shown in the difference models represents the net change rather than capturing a particular extreme variation caused by a large event.

All of the difference models for each individual year from 2003-2010 are included in Appendix I.

Figure 4.1: Difference Model 2003-2010: Hastings Harbour

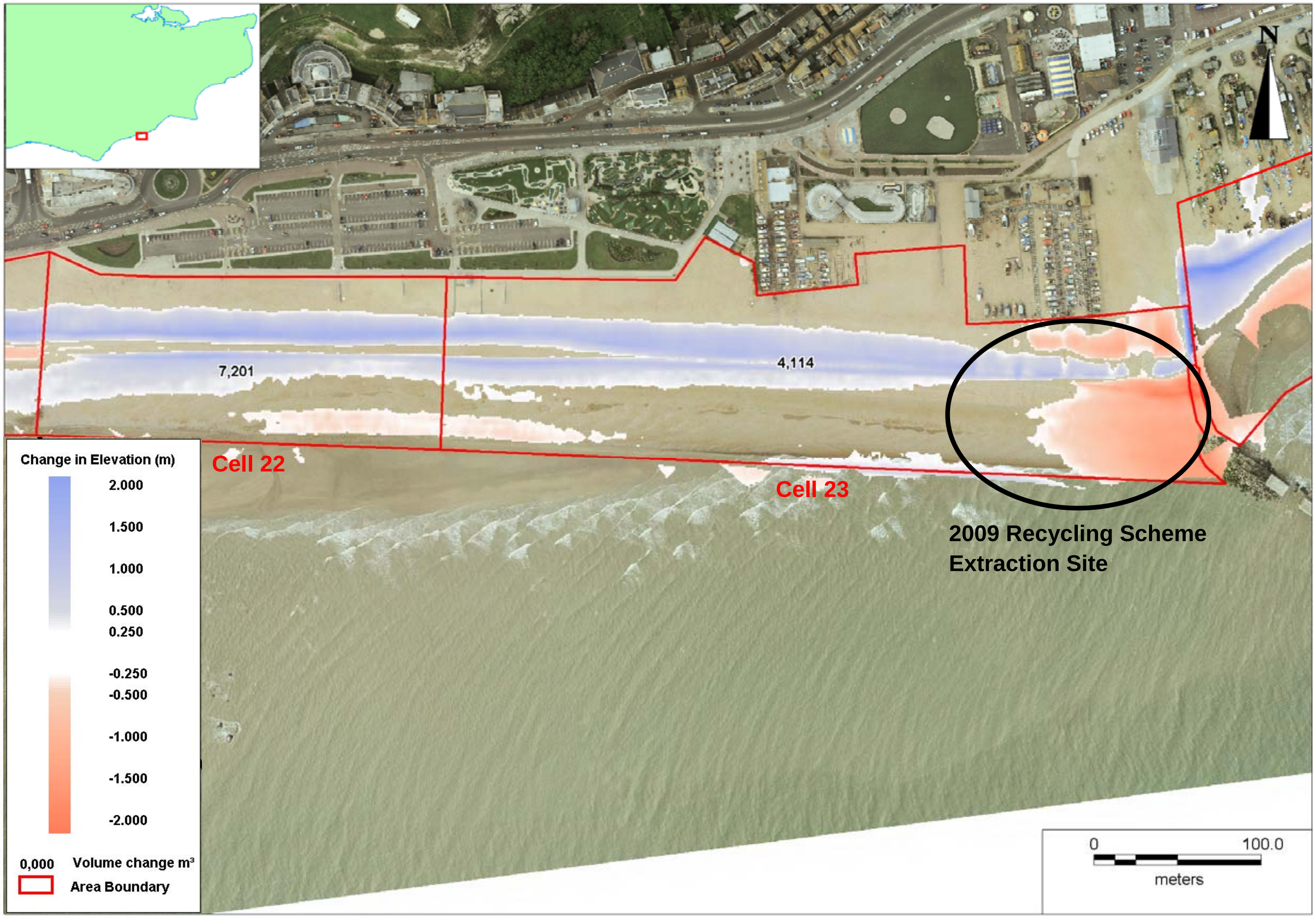


Figure 4.2: Difference Model 2003-2010: Marine Parade

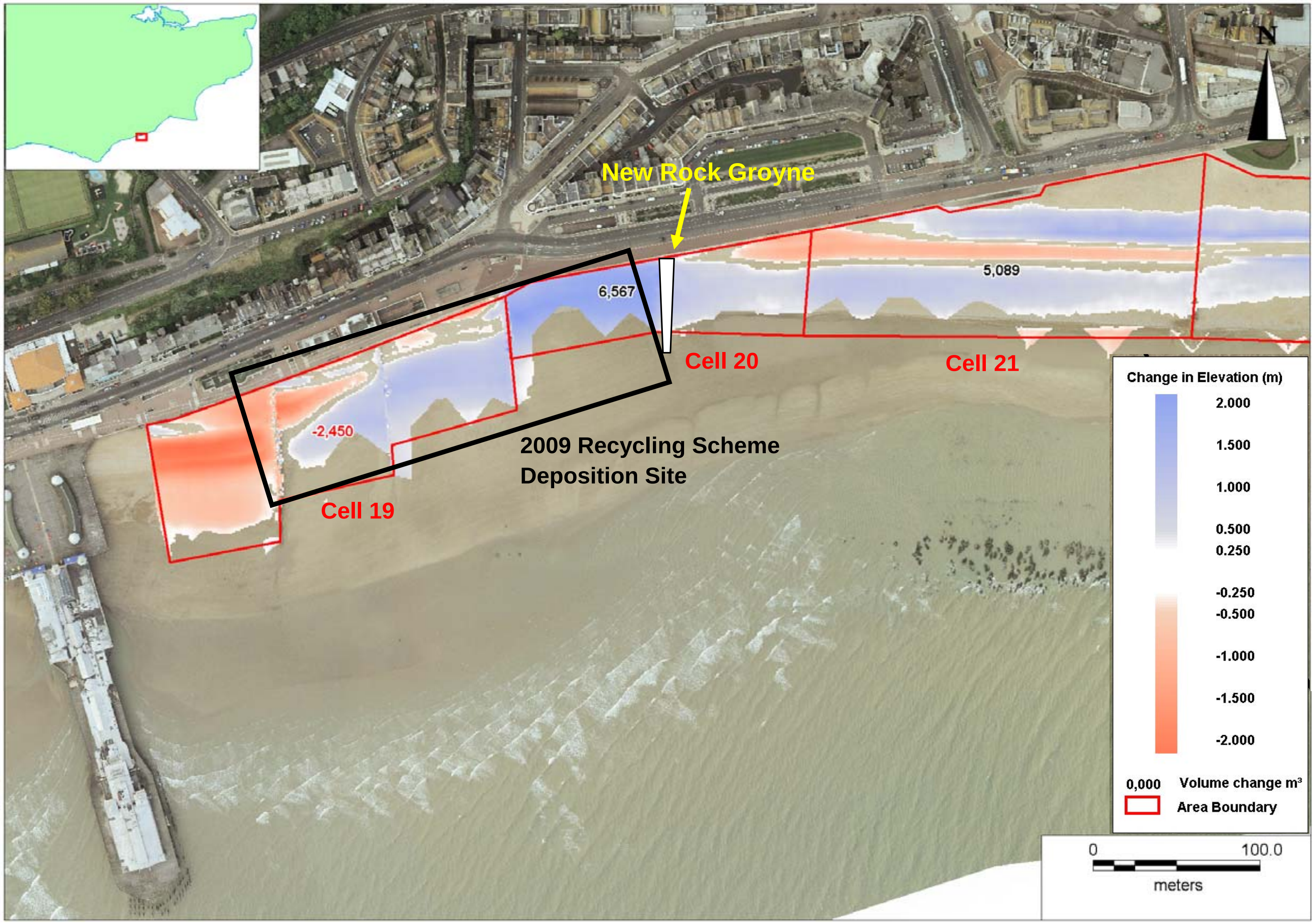


Figure 4.3: Difference Model 2003-2010: White Rock to Marine Parade

4.2 Beach Profiles

While beach plan surveys provide a more accurate view of morphological change and beach volume levels, profiles clearly illustrate the changes in beach cross section. In addition, the 2010 survey beach profiles have been cross-referenced with the other profile surveys carried out over the past seven years in order to ensure that the results from the difference models are representative of net profile change. This then gives an indication of the beach variability over several time steps.

The analysis of a number of cross shore profiles was carried out as part of this study, in order to identify evolution trends along the study area. Figure 4.4 shows the full set of beach profiles available in the study area.

Figure 4.4: Beach Profile Locations within the Hastings Harbour Beach

4.3 Analysis

Figures 4.1–4.3 illustrate the volumetric changes along the Hastings Frontage between the summer 2003 survey and the spring 2010 survey. Overall, the area between the pier and the harbour arm lost 4,742m^3, and the harbour area gained 3,990m^3.

The area of pronounced erosion on the western side of the Harbour Arm (Figure 4.2) at Marine Parade corresponds to the same area where beach material was extracted during a recycling event in May 2009. Approximately 15,000m^3 of shingle was extracted to recharge the beach in the depleted area of White Rock just to the west. Not surprisingly, a large amount of accretion has occurred on the beach adjacent to the newly constructed rock groyne (6,567m^3- Figure 4.3), the site of the deposited material. It can be seen that the crest height is now almost 2m higher than previously. There is also a linear pattern of accretion along the beach crest in cells 21, 22 and 23 to the east of the rock groyne (Figure 4.2 & 4.3), suggesting that surplus material from the over-filled groyne bay has been mobilised eastwards with the littoral drift and deposited along the beach crest.

The groyne bays in Cell 19 were also re-profiled as part of the scheme, and some planking was removed from the upper sections of the groynes in order to prevent sediment build-up starving the beach in Cell 20. This explains the apparent significant losses in the western groyne bay in Cell 19, where a large build of material on the beach crest was redistributed across the whole cell.

In total, the area of beach fronting the fishing fleet has experienced a net gain of 3,990m^3 over the last seven years since the monitoring project began (2003-2010) (Figure 4.1). This gain is probably the result of replenishment works carried out at Bulverhythe in recent years.

Since the capital works and recharge began at Bulverhythe, approximately 4km west of Hastings, any material that moves east cannot be retained by the groynes. The material therefore overtops the groynes, creating a supply of sediment that is moved eastward by longshore drift and transported into the Hastings frontage, generating a ‘wave-like’ pattern in beach levels along the way. It also creates distinct areas of loss and gain. Therefore, as sediment moves east from Bulverhythe and along the Hastings frontage, it eventually overtops the harbour arm and ultimately builds in Hastings Harbour. The shelter afforded by the harbour arm and the terminal groyne at either extents of the harbour beach have resulted in a great deal of updrift accretion.

Due to the large increase in material, the change in sediment size and profile gradient has made it more difficult to launch the boats. Profile *4c01349* (Figure 4.5), in the west of this section, illustrates where the beach sediment has been distributed. The majority of the beach face has increased in elevation, and a large berm 2.0m in height has been formed. Profile 4c01347 (Figure 4.6) clearly illustrates the steepening of the beach face between 2003 (gradient of 1:10) and 2009 (1:5).

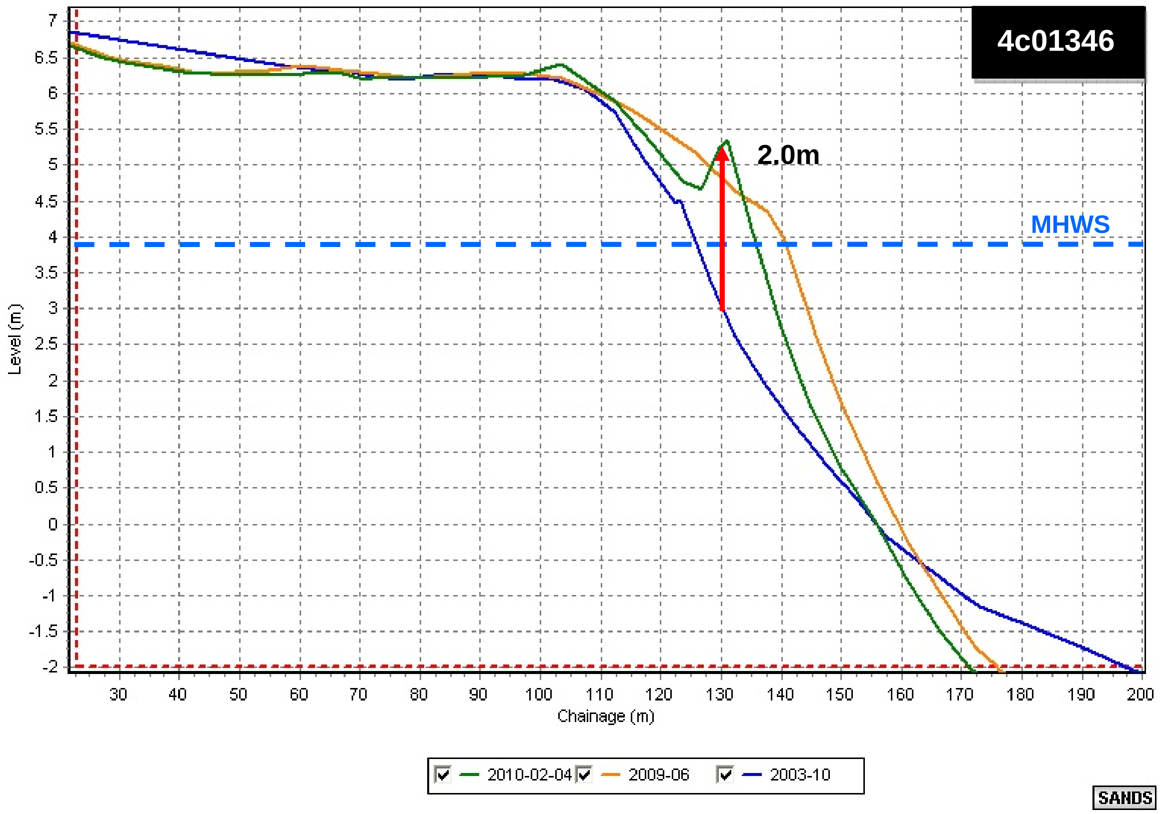


Figure 4.5: Profile 4c01346

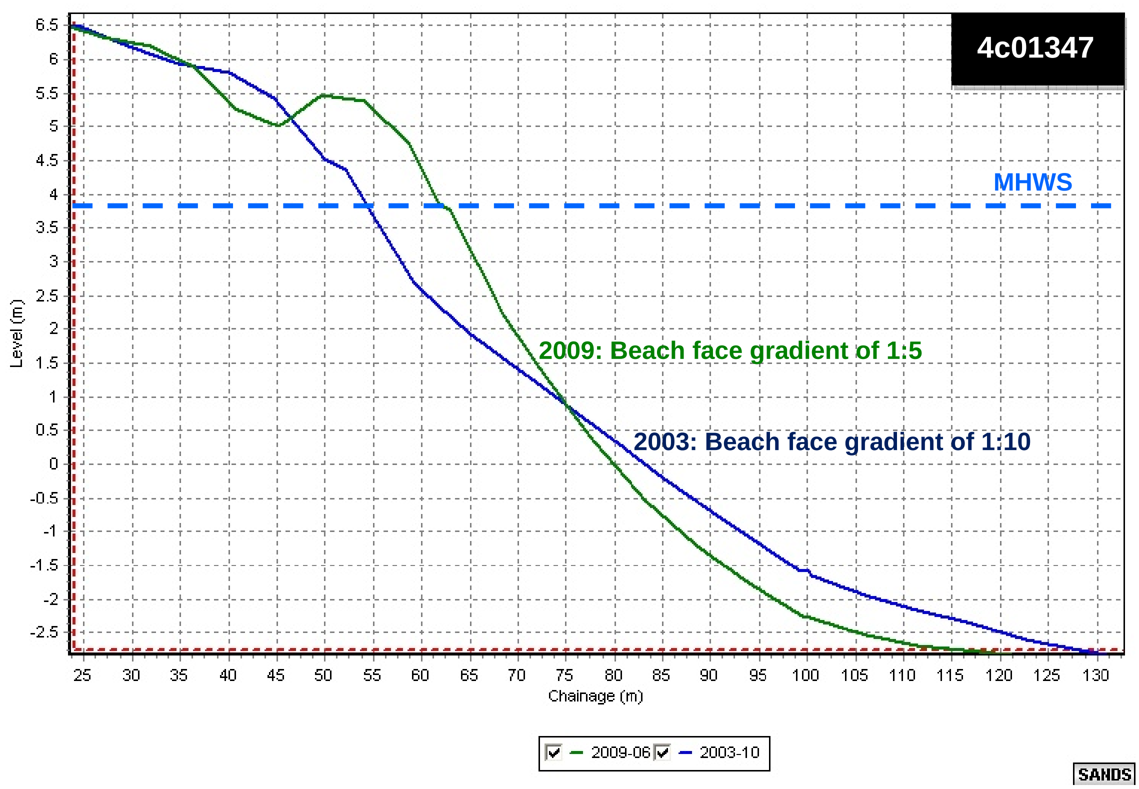


Figure 4.6: Profile 4c01347

Following the April 2010 regrading scheme, the crest has lowered by 1.5m within the harbour beach with a gentler slope of 1:7 on the beach face (Figure 4.7).

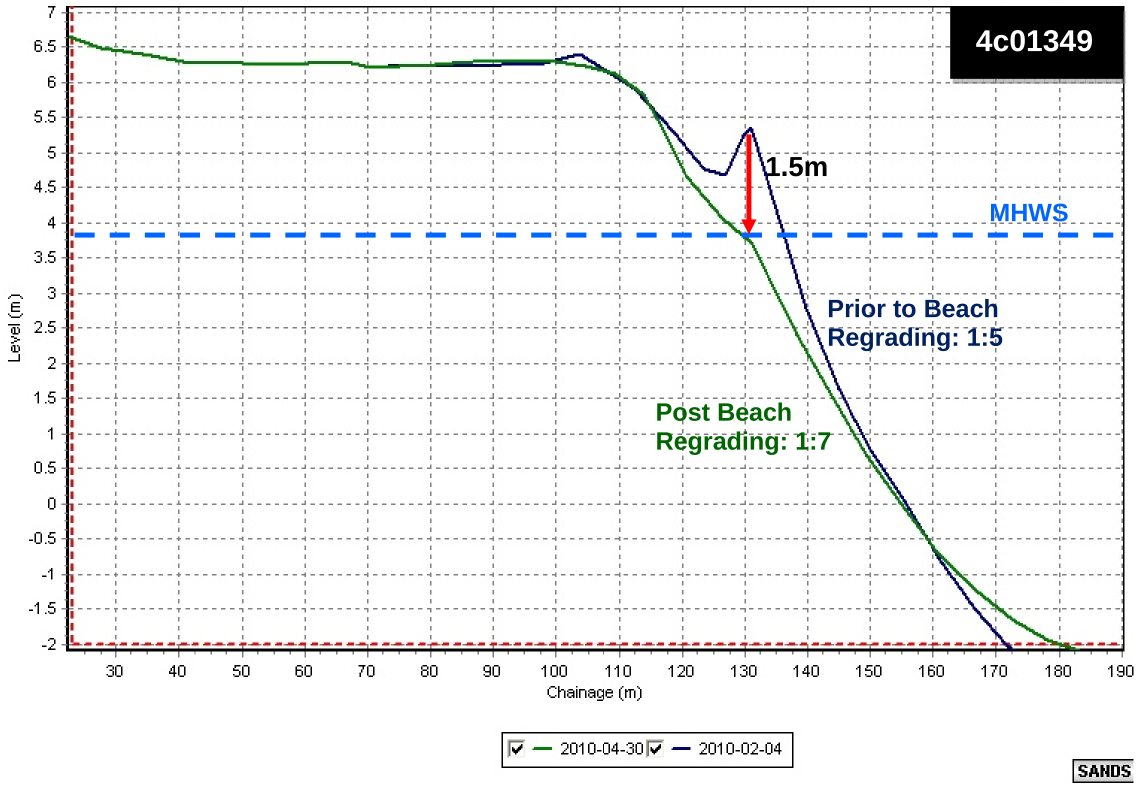


Figure 4.7: Profile 4c01349

A continuation of the strategic monitoring programme at this location is essential to ensure that any significant beach movement is known and the need for any recycling and regrading can be assessed.

5.0 Coastal Processes

Sediment transport along the Hastings frontage is primarily driven by the wave climate. As a result the drift is bi-directional dependant on the direction of the waves, which in turn is dictated by the predominant wind direction at any given time. Both modelled data and actual records demonstrate the predominance of waves in from a south-westerly direction. These drive the annual net sediment transport in an easterly direction. Controlling structures in the form of groynes and more significantly the harbour arm restrict sediment transport and help to maintain a suitable beach.

Figure 5.1 illustrates the sediment movement in and around the harbour beach, with the width of the arrows indicative of the amount of shingle transport. The net easterly drift has resulted in material building up on the western side of the harbour arm. This in turn feeds the harbour beach when it overtops the structure, and to a lesser extent circumnavigates the seaward extent. Due to the large height difference, either side of the harbour arm, shingle that bypasses the harbour arm is unable to move back in the event of a reversal in drift direction. In a similar fashion material moving through the open sluice gates (Figure 5.2) and round the terminal groyne is lost to the system.

At the eastern end of the harbour beach shingle moves in both directions, in response to wave direction, as is observed along the rest of Hastings beach. At the western end the transport patterns behave differently as a result of the sheltering effect of the harbour arm. Material moves in a westerly direction at similar rates to the rest of the coastline when subjected to waves from this direction, however very little material is able to move back in an easterly direction. The material that does move also tends to be finer given the reduced intensity of the hydrodynamic conditions. This has three effects:

1. Net sediment drift is in a westerly direction, resulting in accretion of material on the eastern side of the harbour arm.

2. Orientation of the beach berm is in a SW – NE direction as opposed to W – E that is observed along the rest of the frontage, producing a crenular shaped bay.

3. A natural sorting mechanism exists whereby large material is driven to the western side of the beach with aggressive easterly waves. This is then effectively trapped as the sheltering effect of the harbour arm results in only smaller material moving back eastwards.

Beach face gradients are a function of sediment size/composition and hydrodynamic climate. As a general rule coarser sediment is able to produce a beach with a steeper stable gradient, this phenomenon has resulted in the undesirable 1:5 gradient in front of the fleet at the western end of the harbour.

No sediment grading analysis records exist, so it is unknown if the quantity of coarse material is increasing and exacerbating the problem. Despite no factual record, it is probable that as sediment moves into, and through, the harbour beach more coarse material is being naturally sorted and trapped.

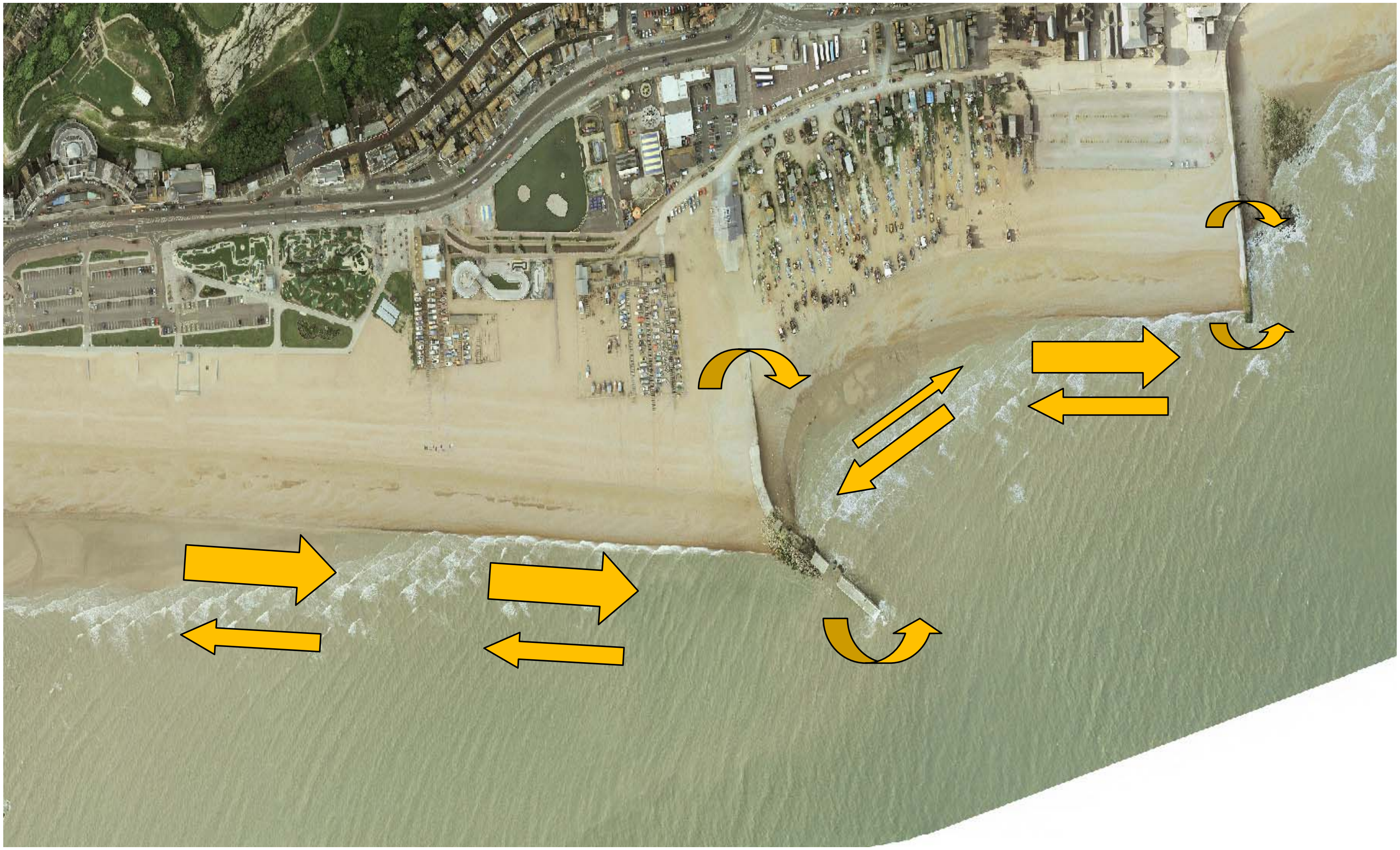


Figure 5.1: Sediment Movement Within and Around the Harbour Beach

Figure 5.2: Open Sluice Gate inside the Harbour Beach

5.1 Sediment Budget

Evolution of the harbour beach over the last thirty years has resulted in a relatively stable beach with similar mounts of material entering and leaving the system. Figure 5.3 demonstrates the evolution of the western side of the beach, a 70m increase in beach width and the development of the crenular bay. Since then the beach has maintained the same approximate plan shape.

More detailed records of beach changes are provided by the Strategic Coastal Monitoring Project. It is difficult to reach any conclusions with a high degree of confidence given the relatively short-term trends produced over a seven-year monitoring period. The data collected to date does however provide an insight into the accuracy of conclusions drawn in previous studies.

Loss rates for shingle along the Hastings frontage are quoted as 5,000m^3/a in the Cooden-Cliff End Strategy Plan (2002). The monitoring data collected from 2003-2006 indicated a loss of 7,200m^3/a for the whole frontage. However, since then, there has been a 43,242m^3 gain in sediment, which equates to an accretion rate of 4,252m^3/a. This shows that sediment change rates cannot be definitively calculated on the basis of short data sets.

Net sediment transport rates are quoted as 4,500-5,000m^3/a easterly in the *South Foreland to Beachy Head SMP* (1996, 2006), whereas the *Cooden to Cliff End Strategy Plan* (2002) estimates rates at 10,000m^3/a with a variability of +/- 5,000m^3. In reality transport rates vary throughout the frontage dependant on type/condition of controlling structures, amount of beach material, orientation of coastline and exposure to hydrodynamic conditions. Previous BMP reports have highlighted that actual transport rates appeared higher than predicted, the likely result of the replenishment works at Bulverhythe. Notwithstanding this anthropogenic distortion of the sediment transport process, the Strategic Regional Coastal Monitoring Project results do correlate with the predictions of the aforementioned studies.

This is best illustrated by the eastward movement of sediment, as shown in Table 5.1. With areas of gain coloured blue and areas of loss red, it can be seen that beach material migrates eastwards along the coastline. As mentioned previously, this is the result of sediment exceeding the capacity of groyne bays, and overtopping into the adjacent bay.

Figure 5.3: Beach Width Changes from 1980-2008. The distance between the front of a building beside the coach park and the beach crest has been measured for both the 1980 and 2008 aerials in order to see how far the beach has advanced over that time period.

Table 5.1: Loss/Gain Section Change Summary (2003 - 2009)

Section	Cell	Volume Change (m^3)					
		2003 - 2004	2004 - 2005	2005 – 2006	2006 - 2007	2007 – 2008	2008-2009
West Marina	1	-5,069	-1,523	-292	12,426	-2,254	-2,977
	2	-3,298	-1,300	-1,236	8,996	-2,266	-986
	3	-878	-1,668	-1,919	-4,620	9,844	3,502
	4	-562	-767	-1,338	-4,893	8,421	3,020
Undercliff Marina	5	-2,067	1,070	-2,305	-4,355	7,432	-1,115
	6	-3,270	980	3,022	-7,572	8,501	-2,843
	7	388	-2,566	432	-105	2,456	1,107
	8	3,125	-3,399	2,337	-2,063	-1,986	1,359
	9	5,222	-2,941	-2,521	2,103	-3,959	-175
Grand Parade	10	1,806	-558	-1,733	1,020	-2,707	-542
	11	238	1,188	-2,396	886	-1,521	-220
	12	982	1,553	-1,692	974	-2,754	-773
Eversfield Place	13	-3,156	3,356	-97	1,434	-5,357	-316
	14	-3,000	1,867	1,836	-917	-3,030	-1,043
	15	-1,481	-158	2,306	-679	-856	-1,941
	16	-1,020	-1,427	2,462	-2,279	2,143	-2,603
	17	-231	-1,585	1,486	-1,955	1,683	-928
	18	217	-747	-353	-900	829	612
White Rock	19	-2,183	-2,726	815	1,275	2,314	2,395
Marine Parade	20	-11	-1,316	-840	5,078	-3,103	10,702
	21	6,331	-1,371	1,980	-2,470	-1,783	4,071
	22	3,307	451	1,537	-312	-638	1,868
	23	1,398	1,578	-1,014	6,122	10,782	-20,296
Harbour Beach	24	-6,032	-2,138	1,059	994	11,392	223
Rock-a-Nore	25	4,480	2,121	-6,328	2,794	-1,323	390

6.0 Climate Change Effects

The impacts of Climate Change are well documented and include sea level rise and the potential increase in intensity, severity and frequency of coastal storms. Using the current DEFRA guidance on net sea level rise and climate change, the effects of increased still water levels, and the associated increase in wave height and storm frequency, have been examined for Hastings beach.

This encompasses the added risk of wave overtopping/damage, flooding, influence on sediment transport and changes to the coastline plan shape and beach face gradient over the next 20, 50 and 100 years.

6.1 Sea Level Rise

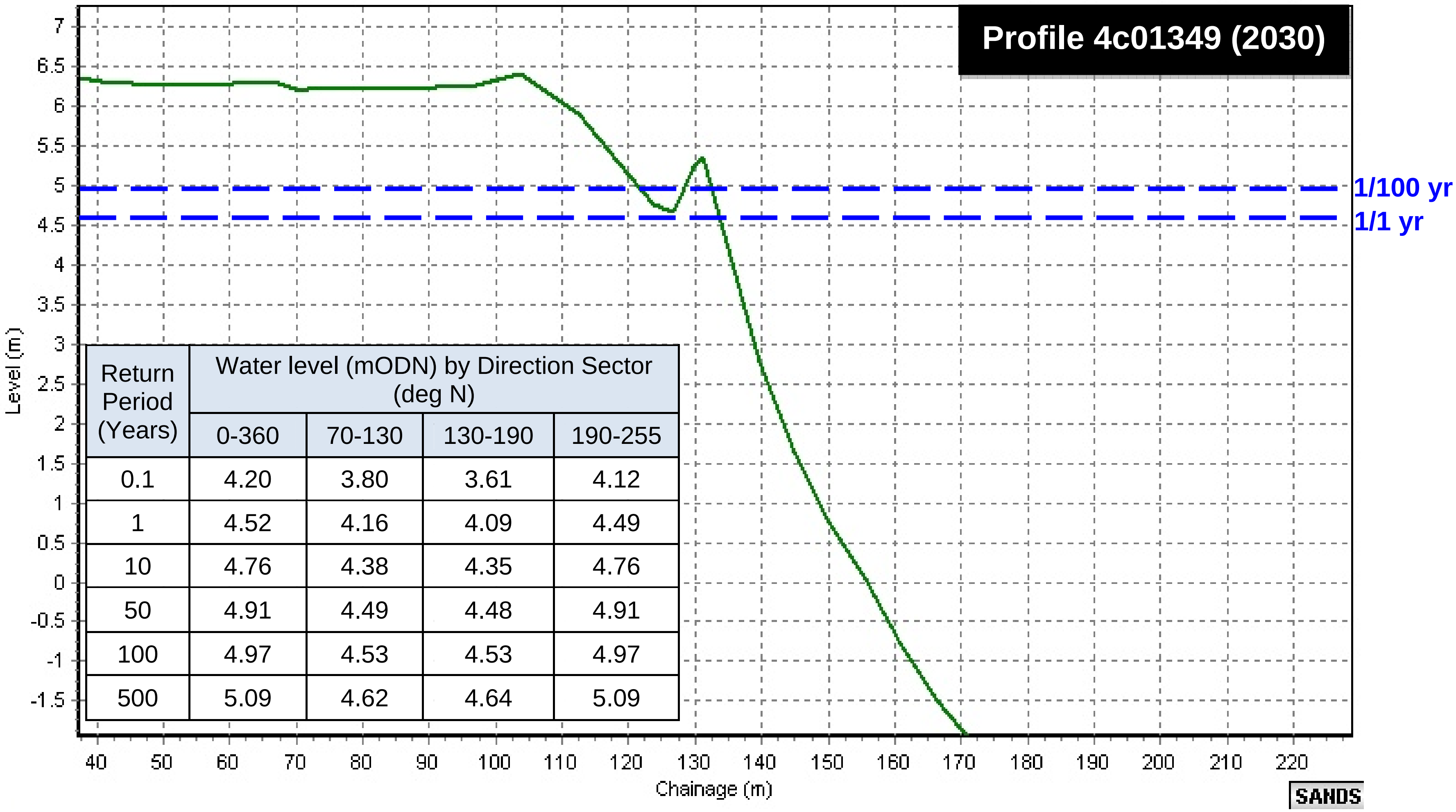
In the Southeast of England anticipated increases in water levels are a combination of two factors. Primarily rising sea levels due to melting ice caps and thermal expansion of the oceans, this is supplemented by the isostatic rebound of Great Britain from the last ice age causing a vertical drop in land levels in the southeast.

DEFRA guidance on climate change impacts was updated in 2006 replacing the previous projections of a linear rise in sea levels, of 6mm/year in the region, to an exponential curve rising from 4mm/year in 1990 to 15m/year after 2085. Table 6.1 uses these guidelines to update the key tidal statistics for the next 20, 50 and 100 years.

Table 6.1: Predicted tidal levels given current sea level rise projections

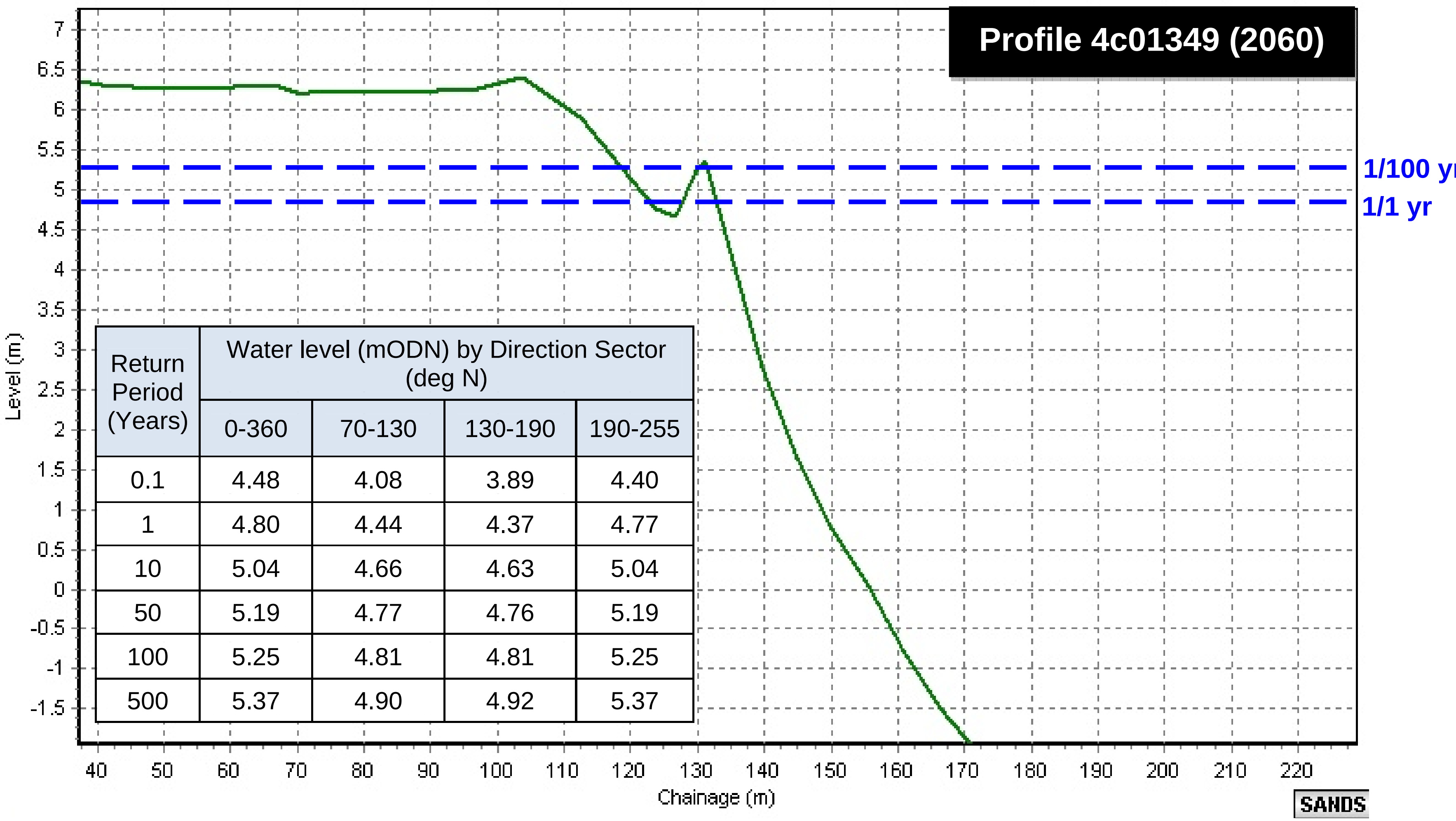
Hastings Admiralty Tidal Information with Projected Sea Level Rise (mODN)							
Year	**MHWS**	**MHW**	**MHWN**	**MSL**	**MLWN**	**MLW**	**MLWS**
2010	3.80	2.90	2.00	0.05	-1.60	-2.25	-2.90
2030	3.90	3.00	2.10	0.15	-1.50	-2.15	-2.70
2060	4.18	3.28	2.38	0.43	-1.23	-1.88	-2.43
2110	4.85	3.95	3.05	1.10	-0.55	-1.20	-1.75

To put these changes into context the levels and anticipated return periods for extreme water levels have been updated and graphically illustrated against a recent profile survey at the western end of the harbour beach (Figures 6.1-6.3).



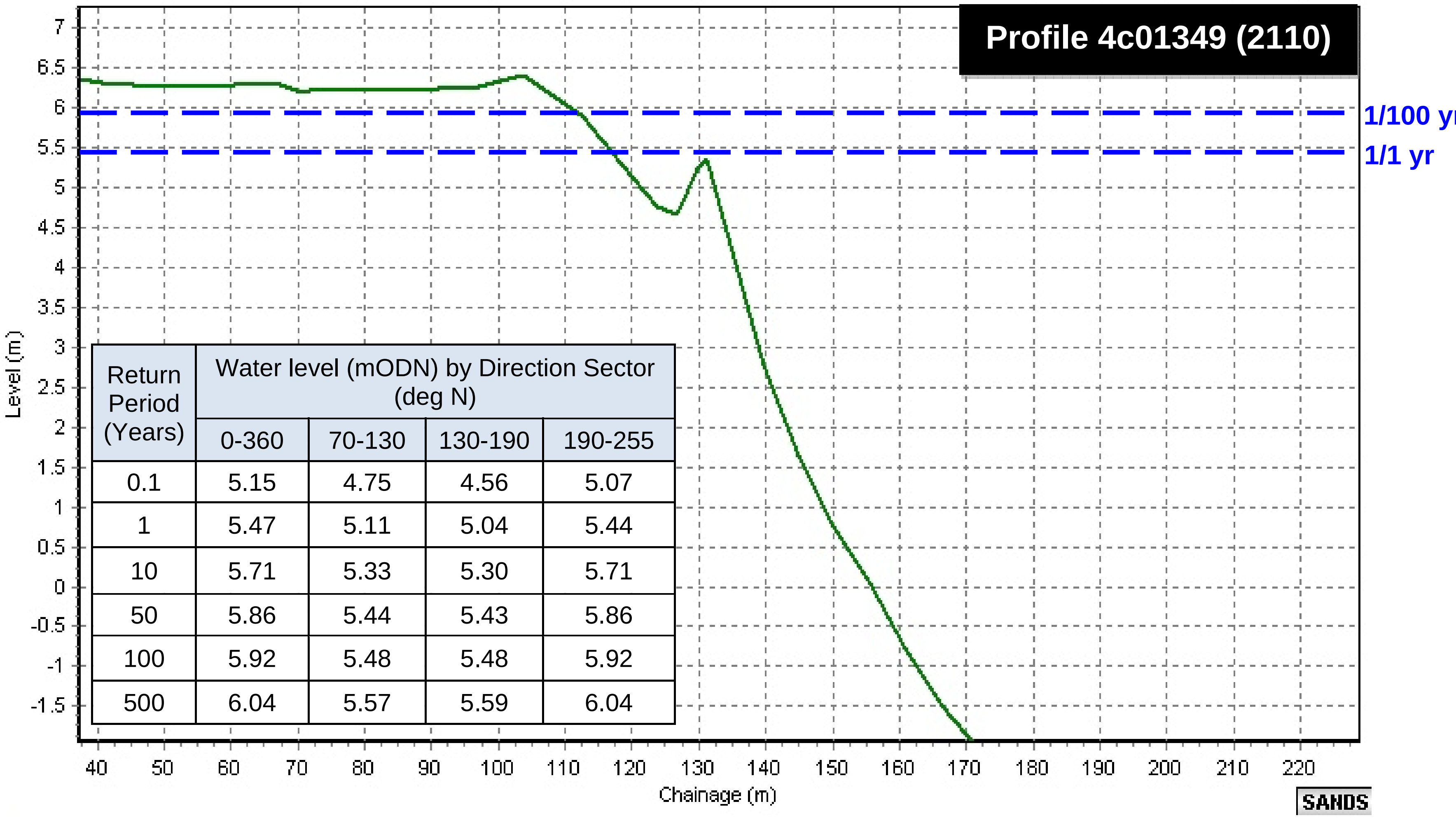
Return Period (Years)	Water level (mODN) by Direction Sector (deg N)			
	0-360	70-130	130-190	190-255
0.1	4.20	3.80	3.61	4.12
1	4.52	4.16	4.09	4.49
10	4.76	4.38	4.35	4.76
50	4.91	4.49	4.48	4.91
100	4.97	4.53	4.53	4.97
500	5.09	4.62	4.64	5.09

Figure 6.1: Predicted Sea Level Rise Extreme Water Levels for 2030



Return Period (Years)	Water level (mODN) by Direction Sector (deg N)			
	0-360	70-130	130-190	190-255
0.1	4.48	4.08	3.89	4.40
1	4.80	4.44	4.37	4.77
10	5.04	4.66	4.63	5.04
50	5.19	4.77	4.76	5.19
100	5.25	4.81	4.81	5.25
500	5.37	4.90	4.92	5.37

Figure 6.2: Predicted Sea Level Rise Extreme Water Levels for 2060



Return Period (Years)	Water level (mODN) by Direction Sector (deg N)			
	0-360	70-130	130-190	190-255
0.1	5.15	4.75	4.56	5.07
1	5.47	5.11	5.04	5.44
10	5.71	5.33	5.30	5.71
50	5.86	5.44	5.43	5.86
100	5.92	5.48	5.48	5.92
500	6.04	5.57	5.59	6.04

Figure 6.3: Predicted Sea Level Rise Extreme Water Levels for 2110

6.2 Storm Frequency/Intensity

In addition to the increases in sea level the frequency and intensity of storm events is also predicted to increase. A 5% increase in wind speeds from 1990-2025 is expected to rise to 10% after 2055, this would be reflected in a comparable rise in wave heights. The problem at the harbour beach will be worse as a consequence of the increased water levels allowing larger waves to reach the beach.

The combination of increased water levels and larger waves will also result in the fleet being subject to an ever increasing probability of disruption/damage from wave overtopping. At some point in the next hundred years this would make the fishing operation untenable without defence works to raise the level of the back beach. It should be pointed out that this is a problem that will affect many areas of the coastline and not just Hastings beach.

Another consequence of the increase in storm frequency is that using the current fishing methodology the fishing fleet will have more days when they are unable to launch the vessels. An effect they have already been subjected too in recent years due to the unnaturally high incidence of storms experienced as part of natural variability.

7.0 Conclusion

A suitable shingle beach can dissipate wave energy, reduce overtopping and prevent damage to the seawall. As a consequence of the dynamic nature of shingle, the hydrodynamic characteristics result in sediment transport and dictate the beach face gradient and orientation of the berm. Without suitable controlling structures this can lead to erosion of the beach and failure to maintain an adequate defence. A large accreting beach is beneficial for sea defence reasons, but this can be at odds with the desired requirements for amenity and commercial use of the beach.

Aerial photographs dating back to the 1980s show the evolution of the harbour beach. In 1980 the beach was much smaller and had a uniform orientation consistent with the adjacent beaches. Through a combination of work on the harbour arm and an increased supply of shingle this evolved into a wider beach with the berm accreting by some 70m. At the western end the beach orientation is now southwest – northeast and is characterised by coarse shingle and a steep beach gradient. These factors are making the launching and landing of vessels increasingly hazardous, time consuming and frequently impossible.

Analysis of the hydrodynamic climate highlights a predominance of waves from a south westerly direction, both in terms of duration and intensity. This drives a net easterly drift of shingle along the frontage estimated to average 5,000m^3 a year. At the harbour beach shingle primarily enters via overtopping the harbour arm, although smaller quantities may circumnavigate the seaward extent of the structure. Due to the huge height difference between the harbour beach and the harbour arm it is impossible for shingle to pass back to the west during the less frequent occurrence of easterly waves. At the eastern end of the beach shingle is lost through the sluice gates in the concrete groyne, overtopping or circumnavigation of the seaward extent. As with the harbour arm an imposing height difference means that transport of shingle back over this structure is virtually impossible.

Historically Hastings frontage as a whole has demonstrated, on average, an annual net loss of shingle. In recent years this has not been the case, primarily due to an increased supply of shingle from coastal defence projects west of Hastings. Of particular note is the Bulverhythe scheme, this resulted in a large quantity of shingle moving along the coastline and the accretion of over 11,000m^3 of shingle at the harbour beach between 2007 and 2008. Future replenishment of shingle west of Hastings will continue to heavily influence the erosion and accretion rates along this stretch of coastline.

The harbour arm has the beneficial effect of sheltering the fleet from the prevailing south westerly waves. Ironically it is this effect that has lead to the formation of the undesirable crenular bay and southeast to northwest berm in the western corner. Confined shingle beaches re-orientate so that they are perpendicular to the dominant wave direction, as this area is sheltered from south westerly waves the driving force is easterly waves resulting in the observed crenular bay.

A further complication is the natural sorting mechanism that results in the build up of coarse material producing a steeper natural stable beach. Along most of the frontage sediment transport is multi-directional dependant on the current wave direction with a net easterly drift due to the more common and typically larger south westerly waves. This is the case at the eastern end of the harbour beach, however in the western corner shingle of all sizes can be driven into the area during periods of easterly waves, but the sheltering effect of the harbour arm means that only finer sediment is driven out when the drift direction reverses. As more shingle overtops the harbour arm it is also sorted in this fashion, this inevitably results in an accumulation of coarse material and the undesirable beach face gradient. Artificial regarding of the beach has been seen to only provide a short term solution with the beach gradient steepening quickly after the completion of the works.

In order to compensate for the effects of climate change the height of the back beach will need to be raised to take into account sea level rise and a more aggressive wave climate. Failure to do so will result in the fleet being subject to an increasing probability of disruption/damage from wave overtopping. An increase in the frequency and intensity of storms will also reduce the number of days it is possible to launch and rising sea temperatures will result in a number of as yet unknown ecological effects.

A number of preliminary options have been suggested by interested parties in order to try and alleviate the current problems, maintain the beach as a viable location for the fishing fleet and accommodate the anticipated future effects of climate change. These are briefly outlined over the following pages.

8.0 Preliminary Options

Although addressed as single points, these are not mutually exclusive and it is quite probable that an effective solution would have to employ a combination of these options;

1. ***Do Nothing***

   A "do nothing" approach will result in regular shingle overtopping into the harbour, with continual loss of material out of the open sluice at the eastern end of the harbour beach. The local hydrodynamic climate will continue to produce an undesirable, steep, coarse sediment beach at the western side. This also does nothing to address the dilapidated harbour arm or deal with the anticipated effects of climate change.

2. ***Boats Moored Offshore***

   In order to remove the problems of launching and landing vessels it has been suggested they are moored offshore with fishermen rowing to and fro as required. There are a number of problems with this approach, not least the fact that it removes Hastings status as one of the largest beach launched fishing fleets in Europe.

   The current type of boats would be susceptible to damage, especially during storm events. There is also the problem of how to land the catch. Both of these issues could be solved by using a different port, which is highly undesirable when trying to maintain the presence of the Hastings Fleet. The present system of winching vessels to the top of the beach provides protection from storms and brings the catch ashore.

3. ***Construction of Launching Ramps***

   Construction of at least two timber/concrete launching ramps positioned at the top of the beach with communal winches for the fishermen to safely launch their boats from. The ramps would ideally require a gradient of between 1:8 to 1:10, and be permeable with struts so that shingle can flow naturally underneath.

   The design of the ramps would be difficult in order to balance structural integrity with a permeable under carriage, whilst trying to ensure it is not possible for boats to slip off the side whilst being winched. There is also the problem of how to move boats to and from the top of the ramp.

4. ***Regular Recycling***

   An annual shingle recycling programme, together with appropriate beach re-grading, paid for by local authorities. This would cost in the order of £10,000 per annum, carried out between April and May to coincide with the best tidal and weather conditions. This may be deemed too expensive given that the beach can return to 'normal' in a relatively short amount of time.

Imported dredged shingle currently costs in the region of £20-30/m^3. On average Hastings loses 5,000m^3 to the east of the harbour, which is effectively lost to the system. To source a similar quantity from a dredge site and have it placed on a beach would cost c. £100,000. This raises the interesting possibility of working in unison with the operating authorities to the west of Hastings in order to intercept and provide this shingle for coastal works. This may be done in exchange for regarding and recycling works in and around the harbour beach.

5. Permanent Bulldozers

Providing one or two permanent large bulldozers along with trained operators to enable the fisherman to regrade the beach themselves. Other than the initial cost of buying the bulldozers and training the fisherman, there are minimal ongoing costs associated with this option. However, moving the shingle around the beach alone is not a viable solution and regular recycling would still be required.

6. Reconstructing the Harbour Arm

The harbour arm acts as a main groyne retaining the beach in front of Carlisle Parade to the west, and it also protects the harbour on the east side from the prevailing south westerly wave activity. It was constructed sometime between 1895 and 1899, but was never fully completed. Subsequent failures and a mix of remedial measures have resulted in a general appearance of dilapidation.

Major refurbishment of the Harbour Arm to maintain its integrity is recommended, as it forms an essential part of the coastal protection for this frontage. Who provides funding for this is a matter for debate, but extending the harbour arm in addition to the refurbishment would be prohibitively expensive.

7. Build further Groynes Updrift

This option would consist of the construction of 3 or 4 small rock groynes to provide adequate beach retention to the section of beach west of the harbour arm. Ultimately this solution should slow the build up of shingle against the harbour arm, and hence reduce the amount of shingle overtopping the structure and entering the harbour beach from the start.

Although this aides the fishing fleet problem in the short-term, it is considered an interim measure as in a few years the newly groyned beach will have filled to capacity. Consequently sediment transport rates and shingle overtopping will revert to those levels observed prior to the new groyne construction.

8. *Build a Breakwater/Enclose Harbour*

Both of these options require a large amount of work, design and construction time. In theory either option would protect the beach and fleet from the majority of wave action. This would provide better conditions for the landing and launching of vessels in addition to preventing waves working the beach into a steeper gradient. Sediment transport would also be significantly reduced.

The problem with such an approach is that it may lead to silting up of the foreshore, which combined with the constant influx of shingle and a reduction in sediment transport may result in the need for regular dredging and recycling work to maintain a suitable water depth. This combined with repair work on the breakwater itself could produce some expensive maintenance costs in future years.

9. *Move the Fishing Fleet East*

The fishing fleet has been located in its current position for a considerable amount of time, so obviously the idea of moving it will have cultural implications. Its current location is sheltered by the harbour arm, there are a number of fixed winches and rights/ownership of the hinterland have been agreed over time. Moving the fishing fleet is not even considered an option by the fisherman, even the short distance to the east side of the beach which has a preferential gradient.

8.0 References

Cooden to Cliff End Strategy Plan (Halcrow, 2002)

General Network Adjustment Report for Canterbury City Council (Canterbury City Council 2003)

Project Appraisal Report; Hastings Coastal Defence Works, Phase I – Urgent Works (Canterbury City Council, 2009)

South Foreland to Beachy Head Shoreline Management Plan (Halcrow, 2006)

Structural Recommendations for Hastings Harbour Arm (Canterbury City Council, 2008)

UK South Coast Shingle Study. Joint Probability Assessment (HR Wallingford, 1992)

APPENDIX I

Annual Difference Model Diagrams

2003 – 2010

Beach Management Plan Site – Difference Model February 2010-April 2010 (post-beach regrading): Hastings Harbour

Beach Management Plan Site – Difference Model June 2009-February 2010 (prior to beach regrading): Hastings Harbour

Beach Management Plan Site – Difference Model 2008-2009: Hastings Harbour

Beach Management Plan Site – Difference Model 2007-2008: Hastings Harbour

Beach Management Plan Site – Difference Model 2006-2007: Hastings Harbour

Beach Management Plan Site – Difference Model 2005-2006: Hastings Harbour

Beach Management Plan Site – Difference Model 2004-2005: Hastings Harbour

Beach Management Plan Site – Difference Model 2003-2004: Hastings Harbour