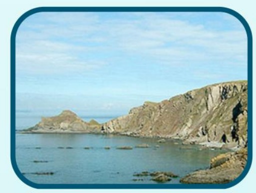
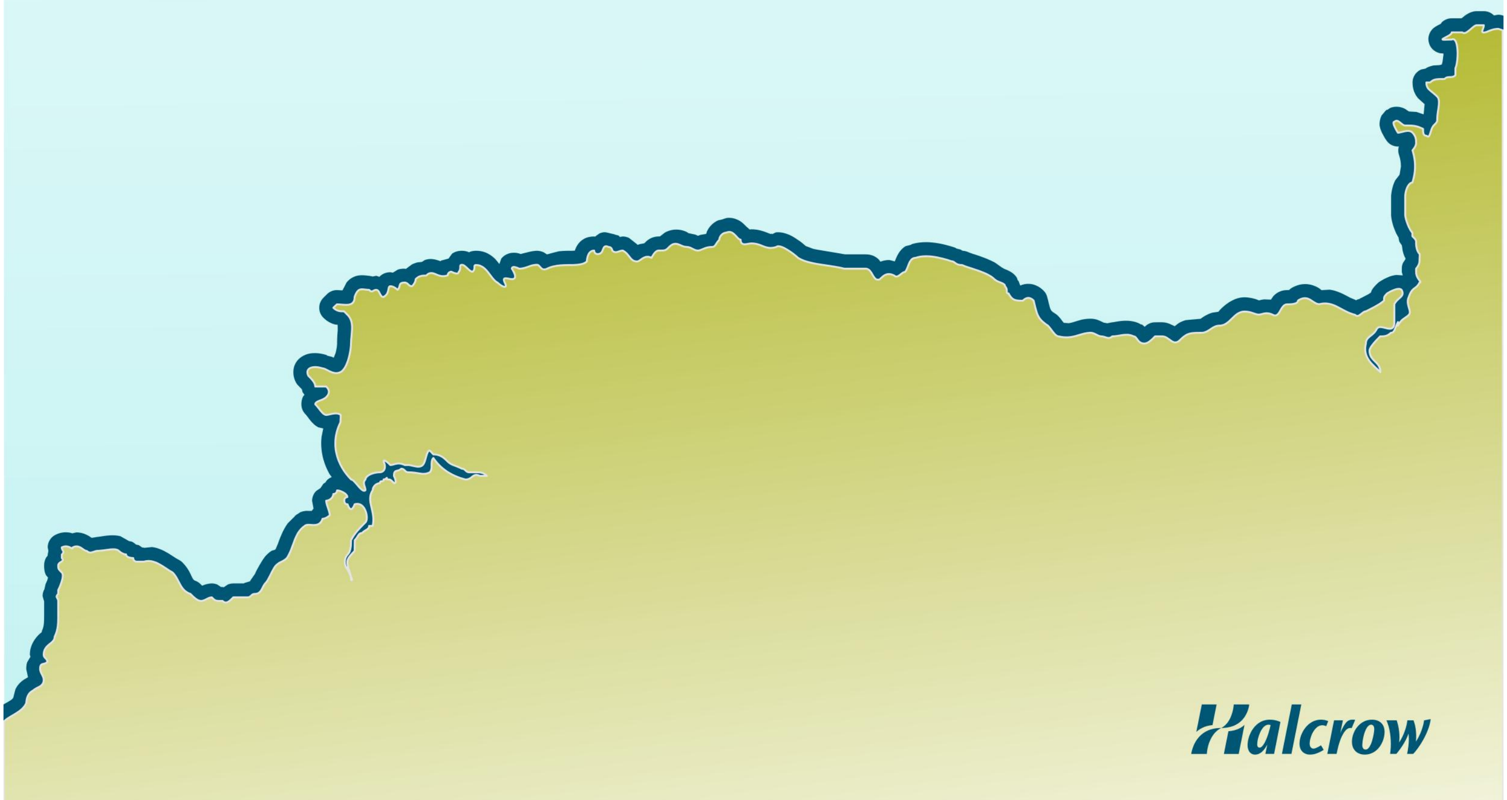
North Devon and Somerset Coastal Advisory Group (NDASCAG)

Shoreline Management Plan Review (SMP2) Hartland Point to Anchor Head

Appendix C – Baseline Processes Understanding





Halcrow

The Supporting Appendices

These appendices and the accompanying documents provide all of the information required to support the Shoreline Management Plan. This is to ensure that there is clarity in the decision-making process and that the rationale behind the policies being promoted is both transparent and auditable. The appendices are:

A: SMP Development	This reports the history of development of the SMP, describing more fully the plan and policy decision-making process.
B: Stakeholder Engagement	All communications from the stakeholder process are provided here, together with information arising from the consultation process.
C: Baseline Process Understanding	Includes baseline process report, defence assessment, NAI and WPM assessments and summarises data used in assessments.
D: SEA Environmental Baseline Report (Theme Review)	This report identifies and evaluates the environmental features (human, natural, historical and landscape).
E: Issues & Objectives Evaluation	Provides information on the issues and objectives identified as part of the Plan development, including appraisal of their importance.
F: Initial Policy Appraisal & Scenario Development	Presents the consideration of generic policy options for each frontage, identifying possible acceptable policies, and their combination into 'scenarios' for testing. Also presents the appraisal of impacts upon shoreline evolution and the appraisal of objective achievement.
G: Preferred Policy Scenario Testing	Presents the policy assessment and appraisal of objective achievement towards definition of the Preferred Plan (as presented in the Shoreline Management Plan document).
H: Economic Appraisal and Sensitivity Testing	Presents the economic analysis undertaken in support of the Preferred Plan.
I: Strategic Environmental Assessment (SEA) Report	Presents the various items undertaken in developing the Plan that specifically relate to the requirements of the EU Council Directive 2001/42/EC (the Strategic Environmental Assessment Directive), such that all of this information is readily accessible in one document.
J: Appropriate Assessment Report	Presents the Appropriate Assessment of SMP policies upon European designated sites (SPAs and SACs) as well as Ramsar sites, where policies might have a likely significant effect upon these sites. This is carried out in accordance with the Conservation (Natural Habitats, &c.) Regulations 1994 (the Habitats Regulations).
K: Water Framework Development Report	Presents assessment of potential impacts of SMP policies upon coastal and estuarine water bodies, in accordance with the requirements of EU Council Directive 2000/60/EC (the Water Framework Directive).
L: Metadatabase and Bibliographic database	All supporting information used to develop the SMP is referenced for future examination and retrieval.
M: Action Plan Summary Table	Presents the Action Plan items included in Section 6 of the main SMP document (The Plan) in tabular format for ease of monitoring and reporting action plan progress.

Within each appendix cross-referencing highlights the documents where related appraisals are presented. The broad relationships between the appendices are illustrated below.

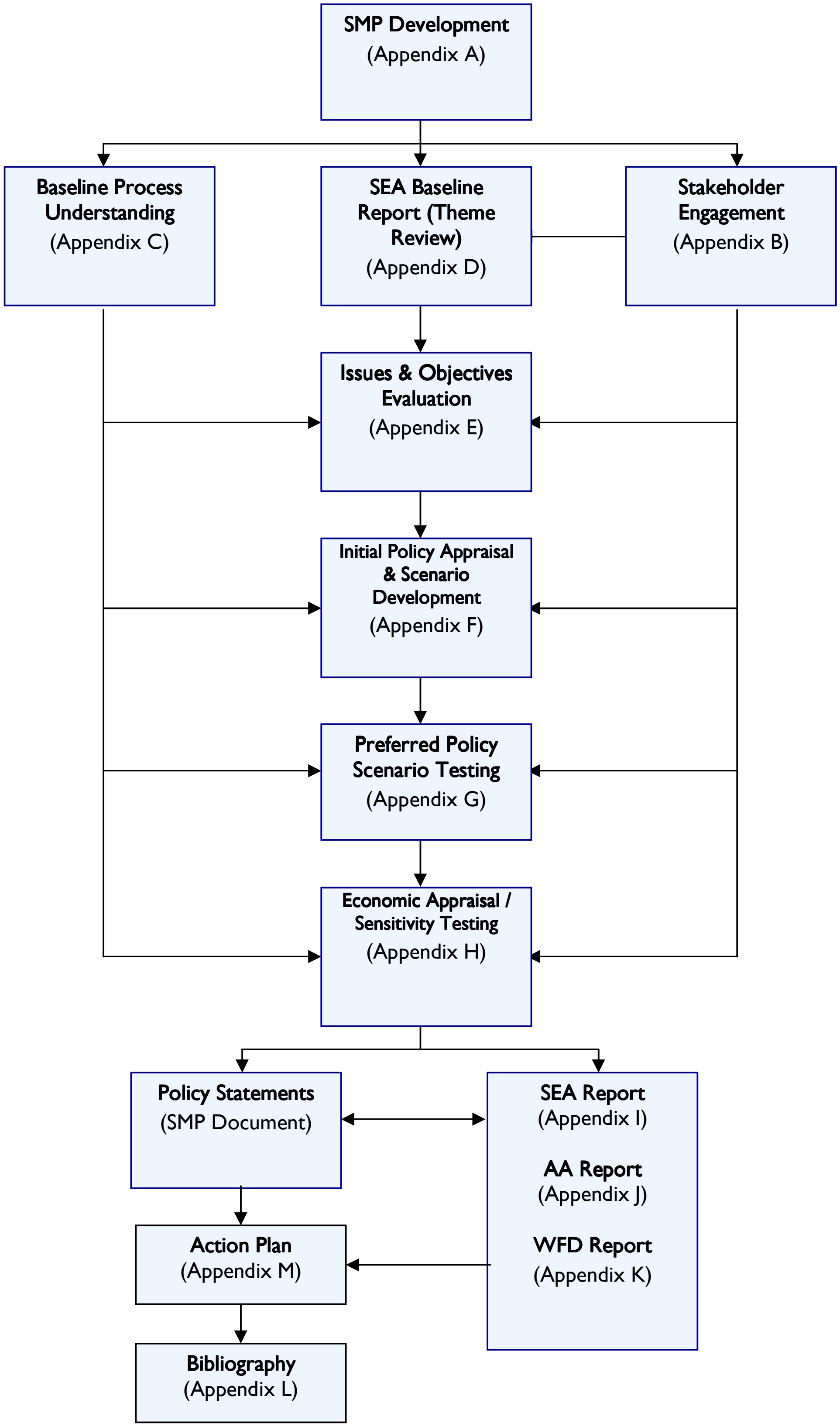

SMP Development
(Appendix A)
Baseline Process Understanding
(Appendix C)
SEA Baseline Report (Theme Review)
(Appendix D)
Stakeholder Engagement
(Appendix B)
Issues & Objectives Evaluation
(Appendix E)
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Table of Contents

C.1 Assessment of Shoreline and Estuary Dynamics

C.1.1 Introduction

This report should be viewed as complementary to information held within Futurecoast[1] (Halcrow, 2002) and more specifically the Shoreline Behaviour Statements (SBS) for the following areas:

- West Coast:
  - Hartland Point to Westward Ho!;
  - Westward Ho! to Saunton Down;
  - Saunton Down to Morte Point;
  - Morte Point to Minehead;
  - Minehead to Hinkley Point;
  - Hinkley Point to Brean Down;
  - Brean Down to Clevedon (although only information relevant to the coast up to Anchor Head was used).

It contains a synopsis of the information contained within Futurecoast supplemented with relevant information and analysis produced either post-Futurecoast or at a level of detail not included within Futurecoast (e.g. alongshore variations in sediment transport and cliff retreat rates based upon analysis of historical Ordnance Survey maps). The two reports should be read in conjunction with one another to provide a full understanding of dynamics and behaviour across different spatial and temporal scales. It should be noted that the information in this report, unless otherwise stated, is taken from Futurecoast (Halcrow, 2002).

Information for Lundy is primarily based upon that contained in the first generation Shoreline Management Plan (Halcrow, 1998), as it was not covered by Futurecoast (Halcrow, 2002).

The assessment of shoreline and estuary processes presented here is split between discussion of large scale and local scale processes. This is because large scale and long term understanding is necessary to assess the sustainability of management options and to take into account any long term trends or drivers of coastal change, which may vary from short term and local observations. For instance, trends of shoreline movement, purely based upon recent beach monitoring, or sediment movements derived from a decade of wave data, are not necessarily representative of long term processes. Shorter term and smaller scale understanding is therefore also important because it identifies local detail and variations from the larger scale. For example, long term prediction of change from high-level studies, such as Futurecoast, may not reflect variability at the shorter timescales, which may be a key factor in setting policy for the 0 to 20 year period (Halcrow, 2002).

C.1.2 Overview of Shoreline Evolution

The coastline between Hartland Point and Anchor Head lies along the southern side of the Bristol Channel and, at the eastern end, the outer limits of the Severn Estuary. The evolution of the present coastline is therefore directly related to the development of the Bristol Channel. In addition, Lundy lies to the north of Hartland Point in the middle of the Bristol Channel midway between the North Devon and Wales coasts, where it is exposed to high wave energy from the North Atlantic, although it has little or no influence upon the shoreline processes along the mainland.

During the last glacial period sea levels were much lower and the exposed bed of the Bristol Channel was covered extensively by periglacial sediments. Following the end of the last glacial period, sea levels rose slowly during the Holocene marine transgression (commencing c.10,000 years Before Present (BP)), resulting in the re-working of these sediments and moving some of it landwards, where it has since been added to by sediment input from both rivers and coastal erosion. Sea levels reached more or less their current levels around 5,000 years BP, establishing the modern ebb-dominant tidal regime and associated sediment transport regime.

[1] Futurecoast was a Defra-commissioned project to look at future coastal evolution around the coast of England and Wales. Further details are available on the Defra website.

The coastline around Bideford Bay, between Hartland Point and Morte Point, is characterised by sandstone and clay cliffs interrupted by embayments of varying sizes. Key features along this section of coast include: pebble and boulder strewn beaches between Hartland Point and Westward Ho!, a pebble ridge at Westward Ho! that is experiencing erosion, a large sand dune system at Braunton Burrows, and wide sandy beaches in Croyde and Morte Bays. In addition, the Taw/Torridge Estuary discharges into the bay between Westward Ho! and Saunton Down and has a significant interaction with the coastal processes within this part of Bideford Bay.

The eastern part of the coastline, between Morte Point and Anchor Head, is similar to that further west for much of its length to Hinkley Point, being comprised of cliffs that include sandstone, limestone and clays, and interrupted by embayments of varying sizes. East of Hinkley Point, the topography of the landscape changes to one dominated by the extensive lowlands of the Somerset Levels. The key features along this section are the sizeable headlands such as Foreland Point and Brean Down that form strong geological controls to littoral transport of sediment along the coast and shoreline evolution in general. The Parrett Estuary also discharges into Bridgwater Bay and has a significant influence on the coastal processes in this area.

The tidal regime along this frontage is a result of the Bristol Channel narrowing from west to east in a funnel shape towards the Severn Estuary and is the reason for this area having one of the largest tidal ranges in the world, increasing from about 5m in the outer channel near Lundy, to about 12m at Avonmouth in the Severn Estuary. As a consequence very strong tidal currents occur, increasing from west to east, which transport large volumes of sand and mud every tidal cycle.

It is within the context of this wider Bristol Channel and Severn Estuary sediment transport regime that sediment transport along the coastline between Hartland Point and Anchor Head, as well as the nearshore zone, is set. However, whilst there are strong links between transport in the nearshore zone and development of the adjacent coastline, there are few (if any) known sediment transport links between the nearshore and offshore zones.

Sediment transport in the nearshore zone varies along the coastline between Hartland Point and Anchor Head, depending upon the strength and exposure to both tidal currents and wave action (which is largely a function of shoreline orientation).

The sediment transport regime within Bideford Bay is outside of the main Bristol Channel currents and, with the two headlands of Hartland Point and Morte Point providing strong geological controls, is therefore largely independent of the adjacent coasts. The Bay acts as a sink for mostly sand-sized sediments, with sand deposits, up to 12m in thickness, present. Sand is transported within Bideford Bay by ebb-dominant tidal currents that lead to south-westerly transport of sand, whilst wave driven transport (mainly during storm events) is in a south-easterly direction transporting some sand into the Bay from locations further to the west of Hartland Point. Within the Bay, the Taw/Torridge Estuary and its offshore sub-tidal ebb delta act as a further sink for sediment.

By contrast, Bridgwater Bay is less exposed to tidal currents and wave action and so has a lower energy environment, which is conducive to deposition of finer grained sediments; these are derived from the high suspended sediment concentration carried in the main inner Bristol Channel/Severn Estuary current flow. As a result, Bridgwater Bay has developed into a shallow embayment, with an almost complete cover of muddy sediment, ranging between 5 and 15m in thickness, which forms a local store for fine sediments.

Littoral sediment transport along the whole coastline from Hartland Point, in the west, to Anchor Head, in the east, is driven by the dominant swell waves from the North Atlantic. This wave-driven west to east littoral transport occurs under both calm and storm wave conditions, although local reversals of littoral transport direction do occur, largely due to the influence of headlands or the Taw/Torridge and Parrett estuaries within Bideford and Bridgwater Bays respectively.

Despite the strong potential for littoral transport, there is a lack of contemporary sediment inputs along the coastline and therefore when longshore transport occurs, it is generally a re-working of existing material within individual embayments rather than an influx of new sediment. Erosion of cliffs of suitable beach material along this section is often a slow process due to the cliffs being of resistant composition and so eroding at very slow rates. In places this may also be affected by the presence of defences along the cliff toe, although such impacts on this section of coast are likely to be localised.

Whilst there are numerous estuaries along the frontage, only the Taw/Torridge and Parrett estuaries have a significant impact on coastal processes, with both these estuaries having significant sand features at their mouths (i.e. ebb tidal deltas) that form part of complex, cyclic sediment transport systems. Discussion of the estuaries along the coastline between Hartland Point and Anchor Head, and their varying interactions with open coastal processes is contained in the relevant sections of this report.

For the purposes of this report, the coastline has been divided into stretches of coast based upon sediment linkages; these coastal sections are typically bounded by headlands that act as significant controls and barriers to sediment movement. These are as follows:

Large scale	**Local scale**
Lundy	• Lundy
Hartland Point to Westward Ho!	• Hartland Point to Westward Ho!
Westward Ho! to Saunton Down	• Westward Ho! to River Taw/Torridge • River Taw/Torridge to Saunton Down (Braunton Burrows)
Taw/Torridge Estuary	• Taw/Torridge Estuary: Outer Estuary • Taw/Torridge Estuary: Torridge Estuary • Taw/Torridge Estuary: Taw Estuary
Saunton Down to Morte Point	• Saunton Down to Baggy Point • Baggy Point to Morte Point
Morte Point to Minehead	• Morte Point to Foreland Point • Foreland Point to Gore Point • Porlock Bay • Hurlstone Point to Minehead
Minehead to Hinkley Point	• Minehead to Blue Anchor • Blue Anchor to St Audrie's Bay • St Audrie's Bay to Hinkley Point
Hinkley Point to Brean Down	• Hinkley Point to River Parrett • River Parrett • River Parrett to Brean Down
Brean Down to Anchor Head	• Brean Down to Anchor Head (Weston Bay)

C.1.3 Overview of Present Coastal Conditions

Information on the wave and tide conditions along the North Devon and Somerset coastline is presented in this section to demonstrate the coastal conditions that are driving the present day evolution of the coast.

Wave climate

The wave climate information presented below is taken from the South-West Regional Coastal Monitoring Programme (Plymouth Coastal Observatory, 2008). Data presented is from the wave buoy deployed at Minehead. The data shows typical mean wave heights experienced in the recent past (Tables C.1.1) as well as the three highest wave events recorded in 2008 (Table C.1.2).

This information confirms that the largest waves along this coastline are from a predominantly north-westerly direction. Analysis of inshore wave climate completed for the Futurecoast Project (Halcrow, 2002) further supports these findings. At Wringcliff Bay near Lynton, waves are predominantly from the north-west. To the South-West at Westward Ho!, waves are dominantly from a west-north-west direction.

Month	Hs (m)	Tp (s)	Tz (s)	Direction (°)	SST (°C)	No. of Days
January	0.83	7.3	4.6	288	8.2	31
February	0.59	6.9	4	234	8	29
March	0.86	6.4	4.3	280	8.2	31
April	-	-	-	-	-	0
May	-	-	-	-	-	0
June	-	-	-	-	-	0
July	-	-	-	-	-	0
August	-	-	-	-	-	0
September	0.53	5.4	3.5	193	16.3	8
October	0.72	6.7	4.4	290	14.3	31
November	0.73	5.9	4	270	10.8	28
December	0.63	6.6	4.2	248	8.3	31

Table C.1.1 Monthly mean wave heights for Minehead wave buoy between January 2008 and December 2008 (Channel Coastal Observatory, 2008)

Location	Period of Record	Date	Hs (m)	Tp (s)	Tz (s)	Direction (degN)	Water Level (mOD)
Minehead	2008	10/03/2008	2.77	7.7	7	307	-0.5
Minehead	2008	01/03/2008	2.47	5.9	5.6	293	-0.5
Minehead	2008	07/01/2008	2.43	10	5.2	308	3.2

Table C.1.2 Three highest wave events recorded at Minehead in 2008 (Channel Coastal Observatory, 2008)

Tides

Table C.1.3 presents the tide conditions for a number of locations along the North Devon and Somerset coast, taken from the Admiralty Tide Tables (United Kingdom Hydrographic Office, 2008). All of the tide values have been converted to a common datum (Ordnance Datum from Chart Datum). Towards the eastern end of the SMP area the high tide levels are about a metre lower than towards the western end, whilst the low water levels are about a metre higher.

For comparative purposes, extreme tide levels calculated for several of these locations are shown in Table C.1.4. These are taken from the Environment Agency report on regional extreme tide levels in the South-West (Posford Duvivier, 2003).

Location	Tide Level (mOD) for Tidal Condition					CD to OD conversion
	MHWS	MHWN	MLWN	MLWS	MSL	
Standard Port - Port of Bristol (Avonmouth)						
Weston-super-Mare	6	2.8	-3	-5.2	7.06	-6
Burnham-on-Sea	5.77	2.77	-2.73	-5.23	No data	-5.13
Bridgwater	6.1	3.2	5.3	2.5	No data	1.5
Watchet	5.5	2.5	-1.9	-4.7	7.03	-5.8
Minehead	5.2	2.5	-1.8	-4.4	7.27	-5.4
Porlock Bay	5	2.4	-1.5	-4.3	7.38	-5.2
Lynmouth	4.6	2.1	No data	No data	No data	-5
Standard Port - Milford Haven						
Ilfracombe	4.5	2.2	-1.7	-3.8	4.04	-4.8

Location	Tide Level (mOD) for Tidal Condition					CD to OD conversion
	MHWS	MHWN	MLWN	MLWS	MSL	
Appledore	4.32	2.02	-1.58	-2.98	4.3	-3.18
Yelland Marsh	4.34	2.04	-1.46	-2.66	4.06	-2.76
Fremington	4.47	1.97	-1.13	-1.23	No data	-1.43
Barnstable	4.7	2	0.9	0.9	No data	0.6
Bideford	4.52	2.22	-1.38	-1.38	No data	-1.38
Clovelly	3.9	1.9	-1.7	-3.5	No data	-4.4
Lundy	3.8	1.8	-1.5	-3.4	3.98	-4.2

Table C.1.3 Tide levels between Port of Bristol (Avonmouth) and Lundy from the 2009 Admiralty Tide Tables (United Kingdom Hydrographic Office, 2008)

Location	Return Period (1 in X Years)					
	1	10	50	100	200	500
Weston Super-Mare	7.29	7.59	7.86	8.03	8.13	8.28
Burnham-on-Sea	7.05	7.33	7.58	7.73	7.83	7.97
Bridgwater, West Quay*	7.54	7.81	8.05	8.21	8.30	8.30
Burrowbridge*	7.10	7.32	7.51	7.64	7.70	7.70
Hinkley Point	6.97	7.23	7.46	7.61	7.70	7.83
Watchet	6.75	6.99	7.20	7.34	7.42	7.54
Minehead	6.53	6.76	6.96	7.09	7.18	7.29
Porlock	6.43	6.65	6.85	6.98	7.06	7.17
Lynton	5.90	6.12	6.31	6.43	6.51	6.62
Ilfracombe	5.45	5.67	5.85	5.98	6.05	6.16
Appledore*	5.18	5.39	5.58	5.72	5.78	5.88
Yelland*	5.35	5.57	5.75	5.87	5.95	6.05
Barnstaple*	5.60	5.80	6.00	6.10	6.15	6.27
Bishops Tawton*	5.73	5.93	6.13	6.23	6.28	6.40
Braunton*	5.35	5.57	5.75	5.87	5.95	6.05
Bideford*	5.32	5.53	5.72	5.84	5.92	6.02
Westward Ho!	5.09	5.30	5.49	5.61	5.69	5.79
Clovelly	5.01	5.22	5.41	5.53	5.60	5.71

*Table C.1.4 Extreme tide levels for a range of return periods at locations along the North Devon and Somerset coast (Posford Duvivier, 2003). NB: Estuary Sites are indicated by *.*

C.1.4 Lundy

LARGE SCALE

Interactions

Lundy is a small island some three and a half miles long and half a mile wide located north of Hartland Point in the middle of the Bristol Channel (Lundy Field Society website). The island rises steeply from the bed of the Bristol Channel and is comprised mostly of Tertiary granite, although there are some slates present at the southern end of the island (Lundy Field Society website).

The presence of the island has resulted in the development of offshore sandbanks that have accumulated on the flat seabed around the island, in particular in the lee of the island. These offshore banks provide shallow areas of seabed that in turn help to protect the shoreline of Lundy from the full force of storm wave attack, particularly along the northern shore of the island. There is, however, little or no effect on the mainland shoreline caused by the presence of Lundy (Halcrow, 1998).

Movement

The rocks that make up Lundy are very resistant to erosion and so only erode very slowly, even though they are exposed to high wave energy resulting from storms propagating from the North Atlantic.

Much of the coast is comprised of granite cliffs, although there are small embayments in which small pocket beaches have accumulated, most notably in Landing Bay, where Landing Beach is situated.

Modifications

The only human modification along the coast of Lundy is within Landing Bay, where a range of defences provide protection against coastal erosion to the only access road, which links Landing Beach to the other properties that sit on top of the island. These defences include a concrete seawall and masonry splash wall, with a concrete breakwater to the south and concrete and stone gabion revetments to the north (Halcrow, 1998).

Recent extreme weather conditions and heavy rainfall has resulted in localised cliff instability and landslides in this area and has also caused damage to the road, which is now in danger of being lost in the immediate future without further intervention to stabilise the cliffs (Landmark Trust's Lundy Island website, accessed Jan 2009).

LOCAL SCALE: Lundy

Interactions

The majority of the coast of Lundy consists of granite cliffs topped with a broad plateau of undeveloped land. The slow erosion of these cliffs is caused by undermining of the cliff toe by marine action and provides boulders, which rest on top of the bedrock platform in the intertidal zone around much of the island. The small pocket beaches that indent the shoreline of the island are maintained by the infrequent, low input of material from erosion of the local cliffs (via erosion at the toe and weathering of the cliff face) that back them and the subsequent slow breakdown of this material by wave action. Coarse sand and slate gravel has accumulated within Landing Bay due to the occurrence of slate bedrock along this section. There is little or no exchange of material with adjacent sections of coast, and so beaches such as Landing Beach may be considered as being largely self-contained (Halcrow, 1998).

Offshore, sub-tidal slopes of bedrock and boulders form steep submarine cliffs off of the north and east coasts of Lundy. These extend down to a plain of sand and gravel that lies at a depth of 30 to 40mCD around much of the island, apart from at Knoll Pins and Landing Bay (Halcrow, 1998).

Movement

The cliffs of Lundy are hard and erosion resistant with erosion controlled by the direction and intensity of jointing within the bedrock (Halcrow, 1998). Therefore along much of the coastline the cliffs erode only very slowly, with negligible erosion having occurred over the past century; however, there has been some erosion in recent years in Landing Bay that has caused problems for the access road that runs across the cliff in this area. This has been associated with extreme weather conditions and heavy rainfall (Landmark Trust's Lundy Island website, accessed Jan 2009) and is also the area of Lundy where slate bedrock occurs, which is slightly less stable than the granite bedrock that forms the majority of Lundy (Halcrow, 1998).

There has been no long term monitoring of these beaches and as such it is uncertain as to the mobility of the pocket beaches; however from historical mapping reviewed as part of this SMP, it is thought that Landing Beach has changed very little over the past forty years.

Existing Predictions of Shoreline Evolution

Futurecoast (Halcrow, 2002) did not appraise Lundy and therefore no predictions are available from this study. The SMP1 (Halcrow, 1998) was not able to identify any reports on historical change or evolution and proposed that given the resistant nature of the coastline that retreat of the coastline over the next 50 years would not exceed 10m, but did acknowledge a potential issue in Landing Bay.

C.1.5 Hartland Point to Westward Ho!

LARGE SCALE

Interactions

The western most part of the frontage comprises a cliffed coastline that forms the southern side of the deep embayment of Bideford Bay. The cliffs rise up to a plateau at a height of around 150m, with east-west trending valleys intersecting the cliffs at a lower level.

The present shoreline has evolved as a result of differential erosion of this hard-rock coast composed of inter-bedded sandstones and shales, which are overlain by head deposits, laid down during previous glacial periods. Cliff recession, mainly caused by a combination of erosion at the toe by marine action, and instability of the cliff face brought about by weathering, is generally slow and provides a limited supply of coarse sediment (sand, gravel, cobbles and boulders) to the shoreline, where it contributes to the formation of localised gravel storm ridges and beaches. Between Hartland and Babbacombe Mouth, cliff erosion is driven by landslips, which are in turn a consequence of the local geology.

As discussed in Section C.1.2, sediment transport within Bideford Bay is largely self-contained and occurs in a clockwise circulation whereby mud and fine sand, which is derived from both the erosion of the inter-bedded sandstone and shale cliffs and the seabed, is transported westwards towards and beyond Hartland Point by tidal currents, entering the circulation system to be returned and deposited within Bideford Bay, where there are extensive sand deposits.

Hartland Point itself is a prominent headland that has evolved over a long period of time and now provides a dominant control over the whole of Bideford Bay to the east of it. Along this section it directly provides protection against the dominant south-westerly swell waves from the North Atlantic to the coastline up to the west of Clovelly, from where the alignment of the coast to Westward Ho! is affected by diffracted swell waves only. In this area, wave induced transport only occurs periodically, during storm events, when there is sufficient wave energy to transport the coarse sediment alongshore. The volume of sediment transport is reliant on there being sufficient sediment on the shoreline to be transported in the first place, which in turn is directly dependent upon the rate of local cliff failure events.

The pebble ridge at Westward Ho! (discussed in Section C.1.5) formed when large gravel banks swept landwards as sea levels rose at the end of the last glaciation, becoming isolated from its original sediment source. It is thought that the Pebble Ridge may also have once been supplied with sediment from further west that was derived from erosion of both cliffs and raised beaches that contain similar rounded pebbles (i.e. erosion of this stretch of coast between Hartland Point and Westward Ho!). However, there is currently little or no contemporary sediment source to the pebble ridge due to the low rates of erosion to the west.

Movement

The resistant nature of the geology along this frontage forms the dominant control to shoreline evolution. Landslips occur periodically between Hartland and Babbacombe Mouth and may provide occasionally larger inputs of sediment to the shoreline. However, the overall trend is for slow erosion with small scale, episodic cliff failure events.

Towards Westward Ho! the resistant cliffs also form strong geological control to the Taw/Torridge Estuary lowland, preventing it from migrating or expanding in this direction.

Modifications

There has been very little in the way of coastal defence or management intervention activity along this section of largely sea cliff dominated coast. There is, however, a number of small scale, localised, defences including breakwaters, concrete groynes and a seawall at Clovelly, which protect against erosion and wave overtopping, and stone gabions and a seawall at Buck's Mill, which provide erosion protection. However these defences are not thought to have any significant wider scale coastal process impacts.

LOCAL SCALE: Hartland Point to Westward Ho!

Interactions

This section consists of cliffs cut into inter-bedded sandstone and shale, which rise up to a plateau 150m high. This plateau is thought to have formed during periods of high sea levels stands. The cliffs are geologically resistant and so erode very slowly; providing limited amounts of sediment to the shoreline. Cliff erosion between Hartland Point and Clovelly is a caused by undermining of the cliff face by marine action at the toe, and some weathering of the cliff face. Between Hartland Point and Clovelly the cliff top plateau provides a flat top to a single steep slope that extends down to the shoreline. East of Clovelly to Peppercombe, the cliffs consist of a long, straight, vegetated escarpment slope above a low wave cut base that is about 20m in height. Between Hartland Point and Babbacombe Mouth, the cliffs are subject to rotational slips; caused when the permeable upper layers of rock become saturated with rainwater.

The foreshore consists of a rock platform that is, for the most part, interspersed by small pockets of coarse gravels and boulders that are fed by localised cliff erosion. Between Clovelly and Babbacombe these sediment deposits are more continuous and form a gravel barrier; this provides protection to the cliff toe from waves diffracted around Hartland Point further west.

Whilst there is potential for wave-driven west to east longshore transport of sediment, there is a limited sediment supply due to low rates of cliff erosion and so sediment transport along this section is limited to re-distribution of beach sediment within the localised embayments. The longshore sediment transport potential increases towards Westward Ho! as the sheltering effects of the headland at Hartland Point reduce.

Movement

As discussed above, the cliffs along this section show evidence of landslips along much of the coastline with a number of landslip scars indicating both old and active rotational slips, particularly between Hartland Point and Babbacombe Mouth. Futurecoast (Halcrow, 2002) suggests that cliff failure events along this section occur with a frequency of anywhere between 1 and 250 years, resulting in between less than 10m to about 50m of cliff top recession in any one event.

The small pocket beaches that indent this section of coast are maintained by sediment supply from erosion of the local cliffs. However, there is little data about the mobility of these beaches, although it is likely that they are relatively stable as each is largely self-contained with sediment retained within each embayment.

Existing Predictions of Shoreline Evolution

SMP1 (Halcrow, 1998) stated that as regional rates of erosion are slow throughout this unit, that less than 10m of erosion would be expected during the next 50 years, except near Abbotsham towards the eastern end of this section where the SMP1 reported that erosion was already occurring at a rate of up to 1m/year. The SMP1 did, however, note that some erosion problems could occur where defences already exist, if these were not maintained, particularly at Clovelly.

For an 'unconstrained' scenario, Futurecoast (Halcrow, 2002) predicted that the rate of cliff recession observed historically would continue over the next 100 years. 'Negligible/no change' (less than 10m by year 100) in cliff position was therefore predicted for this shoreline. The removal of the various small scale defences along this section that currently prevent erosion would result in these areas also experiencing recession, likely at rates similar to adjacent unprotected cliffs. There could be re-activation of landslips which could increase cliff recession. The foreshore would continue to receive an intermittent supply of sand and gravel from cliff erosion, but this would be unlikely to provide sufficient material to feed anything other than local sediment stores. During periods of non-sediment supply (as a result of intermittent cliff failures), existing local stores of sediment could be subject to redistribution or removal.

As there is limited human intervention along this section, the Futurecoast (Halcrow, 2002) prediction for a 'with present management' scenario is for this scenario to be similar to the unconstrained scenario behaviour over the next 100 years, except in the areas where there are presently small scale defences such as Clovelly. In these areas the continued presence of defences would restrict cliff erosion from providing local inputs to the foreshore, though beaches fronting the defences would be likely to be maintained by erosion of sediment from adjacent unprotected cliffs. Given the low rates of longshore sediment transport, Futurecoast suggested that maintenance of the Clovelly breakwater would have minimal impact on sediment movements.

C.1.6 Westward Ho! to Saunton Down

LARGE SCALE

Interactions

This section comprises the mouth of Taw/Torridge Estuary and its associated extensive spit and dune systems (refer also to Section C.1.6) and is defined at either end by cliffs at Westward Ho! in the south and Saunton Down in the north, both of which provide strong geological controls on the extent of the embayment (Halcrow, 2002). This embayment, which lies within the central part of the wider Bideford Bay, is backed by low-lying land formed by the differential erosion of Permian-Triassic rock that is now occupied by the spit-flanked estuary of the Rivers Taw and Torridge.

Along the southern part of this section is a pebble ridge that extends northwards for approximately 3km from Westward Ho! into the mouth of the Taw/Torridge Estuary. This ridge is fronted by a wide expanse of intertidal sands and provides protection against flooding to the large low-lying expanse of Northam Burrows, the northern end of which is characterised by the Pebble Ridge backed by a sand dune system.

However, the Pebble Ridge currently has little or no contemporary sediment source due to insufficient erosion to the west presently occurring, combined with the development of headlands further west that prevent longshore drift of sediment towards Westward Ho!. It is therefore considered to be a relict feature that is reducing in size due to both erosion and the subsequent re-working of material as it migrates landward on to the backing low-lying land (Halcrow, 2002; Slade, 2009), and also the loss of sediment as a result of net northward drift along the ridge, with sediment possibly entering the extensive gravel spread along the south shore of the estuary but with no corresponding input at the southern end (Pethick, 2007). Should a large cliff failure event occur to the west of the Pebble Ridge (see Section C.1.4), this could possibly provide an input of new sediment in the future. However this would still only represent an occasional input and not a continuous source.

The northern part of this section includes the extensive dune system of Braunton Burrows which extends southwards approximately 5km from the headland of Saunton Down into the mouth of the Taw/Torridge Estuary.

Based upon geomorphological evidence, rather than any modelling or tracer studies, Pethick (2007) developed a conceptual model of the Bideford Bay system and proposed that a counter-clockwise tidal gyre exists which recirculates sand northwards along the nearshore and coast with a southerly return in the offshore zone; effectively meaning that this is a closed system. This mechanism is augmented by wave induced currents generated by the angle of approach of the dominant south-westerly waves that affect this shoreline (Pethick, 2007). Pethick (2007) did, however, identify a leakage in this system, with sandy sediment being moved into the outer estuary. The mouth of the Taw/Torridge Estuary presents a major obstacle to this northerly shoreline sediment transport and a complex tidal delta system has developed in this area whereby sediment transported from the south into the estuary mouth enters the tidal delta circulatory system and either remains within the estuary or is transported into the wider Bideford Bay circulatory gyre. Sand-sized sediment deposited in the estuary as sea levels rise results in a reduction of the total sand volume in the overall system as there is no new input of sediment (Pethick, 2007).

The concept of a single gyre differs from the sediment model suggested by SMP1 (Halcrow, 1998), and discussed in Futurecoast (Halcrow, 2002), which was based on work by GeoSea Consulting (1997). This sediment model suggested that two gyres are present, with a local reversal of sediment transport occurring offshore of Airy Point. Pethick (2007) argues that this is not supported by geomorphological evidence. He goes on to propose that there is not a sediment circulation in the area of Airy Point, but rather that sediment reaches this part of the coast as a result of the onshore movement of sand waves from the ebb tidal delta becoming attached to the upper shore of Saunton Sands during extreme storm wave events. This latter theory is in line with the net northerly drift of material along this section that is the result of the wider Bideford Bay tidal gyre circulation.

Movement

The Pebble Ridge is believed to have formed as a result of sediment, in the form of bay-bar gravel banks, being swept landwards as sea levels rose at the end of the last glaciation (Halcrow, 2002). It is likely that the 'pebbles' of the pebble ridge are a more recent feature that entered the system as recently as the 16th or 17th centuries as a result of major landslips at the Gore to the west that provided a major pulse of sediment to the system (Orford, 2004), although Slade (2009) queries this, based upon observation that the cliffs to the west consist of a different material from the pebbles.

Pethick (2007) proposes that the two barrier systems evolved in opposite directions under difference mechanisms: Northam Burrows accreted northwards as sand arrived from the south, whilst Braunton Burrows accreted southwards as sand arrived at the proto-Airy Point and became shore-attached. Based on the conclusion by Orford (2004) that the age of the Pebble Ridge is around 300 years old, Pethick concluded that the Northam Burrows dunes and marine clays were laid down *before* the Pebble Ridge developed.

Behind Braunton Burrows lies Braunton Marsh, which is believed to have formed as a result of the formation of a sheltered environment being created as the dune system developed (Manning, 2007). Enclosure and drainage of Braunton dates from the early 1800s.

Modifications

Human intervention along this frontage has occurred for many years in the form of both hard defences and beach management activities. The developed frontage of Westward Ho! is protected from flooding and erosion by a seawall constructed in 1932 (Torridge District Council, 2006), which has rock armour in places to provide additional protection against wave overtopping (Halcrow, 2002). A slipway at the northern end of the seawall was extended in 1989 to reduce the risk of undermining from fluctuating beach levels at its toe. This structure periodically traps very small amounts of gravel material being transported from the west towards the pebble ridge, however this is unlikely to have significant implications for the long term evolution of the ridge due to the quantities involved (Halcrow, 2002).

The Pebble Ridge that extends north from Westward Ho! provides natural flood protection to the low-lying land of Northam Burrows behind, including a former landfill site at the very northern end towards the mouth of the Taw/Torridge Estuary (Orford and Bradbury, 2008). The northern seaward side of Northam Burrows is protected by rock armour where it re-curves into the estuary mouth (Halcrow, 2002).

Annually, the pebble ridge is subject to a local practice referred to as 'Potwalloping'. Potwalloping is a custom which dates back to the 1800's, whereby local residents, in order to protect their grazing rights, would throw back pebbles which had been washed down, onto the pebble ridge (adapted from visitdevon.co.uk). Today, this custom is celebrated with the 3-day annual Westward Ho! Potwalloping Festival, where people put back the pebbles that have been taken from the ridge to the sea shore. It is unknown what long-term impact this may have on the sustainability of the

The crest of the Pebble Ridge has been maintained historically by regular beach management activities that recharged the southern end of the ridge with re-cycled material derived from the northern end of the ridge at Grey Sand Hill (Futurecoast, 2002). This re-cycling began in 1981 and involved the annual movement of between 1,000 and 2,000m^3 of material (Orford, 2005), though may have been as much as 5,000 to 6,000m^3 of material in some years (Halcrow, 2002). Management of the ridge in this way has now ceased, although should the ridge be breached by extreme storm conditions then remedial action to repair the breach would occur (Torridge District Council, 2006). Cessation of this beach management has resulted in the ridge crest becoming lower and flatter, such that it provides a less effective flood defence than when it was maintained at a higher level (Slade, 2009).

Much of the Braunton Burrows frontage is undefended; apart from along the southern stretch of coast; here the first groynes were erected in the vicinity of the lighthouse (Airy Point) in 1874. Rock has also been placed along Crow Neck (discussed in more detail in following sections). This area was breached in both 1921 and 1984, the latter causing a breach about 75m wide that was subsequently artificially repaired (Halcrow, 2002). Crow Point itself was, until 1998, subject to sand and gravel extraction. Towards 1998 about 15,000T of material was extracted annually, but this was as much as 83,000T per year in the 1930s (Halcrow, 2002).

Despite defences, in 1910, high tides combined with a south-westerly gale resulted in severe flooding of the Braunton Marshes, posing a flood risk to the houses nearby, damaging dry-stone walls and killing livestock. A breach occurred along the straightened section of the Braunton Pill. At Horsey Island 5 breaches occurred, one with a gap of 254ft, (approximately 78m) in the embankment causing extensive damage to the local area (Taw-Torridge Estuary Forum, 2007).

Military use of Braunton Burrows during World War 2 did extensive damage to the dunes, but repair works were carried out in the 1950s and the dune system appears to have recovered from this activity (May, 2003a).

LOCAL SCALE: Westward Ho! to River Taw/Torridge

Interactions

Net alongshore drift of sediment is driven by a combination of wave and tidal currents from south to north along the frontage; the orientation of this shoreline means that alongshore transport rates are likely to be greater along this shoreline than along the Braunton Burrows frontage; although no estimates are available for the potential or actual volumes of sand being moved alongshore (Pethick, 2007).

This stretch of coast sits within the wider coastal setting of Bideford Bay, where a larger scale sediment transport system exits; which is discussed above in more detail. Effectively this means that sand sized sediment is moved northward by tidally-induced currents, with some loss of sediment into the outer estuary, before being returned to this shoreline.

There is also a net northward drift of coarse sediment, which is the result of wave-driven currents in the nearshore zone. There is a general consensus (e.g. Halcrow, 1998; May, 2003c; Pethick, 2007; Slade, 2009) that there is no *significant* contemporary source of sediment for the Pebble Ridge. The cliffs immediately to the west may contribute some sediment to the system, but this is not sufficient to sustain the ridge integrity. Therefore the Pebble Ridge is considered to be effectively a relict feature that is subject to re-working of existing material (Halcrow, 2002; Slade, 2009).

From geomorphological evidence Pethick (2007) concluded that up to 5,000m^3 of coarse sediment may be lost from its distal end with no corresponding input at the southern end. These pebbles are moved into the outer estuary at Grey Sand Hill Spit, with resultant growth of Spit Head. Slade (2009) suggests that it is unlikely that pebbles are moved any further into the estuary; however volumetric analysis needs to be undertaken to assess whether there is an actual loss of volume form the whole Pebble Ridge system, or whether it is being effectively stored at Grey Sand Hill Spit.

Movement

The Pebble Ridge has been migrating landwards for more than a century; between 1850 and 1991 the ridge retreated by between 150m and 200m. This has been accompanied by narrowing and lowering of the ridge crest, with particular steepening of the ridge at the southern end. In 1861, the ridge was 1.8km long, but in the following 100 years it migrated landwards some 152m (May, 2003c); accretion at the northern end was accompanied by both retreat at the southern end and also a reduction in overall volume (May, 2003c). The lateral extent of the ridge has also reduced: it formerly extended further westwards (Spearing, 1884).

This process is a result of little or no contemporary input of coarse sediment to the system and the progressive longshore drift northwards of the existing pebbles and cobbles. It has been postulated that the ridge formed due to a one-off pulse of sediment, resulting from a series of large landslides to the west and therefore unless a similar event occurs in the future the ridge has a finite life. Even should such an event occur, it has been postulated that the sediment transport path is now interrupted, due to retreat of ridge (Orford, 2004).

The present rate of retreat is between 1.5m/year and 3m/year (Keene, 1996; Orford, 2004; Slade, 2009), with greater rates at the southern end. Overall, the ridge is rotating anti-clockwise to become more swash-aligned (Pethick, 2007) compared to its historic drift-aligned form. This landward migration of the ridge has involved overwash and breaching of the feature during extreme storm events (Orford and Bradbury, 2008). This movement towards a swash-aligned ridge is associated with a gradual reduction in the amount of alongshore drift and loss of material towards the north, and has resulted in the southern end of the ridge retreating eastwards whilst the northern end accretes seawards (Pethick, 2007). Pethick suggests that this process is still ongoing and Slade (2009) proposes that the southern part of the ridge may need to retreat eastwards by about a further 130m in order to achieve a more stable, swash aligned plan form given the current prevailing wave direction. Slade (2009) also states that much of the 'Promontory' shoreline, which extends from Sandy Mere to Grey Sand Hill Spit, is also now eroding. Along much of this shoreline, there is no longer evidence of a Pebble Ridge.

The northern end of the ridge has experienced severe erosion due to wave focussing in this area, with Slade (2009) reporting up to 50m of erosion occurring in this area over the course of a few months in 2008. This erosion may be associated with increased erosion of the intertidal mudflats and salt marsh at the northern end of Northam Burrows, though there is no direct evidence for this. The erosion at the northern end of the pebble ridge may also have been exacerbated by the removal of material from Grey Sand Hill to renourish the southern end of the ridge in the past (Halcrow, 2002).

Existing Predictions of Shoreline Evolution

The following text is from the 'unconstrained' scenario prediction provided by Futurecoast (Halcrow, 2002). The Pebble Ridge would continue to roll back with sea level rise, but as the original source of the shingle (cliffs west of Westward Ho!) no longer appears to be supplying this frontage, it is likely that the height and volume of the ridge would gradually reduce, due to attrition and longshore movement of shingle toward Grey Sand Hill. This process would reduce depth limitation of waves, increasing energy conditions on the ridge. This would gradually increase the likelihood of breaching of the shingle ridge, threatening its integrity and increasing the possibility of barrier breakdown. Any significant breach of the Pebble Ridge would result in the inundation of the backing low-lying Northam Burrows. Given the reducing sediment volume of the ridge, the capacity for longshore drift to reseal any breach would also be reduced. The location of any significant breach would be important with regard to the possibility of formation of a tidal inlet, as a breach in front of the dunes which back the northern part of the ridge would be unlikely to create an inlet, whereas a breach into Sandy Mere lagoon or the low land to the south would have the potential for inlet formation. It is likely that a major breach of the ridge would cannibalise shingle from the adjacent barrier either through the formation of tidal deltas or loss of material offshore or into the tidal inlet. Either way, the integrity of the barrier would be further reduced. It is probable that there would be a major breach of the Pebble Ridge over the next century, however a complete realignment of the coast on this frontage is unlikely as the fronting wide sand beach would buffer any change.

Futurecoast suggested that the retreat by year 100 would be 'very high', i.e. between 100 and 200m.

The Futurecoast (Halcrow, 2002) prediction for a 'with present management' scenario was that continuation of the current management practice of re-nourishment of the Pebble Ridge with sediment from Grey Sand Hill could lead to the development of a lower angled, less permeable and less stable ridge. Ongoing sea level rise would result in continued retreat of the feature over the backing low-lying land, which should assist in maintaining the overall height of the ridge. However, this retreat would create a step in alignment at the end of the defences at Westward Ho! and rock armouring at the northern end of the ridge: these would become points of wave energy focusing and would be vulnerable to breaching over the next century. Ongoing re-nourishment would prevent any such breach becoming permanent.

SMP1 (Halcrow, 1998) predicted that under a 'do nothing' scenario the Pebble Ridge would be likely to retreat between 1 and 2m/year and would be breached at regular intervals, inundating areas of the Northam Burrows behind. The SMP1 also noted that beach levels appeared to be getting progressively lower, increasing wave exposure and therefore threatening the integrity of the ridge.

More recent work has been undertaken by Pethick (2007). Using geomorphological interpretation Pethick suggests that although a progression towards swash-alignment is occurring, it has not yet been achieved; evident from the fact that gravels and boulders continue to be moved northwards. As the coast continues to re-orientate, the movement of pebbles to the north will reduce to a minimum. Therefore although in the short term small breaches would initially naturally infill, over the long term this would become increasingly difficult as the movement of cobbles reduces over time. The continued loss of coarse sediment towards the north, whilst reorientation continues, will also mean that the Pebble Ridge will narrow along the southern end; therefore the risk of overtopping and breaching would increase. The back barrier area of Northam Burrows will therefore be at risk. Using work by Orford (2004), Pethick (2007) estimated that retreat rates of more than 2m/year would be experience over the next 20 years and that this could rise to 4m/year by 2100.

Pethick (2007) also identified that this shoreline is intrinsically linked to changes within the Taw/Torridge Estuary; currently the estuary acts as a sink for sandy sediment, whilst the majority is able to bypass the mouth and be moved northwards to Saunton Sands. However, as Pethick's conceptual model suggests that there is no new input of sand into the this system, if there is any increase in sand transfer to the outer estuary (due to changes in the tidal regime) this will be at the expense of the open coasts to either side. Pethick (2007) made a broad estimate, based upon a sea level rise of 2mm/year, that in order for the outer estuary to keep pace with sea level rise, the resultant erosion of the intertidal beaches on either side would amount to around 0.25m to 0.4m/year horizontal retreat of mean low water mark.

Similarly any changes in the longshore transport along the open coasts will affect the width of the estuary mouth: a decrease in longshore transport, e.g. due to increased swash alignment along the Pebble Ridge, could lead to erosion of the mouth (Pethick, 2007).

LOCAL SCALE: River Taw/Torridge to Saunton Down (Braunton Burrows)

Interactions

This section consists of the extensive Braunton Burrows dune system that extends in a continuous belt from the headland of Saunton Down south to Crow Point, which forms the distal end of a spit that extends into the mouth of the Taw/Torridge Estuary. The dune system at this southern end extends inland for more than a kilometre forming a low-land area that encloses the northern part of the Taw/Torridge Estuary system (Braunton Marshes). Fronting the dunes is the wide sandy foreshore of Saunton Sands, which, in places, exceeds a kilometre in width at low tides (May, 2003a). This sandy foreshore merges into the tidal delta of the Taw/Torridge estuaries (Pethick, 2007).

Individual dune ridges, which can exceed 30mOD in height, are best developed in the central part of the dune system (May, 2003a) and here there are three dune ridges separated by slacks. Throughout the dunes there is a number of 'sub-ridges' perpendicular to the main dune ridge alignment; these may be former blowouts (May, 2003a). Towards the southern end of this frontage, the lowest slack areas lie at approximately 4mOD, which means that if the seaward dune ridges were breached, the slacks would become inundated at high water on spring tides (May, 2003a).

The general stability of Braunton Burrows suggests that there is some feed of sediment from the nearshore (Kidson et al., 1989; reported in May, 2003a); although there is little actual data to quantify this. Even with extraction of sediment at the distal end of the dune system, the dune system is reported to have remained in a positive sediment budget.

Pethick (2007) presents the case for single tidal residual circulation system within the Bay; which means that sand is moved northwards along the Northam Burrows shore (to the south), bypasses the Taw/Torridge estuary mouth and is deposited on Braunton Burrows. From here sediment is moved northwards towards Baggy Point and then returns south towards Westward Ho! Airy Point is thought to be the approximate location of onshore movement of sand, which has been moved northwards and across the mouth of the estuary, from Northam Burrows (Pethick, 2007) From this point some sand-sized sediment is also moved into the estuary, which has, in the past, allowed the outer estuary to keep pace with sea level rise (Pethick, 2007).

Longshore transport along the Braunton Burrows is therefore northwards, but is weaker than along Northam Burrows, due to the differing orientation of the two shorelines relative to the predominant waves (Pethick, 2007). It is thought unlikely that significant sediment is transported around Saunton Down headland, therefore this is considered a barrier to longshore drift.

Movement

May (2003a) noted that there is little geological or geomorphological data specifically relating to the dune system at Braunton Burrows reported in the literature, despite a extensive programme of topographical surveying of the dunes between 1957 and 1960 undertaken by Kidson and co-workers (e.g. Kidson et al., 1989). The actual age of the dunes is uncertain with some authors believing the Burrows to be over 2,000 years old, whilst other evidence suggests that a dune system was present at this location around 70,000 years ago (May, 2003a). A conceptual model was developed by Pethick (2007) as part of his Taw/Torridge report, based on geomorphological evidence, and this suggested that Braunton Burrows developed and accreted southwards as sand arrived at Airy Point and became shore-attached.

in general terms the overall dune system has remained fairly stable over the last 150 years. The dunes suffered extensive damage in the early 1940s, when they were used for military training, this was followed by mine clearance in 1946-7, which was carried out using high-pressure hoses. The dunes were repaired and rebuilt using fencing and planting of marram grass (May, 2003a). May (2003a) suggests that in places the dunes have been over-stabilised.

The northern part of this section has been stable in terms of position over the longer term with little evidence of erosion or retreat for the last 150 years (despite the damage caused during the 1940s) (May, 2003a). A key change in the dune morphology between 1885 and 1957-1960 surveys was the increase in dune height in the central and northern areas of the Burrows (May, 2003a). May (2003a) also reports that a more recent survey by Kidson et al. (1989) suggests that this accretionary trend continued up to (at least) 1983, with the system as a whole having a positive sediment budget.

The dunes of Braunton Burrows have grown over the past century, possibly being maintained by the return of sufficient quantities of sand from offshore to the foreshore. To the north of Airy Point, however, erosion of the dune face has occurred in the more recent past which has led to the development of dune cliffs up to about 6m in height (Halcrow, 2002). However, whilst the shoreline has remained more or less stable, the foreshore appears to have retreated, with the low water mark reported to have moved landwards by between 30m and 80m over the past century, based upon historic mapping (Pethick, 2007).

The southern part of this section that borders the Taw/Torridge Estuary is susceptible to changes in the estuary mouth. As discussed in Section C.1.6, there is great uncertainty about the future evolution of the estuary mouth and its tidal deltas, and the response of these features to sea level rise. This southern most section could therefore experience either stability or erosion and breaching, depending upon how the estuary responds to future sea level rise combined with how the estuary is managed in the future.

Existing Predictions of Shoreline Evolution

For an 'unconstrained' scenario, Futurecoast (Halcrow, 2002) predicted that the overall form of this section would continue to be controlled by the broad scale constraints imposed by the resistant cliffed headlands at Westward Ho! and Saunton Down. Along this section, the dune system at Braunton Burrows is expected to remain generally stable in the next century, with accretion occurring as it has done historically, but this being countered with increased erosion of the dune face as sea levels rise. Overall there could be a net retreat of the dune front as erosion increases in the future due to rising sea levels. Futurecoast suggested that a breach of these dunes is unlikely because of the sizeable extent (more than a kilometre wide) of the dunes. A 'moderate' (10 to 50m) change was therefore predicted over the next century. As there is limited human intervention along this section, the Futurecoast (Halcrow, 2002) prediction for a 'with present management' scenario is similar to the unconstrained scenario behaviour over the next 100 years. The exception being for the defended part of Crow Neck and Airy Point, the former having a revetment that would continue to act as a secondary defence should the spit breach as it has done in the past, whilst the latter has an ineffective groyne system that has minimal impact upon shoreline sediment transport.

Pethick (2007) suggested that Braunton Burrows would be likely to remain as a stable feature over the 'long term' future. However, Pethick (2007) also identified that this shoreline is intrinsically linked to changes within the Taw/Torridge Estuary; currently the estuary acts as a sink for sandy sediment, but the majority of sand is able to bypass the mouth, via the tidal delta, and be moved northwards to Saunton Sands. However, as Pethick's conceptual model suggests that there is no new input of sand into the this system, if there is any increase in sand transfer to the outer estuary (due to changes in the tidal regime) this will be at the expense of the open coasts to either side. Pethick (2007) made a broad estimate, based upon a sea level rise of 2mm/year, that in order for the outer estuary to keep pace with sea level rise, the resultant erosion of the intertidal beaches on either side would amount to around 0.25m to 0.4m/year horizontal retreat of mean low water mark.

C.1.7 Taw/Torridge Estuary

LARGE SCALE

Interactions

This section comprises the Taw/Torridge Estuary and its associated extensive spit and dune systems. The estuary, in the centre of Bideford Bay, is cut into the softer Permian-Triassic rock, which backs the bay and has a significant controlling influence on the adjacent open shoreline (refer to Section C.1.5). The channel is flanked by an incurved sand and gravel spit on either side along with extensive intertidal flats (Halcrow, 2002). Both the Rivers Taw and Torridge discharge via the estuary; the rivers sharing a common estuary channel for 4.5 km from Bideford Bar to Instow.

The Taw/Torridge is a macro-tidal estuary, with a tidal range of 7.5m at the mouth (Pethick, 2007). The estuary is ebb-dominated and almost empties at low tide (Halcrow, 2002). The estuary has a joint composite tidal length of 29.5km, with the Taw being longer and wider than the deep narrow Torridge (Pethick, 2007).

The pebble ridge characterising the shoreline to the south extends into the southern side of the estuary mouth, flanking the northern boundary of Northam Burrows. The gravel is transported northwards along the ridge, resulting in a loss from the distal end. This gravel may enter the gravel accumulation along the southern side of the estuary (Pethick, 2007). The northern side of the estuary mouth is constrained by Crow Neck spit at the end of Braunton Burrows dunes. At the distal end of the spit is Crow Point which developed as a result of wind-blown sand accumulating over a man-made stone weir constructed in the mid-19th Century. The spit extends into the Taw/Torridge estuary from Airy Point.

Within the Taw/Torridge Estuary are extensive intertidal areas largely comprised of sand sediment with some mudflats and salt marsh present in upper parts. This is reflective of the estuary being a sink for both sand and mud (Halcrow, 2002), but there being a lack of muddy sediment available. The geological constraints within the inner estuaries also means there is limited accommodation space for the development of salt marsh, even if sediments were available.

In the wider area of Bideford Bay, sediment transport is dominated by an anti-clockwise tidal gyre that re-circulates sand within the bay (Pethick, 2007). This corresponds to a net northerly drift along the shoreline. However, the estuary mouth presents a major obstacle to this transport, and, as a result, a complex tidal delta system has developed. Sand entering from the south may either be deposited within the estuary or remain within the circulatory gyre. Sand entering the estuary moves as sand waves along Bideford Bar and arrive on the upper shore at Airy Point, where a headland has formed. It may then be transported to a temporary store on Instow Sands before the dominant ebb tides move sediment seawards within the central ebb channel (Pethick, 2007). However, this clockwise circulation of sediment, from Bideford Bar to Airy Point, Crow Point, Instow Sands and back out to sea, does result in net inputs of sediment to the estuary; Pethick (2007) calculated this to be about 20,000m^3 per year.

Movement

The estuary is still in the process of adjusting to the rapid sea level rise that followed the last glaciation during the Holocene period. About 10,000 years ago, when sea levels were 30m lower, the Taw and Torridge rivers discharged across a wide rock platform, partially covered in sediments (Halcrow, 1998). Rising sea levels following the last glaciation resulted in deposition of sediments up to 10m thick along the shoreline. This ongoing process of adjustment since the last glaciation is a result of a lack of available muddy sediment along the Atlantic coast of south-west England to fill the estuary (both the Taw and Torridge), so the rate of estuary bed rise is not as fast as the rate of sea level rise. Within the Taw, the infilling of the estuary with muddy sediments has progressed slowly seawards from the inner reaches of the estuary and has reached approximately Penhill Point (Pethick, 2007). Future sea level rise will lead to a continuation of this situation (in both estuaries) with the rate of sea level rise occurring at a greater rate than the rate at which the estuary is able to accrete with muddy sediment (Pethick, 2007).

The estuary system will, however, also be affected by changes along the open coast; for example any change in longshore transport will affect the estuary mouth.

Modifications

The northern seaward side of Northam Burrows is protected by rock armour where it re-curves into the estuary mouth (Halcrow, 2002), which also protects a former landfill site which is at the very northern end of Northam Burrows (Orford and Bradbury, 2008). Along the northern side of the estuary mouth there is a series of groynes at Airy Point, although their impact on drift is currently minimal, and a rock revetment along Crow Neck that protects against erosion. This revetment was breached in both 1921 and 1984, the latter causing a breach about 75m wide that was subsequently artificially repaired (Halcrow, 2002).

Crow Point was, until 1998, subject to sand and gravel extraction. Towards 1998 about 15,000T of material was extracted annually, but this was as much as 83,000T per year in the 1930s (Halcrow, 2002)

Within the main estuary there is a range of flood protection structures such as flood walls and embankments. These defences protect the many developed areas of the Taw/Torridge Estuary, including Bideford, Barnstaple, Appledore and Instow. There has also been extensive land reclamation within the estuary, particularly along the northern shore of the Taw Estuary, such as at Horsey Island in the 19th Century (Halcrow, 2002; Pethick, 2007). In the upper Taw Estuary (upstream to Barnstaple to the defined tidal limit at National Grid Reference 256798, 128290), earthen embankments have been constructed along the river banks to protect farmland; most of these are believed to have been constructed or improved in the early 1980s (Jacobs, 2008). Along this stretch the edge of the floodplain is bordered by a railway embankment on the right bank and by rapidly rising ground along the left bank.

LOCAL SCALE: Taw/Torridge Estuary: Outer Estuary

Interactions

The Outer Estuary is defined, for the purposes of this report, as extending from where the Rivers Taw and Torridge converge at Appledore Pool, to the sea. At the confluence point there is a shore-attached sand bar, Instow Sands, which Pethick (2007) suggested may represent the flood-tidal delta of the estuary. The channel in the outer estuary is characterised by a number of rock outcrops which constrain channel movement; the main ones (moving inland) are Pulley Ridge, Crow Rock and Cool Stone (Pethick, 2007). The mouth of the estuary is bounded by spits that extend into the mouth from both the north (Braunton Burrows and Saunton Sands) and the south (the Pebble Ridge and Northam Burrows) – refer to Section C.1.5.

At its mouth, the Taw/Torridge Estuary has to discharge across a high energy coast, where sediment transport rates are high. Pethick (2007) proposed that, in order for the estuary to attain enough power to keep an outlet open, two intertidal lagoon areas developed: Horsey Ridge and the Skern. In addition the estuary was forced to cut a narrow channel, thereby increasing tidal velocities within the estuary.

The Outer Estuary is believed to be a sink for both sands and muds. GeoSea (1997) reported that sediment entered the estuary from both the northern and southern sections of adjacent shoreline, and tidal mudflats near the estuary mouth, with a bedload parting zone from Airy Point to Appledore. Conversely, Pethick (2007) suggested that single, rather than double-gyre exists; meaning that sediment is moved across the mouth of the estuary from the south only.

Under Pethick's single gyre model, although much of the sandy sediment within the Bideford Bay system is believed to bypass the mouth of the estuary and continue northwards, some does enter the mouth of the estuary on the flood tides. These flood tides tend to 'hug' the estuary shoreline, while the stronger ebb currents occupy the central channel (Pethick, 2007). Sand is therefore moved in this way from Airy Point into the estuary, via Crow Point. Pethick (2007) goes on to suggest that a clockwise circulation exists within the outer estuary, which means that sand is subsequently moved across the channel to Sprat Ridge and onto Instow Sands, which acts as a temporary sediment sink. From here sediment may be moved into the Skern or seawards again.

Despite the Outer Estuary also being a sink for mud, Pethick (2007) suggests that siltation is extremely slow because the channel bed was over-deepened by the former river channel and there is a relative lack of muddy sediment. There are therefore little or no accumulations of mud at the estuary mouth; instead mud accumulates in the lower estuary reaches where tide and wave energy is at a minimum (Halcrow, 1998).

Movement

Within the estuary the channels are constrained in places by defences, including walls and embankments that provide flood protection to areas of land, extensive areas of which have been reclaimed from the estuary in the past, especially along the northern side of the Taw Estuary (Halcrow, 2002). The effect of these defences is to restrict the ability of the estuary channels to adapt and evolve naturally and so in some places the presence of defences can cause erosionary pressures. An appraisal of historic Ordnance Survey mapping, as part of this SMP, suggests that there has been little change in the estuary channel form over the past century, with only minor changes in the intertidal area being observed. Perhaps the most noticeable change over the long term from this historic mapping is a slight widening of the channel at the mouth, which appears to be associated with a loss of intertidal area along the south side of the channel (the north side of the ebb tidal delta), known as Zulu Bank). SMP1 (Halcrow, 1998) also noted that there was very little evidence of coastal change. Pethick (2007) concluded that this lack of change within the estuary, since the first maps of 1832, suggested that the Outer Estuary is receiving sufficient sand from the open coast to maintain its intertidal morphology relative to tidal levels, whilst sea levels have been rising.

The sands dunes that are present at Crow Point developed in the mid-19th century, probably due to the presence of a stone weir, which intercepted the movement of sand into the estuary from Airy Point (on the northern shore of the estuary. Prior to the development of the dunes, there probably existed a low, intertidal bank, which may have then be used as the platform for the weir structure. The dunes that developed at Crow Point provided a sheltered area, which allowed the deposition of muds and fines, resulting in salt marsh development in the lee of Crow Point. However, the dunes are currently rapidly eroding, which is thought to relate to the fact that the structure no longer exists.

On the southern banks, opposite Crow Neck is the Skern, there is a large area of intertidal mudflats and salt marsh which is backed by a narrow shingle ridge and sand beach. The Skern also represents the northern limit of the pebble ridge which extends from Westward Ho!. It was historically more extensive before land was reclaimed to use as landfill, indeed the current high water line consists of an embankment composed from tipped rubble (Slade, 2009).

SMP1 (Halcrow, 1998) reported recent lateral and vertical erosion of the salt marshes in the Skern such that clays are exposed and subsequently covered with sand. These sand deposits have been substantial and indicate increasing amounts of energy within the inlet. Anecdotal evidence from local residents suggests that this has increased significantly since gravel extraction at Grey Sand Hill began.

The dunes north of Airy Point are reportedly eroding, with rates of erosion increasing and cliffs of up to 6m being cut along the dune faces (Halcrow, 1998). Pethick (2007) also reported erosion of the dunes in the lee of Crow Point as a result of the fishing weir, over which Crow Point developed, disintegrating.

Pethick (2007) noted that where land has been reclaimed by the Skern and at Horsey Island, the resultant loss of intertidal area has placed extra stress on the mouth of the estuary to maintain an open channel .

Existing Predictions of Shoreline Evolution

There is much uncertainty about the future evolution of the Taw/Torridge Estuary as it is very sensitive to sea level rise and other climate change impacts. There is also uncertainty regarding the source of sediment to the Taw/Torridge system.

SMP1 (Halcrow, 1998) suggest that there would be a net trend of retreat of the intertidal areas over the next 50 years as a result of sea level rise; although the current trend for siltation was noted, an explanation for this trend was not offered. Erosion at the Skern was not thought to be producing extensive erosion problems (Halcrow, 1998). SMP1 also discussed the importance of Crow Point to the estuary in terms of the protection it affords; Pethick (2007), however, questioned this conclusion and suggested that the dunes do not offer any protection to the inner estuary and that instead it is the gravel foundations of this dune system which afford protection and also the important sediment pathway for sand into the estuary.

No specific predictions for the estuary were made by Futurecoast (Halcrow, 2002) but the study suggested that with a potential increase of sediment feed to this area, as a result of erosion elsewhere, the breakdown of Crow Point would be unlikely. Crow Neck spit could remain vulnerable to breaching, but the permanency of such a breach would be less likely if sediment supply increases. Futurecoast (Halcrow, 2002) also concluded that accelerated sea level rise, resulting from climate change, could have implications for the future evolution of this area in at least two ways: firstly, this would increase rates of erosion through increased exposure of the backshore, in particular those areas which have to date been partially protected by foreshore platforms attenuating waves, and secondly, the tidal prism of the Taw/Torridge Estuary would be increased, with greater flows potentially removing sediment from the foreshores around the entrance at a much faster rate. The consequences of this are uncertain and depend upon the ability of the system to balance erosion and supply to this area, with potentially increased losses.

Pethick (2007) looked in more detail at the estuary, using regime models to assess the potential changes to the estuary system as a result of sea level rise and managed realignment schemes. This study concluded that although a rise in sea level would lead to an increase in mouth width, in the case of the Taw/Torridge estuary the amount that the mouth would actually be able to erode by would be constrained by both the incised rock channel and the pressure of longshore transport along the open coast, which acts to close the estuary mouth. This study also suggested that that, due to the presence of the cobble spit along the southern shore (at Grey Sand Hill), any erosion would be through erosion of the northern bank, around Airy Point.

Pethick (2007) also looked at the potential impacts of managed realignment of both Horsey Bank (in the Torridge Estuary) and the northern end of the Skern. He had already identified that these areas were originally lagoon areas, formed as an estuarine response to the high longshore energy at the mouth of the estuary. The study concluded that managed realignment at the northern end of the Skern would have only a minor impact, but that any managed realignment at Horsey Bank could have a significant impact both on the estuary mouth and on the estuary as a whole, due to the movement of sediment into this area, and the expense of the rest of the estuary. The study also highlighted the fact that due to the limited input of fine sediments into the estuary, it would be unlikely for salt marsh to form in this area.

From analysis of bathymetric surveys, Pethick (2007) deduced that the Taw and Torridge have occupied their present channels for at least over the Holocene; from this he concluded that its was highly unlikely that the Taw would seek an alternative route, e.g. along the northern flank of the Appledore promontory towards an outfall at Westward Ho!

LOCAL SCALE: Taw/Torridge Estuary: Torridge Estuary

Interactions

This is defined as the stretch of the Torridge Estuary from the confluence of the Taw and Torridge at Appledore and the tidal limit at New Bridge (256798, 128290). The Torridge Estuary is 11.5 km long to its tidal limit and is characterised by a narrow valley floor, with steep sides that constrain the river channels resulting in a deep channel and a relatively small tidal prism. It is narrower and shorter than the Taw estuary. The inner Torridge, south of Torridge Bridge, is characterised by rock-cut meander loops (Pethick, 2007).

Sandy outer channels merge into finer grained muds within the estuary (Pethick, 2007). Although there are significant accumulations of fine intertidal sediments, the constraining geology has limited salt marsh development and intertidal mudbanks; the main exceptions are at Torridge Bridge and along the east bank between East-the-Water and Hallspill. Downstream of Bideford is generally surrounded by higher ground than much of the estuary system, with low vegetated cliffs forming the river banks south of Appledore (Halcrow 1998). The foreshore within this region comprises bedrock, pebble clay and sands.

In both the Taw and the Torridge there is relatively little sediment input from the rivers (Kirby, 1996); therefore the primary source of sediment is from marine sources; however there is a limited source of muddy sediments (Pethick, 2007). Flood tides transport sediment from the bedload parting zone in the outer estuary up the River Torridge, and this is evident in the asymmetric sand ripples found on the river bed (GeoSea, 1997).

Movement

Pethick (2007) concluded that Taw and Torridge have occupied their present channels for at least over the Holocene. He also suggests that both systems are 'immature' because of the relative lack of fine sediment input (due to limited sources in Bideford Bay), which means that they have not infilled at the same rate as sea level has risen since the last ice age.

A review of historic Ordnance Survey mapping as part of this SMP suggests that there has been little change in the estuary channel form over the past century, with only minor changes in the intertidal area being observed.

There is an area where flood defences have breached, at Knapp House, north of Northam. SMP1 (Halcrow, 1998) reported that these defences were breached a number of years ago, not repaired and the land was allowed to flood.

Existing Predictions of Shoreline Evolution

SMP1 (Halcrow, 1998) predicted that localised flooding at Appledore may continue without appropriate defences; however, with suitable defences, no erosion problems were predicted for the next 50 years. No specific predictions were undertaken for the Futurecoast (Halcrow, 2002) study.

The geological structure of the estuary restricts its ability to respond to sea level rise and Pethick (2007) predicted that infill of the sub-tidal channel would continue, albeit at a slow rate due to the lack of muddy sediments. Pethick (2007) also suggested that the effect of sea level rise would be to reduce the rate of accretion rather than resulting in a change to erosion. The study therefore concluded that there would be less stress on existing defences, although his assessment of meander patterns, showed that there could be additional stress at Torridge Bridge and Westleigh and erosion at the confluence with the River Yeo. The meanders of the Torridge have a more significant impact on the banks than the Taw due to the narrow valley sides.

Pethick (2007) also looked at the potential impact of managed realignment within the estuary, through considering two potential sites: Hallspill and Tennacott. The study concluded that such realignments would tend to reduce the rate of accretion rather than result in an erosion trend, but that due to the size of the estuary, that this could have a more significant impact than changes in the Taw Estuary.

LOCAL SCALE: Taw/Torridge Estuary: Taw Estuary

Interactions

The Taw is a wide sandy estuary with the tidal influence extending 18km inland (Pethick, 2007). The main channel in the Outer Taw is narrow and deeply incised (120m width and 10m depth) within the wider estuary bed (Pethick, 2007). The River Caen, a small tributary, discharges into the Taw just upstream of Braunton Marsh and has muddy banks.

Flood tides transport sediment from the bedload parting zone in the Outer Estuary up the River Taw, and this is evident in the asymmetric sand ripples found on the river bed (GeoSea, 1997).

The foreshore comprises muddy sands along much of the estuary, apart from a locally-derived shingle beach in front of Horsey Island (Halcrow, 1998). Landward of Penhill Point there are fine-grained sediments and salt marsh accretion; a significant salt marsh is found at Anchorwood Marsh. The mouth is characterised by small shingle spits which extend eastwards and are covering areas of salt marsh. The estuary has a wide valley floor which is slowly infilling with sediment, with the greater width resulting in a shallower main channel than that of the Torridge (Pethick, 2007).

Gravel spreads within the River Taw are well-developed, extending from Crow Point up the river (Halcrow, 1998). Mud and salt marshes within the river are accreting. There is a large area of sand offshore of Penhill Point with rippled sand banks known as Bassett's Ridge exposed at low tide, just west of the Point.

Downstream from Penhill Point, on the southern side of the Taw, the coastline is exposed to direct estuarine wave attack due to its orientation and this has caused erosion along this frontage (Halcrow, 1998). There are no accumulations of mud west of Instow Barton Marsh due to the increased level of exposure.

In both the Taw and the Torridge there is relatively little sediment input from the rivers (Kirby, 1996).

Movement

Historically the form of the Taw/Torridge Estuary system has been modified by a series of reclamations and embankments. A significant area to be enclosed and drained was Braunton Marsh, which sits behind the dune system of Braunton Burrows. Here works began in the early 1800s, which involved the construction of embankments and drainage channels (Manning, 2007). The enclosure of Horsey Sand, defined as 'a barren patch of sand' then followed in the 1850s; however, works to strengthen the western end of the Horsey Embankment through the construction of a rock groyne were required by the mid 1870s (Manning, 2007).

In 1910 a storm surge event caused significant flooding in this area; with many of the defences in the Braunton Marsh area being breached. These were subsequently repaired and have continued to be maintained (privately) since.

Horsey Ridge, adjacent to Horsey Island, is an intertidal lagoon that was once part of the area reclaimed in the 19th Century to form Horsey Island. Instow Barton and Lower Yelland marshes have been reclaimed from the river and are defended; the latter is the site of a former power station and as such there is material, including asbestos and fly-ash which requires containment (Halcrow, 1998). Sand dunes front parts of Instow Barton marsh and these are currently eroding, along with sand being extracted for commercial activities (Halcrow, 1998).

Within the estuary the channels are constrained in places by defences including walls and embankments that provide flood protection to areas of land, extensive areas of which have been reclaimed from the estuary in the past, especially along the northern side of the Taw Estuary (Halcrow, 2002). The effect of these defences is to restrict the ability of the estuary channels to adapt and evolve naturally and so in some places the presence of defences can cause erosionary pressures. A review of historic Ordnance Survey mapping as part of this SMP suggests that there has been little change in the estuary channel form over the past century, with only minor changes in the intertidal area being observed.

SMP1 (Halcrow, 1998) reported net accretion in the estuary, although extensive land claim has resulted in habitat loss and coastal squeeze. Sediment supply from the rivers has maintained the intertidal areas and this has continued even with sea level rise.

Existing Predictions of Shoreline Evolution

Jacobs (2008) report that along the upper Taw Estuary (upstream of the A39/A361 road bridge), the loss of defences would result in a greatly increased risk of flooding to 95% of currently defended areas on an annual basis, although this risk area is unlikely to significantly increase in the future, even with sea level rise, due to the steeply sloping valley sides that bound the present day flood risk area. Such changes in this upper part of the estuary could, however, have impacts on the wider estuary, though this would require further detailed study.

Similarly, if defences along parts of the outer Taw Estuary, notably Braunton Marsh, were to be lost, then these areas would become inundated as sea levels rise creating extensive areas of intertidal habitat, much as they were thought to have been prior to being enclosed in the early 19th century (Manning, 2007). Such a change in this area would significantly alter the estuary processes as a whole, although the precise implications of such a scenario would require much greater detailed investigation.

From regime modelling, Pethick (2007) predicted that, as for the Torridge, there would be continued slow infilling of the channel, with a deposition front moving seawards from its present position at Penhill Point. The study suggested that the impact of sea level rise would be to reduce this accretional trend rather than inducing a change to an erosional regime. There would also be potential for increased channel width at Barnstaple and at Sticklepath.

Pethick (2007) also looked at the impact of managed realignment. The impacts of changes at Horsey Bank are discussed in the 'Outer Estuary' section above, but the study also considered the potential impact of managed realignment at Home Marsh Farm, two sites at Bishops Tawton, and Anchorwood. Pethick identified that there was potential for the inner estuary channel to erode and widen more than the channel in the outer estuary, but that overall the impact of the managed realignment at the sites considered (except at Horsey Bank) would be relatively small. Within the study, channel meander response to tidal and fluvial discharges, and their predicted increase, was also modelled to 2100 and showed an increase in meander amplitude after 100 years worth of sea level rise, with stress being placing on the estuarine channel banks at West Ashford, Home Marsh Farm and Bickington (Pethick, 2007).

C.1.8 Saunton Down to Morte Point

LARGE SCALE

Interactions

The section of coast between Saunton Down and Morte Point forms the northern part of Bideford Bay. It contains the two embayments of Croyde Bay and Morte Bay that have been formed by the differential erosion of the coast between the resistant headlands of Saunton Down, Baggy Point and Morte Point.

The bays themselves contain wide, sandy, swash-aligned beaches that have accumulated over a long period of time. The sediment is probably derived from offshore, from where it has been transported and deposited within the embayments during periods of higher sea levels; these high stands are evident within Croyde Bay, where a series of raised shore platforms and beaches represent former sea level positions. The swash-aligned form of the beaches is due to the open exposure of this section to North Atlantic swell waves.

The beaches within the embayments are backed by dune systems. In the case of Morte Bay, the development of these dunes has resulted in large volumes of sediment accumulating against rising ground at the back of the bay. Within Croyde Bay, the dunes rest against a stony head deposit at a level of 8 to 9 mOD.

There is little or no sediment exchange between the embayments or the adjacent sections of coast to the north and south, due to the presence of the cliffed headlands. Therefore Croyde Bay and Morte Bay are considered to be 'closed' systems. Sediment eroded within each embayment, for example from raised beach deposits, is therefore likely to remain within that embayment.

Along this section, two separate wave-induced sediment circulations exist, divided by the headland at Baggy Point. These two circulations result in a clockwise sediment circulation within Morte Bay, and an anti-clockwise circulation in Croyde Bay. These circulations allow for the possibility of sediment exchange between offshore and foreshore within the bays during storm events, although the lack of offshore sediment reduces the likelihood of this being a contemporary source of significant inputs of sediment to the beaches within the bays.

The erosion experienced within each embayment is therefore thought to be the only contemporary source of sediment to the beaches, but this supplies only a limited amount of new sediment to the shoreline, although the raised beach deposits may provide larger quantities as they are eroded.

Movement

The cliffed headlands along this section are hard and erosion resistant. As such there has been little or no erosion of these over the past century (Halcrow, 2002). Within the embayments, there has been a general trend of sand accumulation over long time periods, with this sediment being brought into the bays and deposited from offshore sources during periods of higher and lower sea levels that occurred during the Holocene (as represented by a series of raised shore platforms and beaches in Croyde Bay). These bays are now effectively 'closed' systems and any changes in the bay are due to the re-distribution of sediment rather than inputs of new sediment. For example, erosion of sand from the dune face and beaches during extreme storm events is likely to be re-deposited within the bay with potential to be then transported back onshore at a later time.

Modifications

With the exception of local defences at Putsborough Sands in the southern part of Morte Bay, there has been no significant human intervention along this section of coast. The defences that are present are in the form of a sea wall and block revetment that protect individual assets from flooding and erosion. There has also been some dune management at this southern end of Croyde Bay, in the form of sand fencing.

LOCAL SCALE: Saunton Down to Baggy Point

Interactions

This section encompasses Croyde Bay, which is a dune backed embayment fronted by a wide sandy beach and bounded by cliffed headlands at Saunton Down and Baggy Point. These headlands are themselves fronted by rocky foreshore platforms that are between 10 and 14m high along the north side of the bay, and 8 and 10m high on the south side of the bay. There is also a small stream that emerges through the dune system within Croyde Bay.

The cliffs here are largely comprised of glacial drift deposits, which overlay harder rocks. These headlands provide a strong geological control on the evolution of the bay and also act as a barrier to sediment exchange with adjacent coasts. As such, Croyde Bay is considered to be a 'closed' system in terms of coarse sediment transport. The only input of new sediment to the beach in Croyde Bay is from local cliff erosion caused by undermining of the toe by marine action and weathering of the cliff face, although due to the resistant nature of the local geology, such inputs are small and occur infrequently. Anecdotal evidence supplied via the stakeholder process informs the SMP that between Chesil Cliff and Downend, the headland that separates Saunton from Croyde), the cliff has eroded by up to 15m over the past 15 years. This information is based on having to move the fence adjacent to the South West Coast Path on several occasions.

The embayment is open to high wave energy from the North Atlantic and there is potential for a southward transport of coarse sediment, but it is cross-shore sediment transport processes that dominate in this section.

Movement

The dunes within Croyde Bay are generally stable and possibly show some evidence of accretion with the seaward movement of the mean high water line by about 40m over the past century (Halcrow, 2002), with the sediment source being the wide sandy foreshore. Some localised erosion of the dune face and blow-out development has been observed in the centre of Croyde Bay, but this is thought to be associated with the emergence of the stream and human foot trampling rather than coastal processes. Material that is eroded from the shoreline is likely re-deposited within the bay. This material eventually returns to the shore via the wide sandy foreshore during storm events, by means of the dominant cross-shore sediment transport that occurs within the embayment (Halcrow, 2002).

The headlands that bound this section are hard and erosion resistant, and as such have retreated very little as a result of infrequent, small scale, localised events over the past century (Halcrow, 2002). Futurecoast (Halcrow, 2002) suggests that cliff failure events at Saunton Down and within Croyde Bay occur with a frequency of between 10 and 100 years, resulting in between 10m and 50m of cliff top recession in any one event. Events at Baggy Point occur with a similar frequency, but result in less than 10m of cliff top recession in any one event.

Existing Predictions of Shoreline Evolution

For an 'unconstrained' scenario, Futurecoast (Halcrow, 2002) predicted that the overall form of this section would continue to be controlled by the resistant headlands of Saunton Down and Baggy Point, which would experience low rates of recession over the next century, as has occurred historically. Sea level rise would increase pressure on the shoreline, with potential for retreat in the centre of Croyde Bay, although only limited erosion of the dune face is likely to occur with any eroded material being re-deposited within the embayment. The overall implication of this shoreline retreat would be small in terms of future shoreline evolution, as the foreshore width should be maintained and the dunes at the back of the bay are sufficiently wide for limited erosion not to pose a threat to their integrity. A 'moderate' (10 to 50m over the next 100 years) change was therefore predicted, with 'negligible/no change' (less than 10m over the next 100 years) predicted for the headlands. Similarly, SMP1 (Halcrow, 1998) stated that the headlands are erosion resistant, with any retreat expected to be less than 10m over the next 50 years. The SMP1 also stated that there was no evidence for net material loss or gain within the bay, and that the local erosion of the dunes is probably due to the stream rather than coastal processes.

LOCAL SCALE: Baggy Point to Morte Point

Interactions

This section encompasses Morte Bay, an embayment that features the wide sandy beach of Woolacombe Sand, backed by dunes and the steeply sloping hinterland of Woolacombe Down. The embayment is bound by the hard, erosion resistant cliffed headlands of Baggy Point and Morte Point, both of which are fronted by rocky foreshore platforms.

These headlands exert a strong geological control on the evolution of the bay and also act as a barrier to sediment exchange with adjacent coasts. As such, Morte Bay is considered to be a 'closed' system in terms of coarse sediment transport. The only input of new sediment to the beach in Morte Bay is from local cliff erosion caused by undermining of the toe by marine action and weathering of the cliff face, although given the resistant nature of the local geology, such inputs are small and occur infrequently.

The embayment is open to high wave energy from the North Atlantic and there is potential for southward sediment transport of coarse sediment within the bay, although it is cross-shore sediment transport processes that dominate in this section due to the near swash-aligned orientation of the coast. Some offshore transport of sediment occurs in the vicinity of Baggy Point and Morte Point, although the lack of offshore seabed features suggests that sediment is not lost from the bay but is likely re-distributed within it.

Movement

Sediment transport within Morte Bay is driven by extreme events rather than long term progressive rates of change, with localised areas of dune face experiencing erosion during storm events. For example, the dune face at Putsborough eroded between 3 to 6m during a single storm event in 1990 (Halcrow, 2002). It is unclear what impact defences in this area may have had in contributing to such erosion, although some erosion of the dunes is as a result of human trampling to access the foreshore. This has required parts of the dunes to be fenced off and re-planted with marram grass in the past to restore the dunes (Everything Exmoor website, accessed Jan 2009).

Historic mapping analysis presented in Futurecoast (Halcrow, 2002) suggests that over the past century the foreshore within Morte Bay has been steepening. For example, Woolacombe Beach shows an advance of the mean high water line whilst the mean low water has remained static; review of recent beach profile data as part of this SMP also suggests that the beach has been widening slowly from west to east.

The headlands that bound this section are hard and erosion resistant, and as such have retreated very little as a result of infrequent, small scale, localised events over the past century (Halcrow, 2002). Futurecoast (Halcrow, 2002) suggests that cliff failure events along Baggy Point and within most of Morte Bay occur with a frequency of between 10 and 100 years, resulting in less than 10m of cliff top recession in any one event. The cliffs at Woolacombe Down however, experience a lower frequency of events, with cliff failures occurring about every 100 to 250 years, resulting in less than 10m of cliff top recession in any one event.

Existing Predictions of Shoreline Evolution

For an 'unconstrained' scenario, Futurecoast (Halcrow, 2002) predicted that the overall form of this section would continue to be controlled by the resistant headlands of Morte Point and Baggy Point, which would experience low rates of recession over the next century, as has occurred historically. Localised erosion of the dune face during storm events would also continue to occur, with eroded material being deposited on the foreshore within Morte Bay.

Sea level rise would increase pressure on the shoreline, with potential for retreat within the bay. Such shoreline retreat would maintain the beach width as the profile retreats landward, although the steeply sloping topography that back the dunes means that there is little room for the dunes to retreat in line with the beach and so net loss of dune width is likely to occur. This could lead to the complete loss of dunes in some parts of the bay, especially towards Putsborough where the dunes are narrower. Loss of dunes would in turn expose the toe of the backing coastal slope to marine action. Whilst this would begin to cause erosion of the slope in these areas, it is unlikely that it would occur at a sizeable scale over the next century. Futurecoast therefore predicted a 'moderate' net change over the next century, i.e. between 10 and 50m.

As there is very little human intervention along this section, the Futurecoast (Halcrow, 2002) prediction for a 'with present management' scenario is very similar to the unconstrained scenario behaviour over the next 100 years. The exception being in the vicinity of Putsborough Sands where there are small lengths of local defences protecting assets from flooding and erosion. These defences could experience increased pressure as sea levels rise, although Futurecoast concluded that their continued presence would not be likely to have a significant impact upon the fronting beach.

C.1.9 Morte Point to Minehead

LARGE SCALE

Interactions

This section of pre-dominantly east-west trending coast extends from the hard rock headland of Morte Point in the west, to Minehead Harbour arm in the east. It is primarily a hard rock coastline composed of sandstones, slates and shales that has become extensively indented due to local geological variations, such as the embayments at Combe Martin and Lynmouth, both of which have formed over extremely long timescales, as a result of erosion of north-west south-east trending faults. Towards the eastern end of this section, Porlock Bay is an area of low-lying land formed within relatively softer mudstones and breccias, with harder sandstones forming the surrounding higher ground (Halcrow, 2002).

The present shoreline is thought to have been largely unchanged since sea levels reached more or less their present levels about 4,000 years BP. As sea levels rose to their present levels, it resulted in the development of both the Porlock gravel barrier system in Porlock Bay, and a boulder delta formed as a result of river discharge at Lynmouth with associated seaward extension of the intertidal area.

The offshore area along this section is largely uniform in that along most of its length the seabed deepens rapidly into the Bristol Channel to depths of 20m to 30m below Chart Datum. However there are stable offshore sand banks, known as Sand Ridge and Foreland Ledge, that occur offshore of Lynmouth and Foreland Point respectively. These banks may provide some protection to the shoreline from wave action, although there is no evidence for a sediment transport link between these sand banks and the adjacent shoreline (Halcrow, 2002).

The dominant littoral transport of sediment along the shoreline is from west to east, driven by both the open ocean-waves and locally-derived waves to which this section of coast is exposed. However there is no sediment transport into this section of coast from further west due to the headland of Morte Point, which acts as a barrier to such transport. Sediment transport along this section is also limited by the highly indented nature of the shoreline, with little or no connectivity occurring between embayments (Halcrow, 2002).

Movement

Average rates of cliff retreat are generally very low along the length of this hard, geologically resistant section, with embayments forming in areas of differential geology representing the only shoreline changes of any significance (Halcrow, 2002). Only infrequent rock falls and landslips have occurred over this time, particularly on steep slopes, with any sediment supplied to the local shoreline only. Landslips here are a result of the local geology; occurring along bedding planes that are steeply inclined towards the sea, marine action at the toe of the cliff causes instability of the upper plane so that is slides into the sea.

Whilst these cliffs have remained relatively stable, since 1978 there have been three landslide events to the west of Porlock Bay. It may be that this relatively recent increase in landslip events is linked to an increased frequency of exceptionally high tides that cause the removal of toe debris at the cliff toe by allowing greater wave action in these areas (McTernan & Wilson, 1999). Orford (2003) also proposed that human intervention, though the removal of wooded cover along the slopes, may also have contributed to the increase in landslide events.

Modifications

Much of this section of coast is comprised of undefended, natural cliffs. Human intervention and modification has been largely confined to individual embayments such as at Lee Bay, Ilfracombe, Hele Bay, Combe Martin and Lynmouth, where both coastal defences and other structures associated with harbour development have been constructed. Where coastal defences are present they are generally seawalls that protect against coastal flooding and erosion locally, but which have little impact upon the wider coastline (Halcrow, 2002). There are also flood defences along the rivers that discharge at places such as Lynmouth and Combe Martin, although the SMP does not extend into these areas and so they have not been considered in detail.

Within Porlock Bay historical management has been undertaken in an attempt to maintain a continuous and static barrier. This intervention began with the early construction of a near terminal groyne to protect the harbour around 200 years ago, which both starved the beaches to the east by restricting sediment transport along the shoreline and changed the angle of wave approach to the shoreline (McTernan & Wilson, 1999). The combination of these factors likely led to the 1824 construction of groynes to the east of Porlockford (Bray & Duane, 2005), which has been primarily aimed at maintaining the integrity of the barrier as a flood defence for the low-lying land behind. Since the mid-1800s a sluice at New Works has regulated water levels; the New Works was built at the transition point between the ridge being swash-aligned updrift and drift-aligned downdrift, but is not thought to have caused the development of this transition point (Orford, 2003).

In 1910, storms destroyed much of the defences at Porlock Weir and so the most recent development in this part of Porlock Bay has been construction of a large groyne along the west side of the harbour channel in 1913 that effectively acts as a terminal groyne and which continues to prevent the west to east drift of sediment to the shoreline (McTernan & Wilson, 1999). From information provided through public consultation, it is understood that the most recent works at Porlock Weir were designed to minimise the extent to which sediment transport across the frontage is inhibited. There have also been various beach management activities, including beach replenishment, through mining fossil recurves behind the barrier, and reprofiling the barrier after washover events (Bray & Duane, 2005). Since the mid-1990s the management of the ridge has been relaxed, with a 700m length of the barrier to the west of New Works having been re-worked to a natural, lower but wider form which occupies a position about 50m landward of the adjoining section of maintained barrier (Bray & Duane, 2005). The defences at New Works sluice still affect barrier retreat; these defences act as a 'headland' that controls barrier movement locally and has resulted in the development of small embayments either side of the sluice (Halcrow, 2002).

The shoreline at the western end of this section, immediately to the west of Minehead Harbour breakwater, has been modified by the construction of groynes and a concrete seawall, as well as by the presence of the harbour breakwater itself, all of which limit the littoral drift of sediment from west to east (Black & Veatch, 2006a).

LOCAL SCALE: Morte Point to Foreland Point

Interactions

This is pre-dominantly a cliffed coast comprised of Devonian sandstone and slate, indented with north-west south-east trending bays that are controlled by similarly trending fault lines. One such bay is Lynmouth Bay, which occupies a steep sided valley that drops rapidly to the coast. It is fronted by a boulder delta that is thought to be the result of very infrequent flash flooding events that result from heavy rainfall leading to surface water run-off being channelled down the narrow, steep sided river valley, carrying a range of sediments, including large cobbles and boulders, which are then deposited on the foreshore. There is likely to have been a number of such events in the past, with the most recent one having occurred in 1952 and which resulted in boulders estimated to be up to 50 tonnes in weight being transported (Halcrow, 2002). The boulder delta pushes the low water mark seawards, with the intertidal area extending for about 350m from shore at its widest point; however, the infrequency of such events means it can not be relied upon as a regular mechanism of sediment input to the shoreline (Halcrow, 2002). Also a flood defence scheme was implemented at Lynmouth and Lynton in 1956, since when there has been no significant flooding (Environment Agency, 2008).

The cliffs vary in height and form due to geological variations. A notable change in form occurs in the cliffs to the east of Hangman Point, where the cliff profile becomes more uniform. This coincides with a change in bedrock from slates in the west to sandstones with alternating slate and shale bands to the east (Halcrow, 2002).

Littoral transport of sediment is from west to east, however this is largely restricted to individual embayments due to the highly indented nature of this section of coast which inhibits sediment exchange with adjacent embayments. There is also a limited amount of mobile offshore sediment along this section and so the supply of sediment to the shoreline from offshore is also restricted (Halcrow, 2002).

Movement

The cliffs along this section have historically experienced very low rates of recession. Slightly higher rates of recession (although still low compared to other coasts) occur between Morte Point and Bull Point due to the occurrence of localised rock falls (Halcrow, 2002). Futurecoast (Halcrow, 2002) suggests that cliff failure events along this section occur with a frequency of between 10 and 250 years, typically resulting in less than 10m of cliff top recession in any one event, although up to 50m of cliff top recession may occur in some parts, depending upon specific local geology.

The embayments along this section are subject to storm driven changes, primarily the wave driven eastward transport of coarse sediment along the upper foreshore. These changes vary from bay to bay, with Lee Bay at Ilfracombe experiencing progressive foreshore steepening whilst storms result in the shallowing of the harbour at Combe Martin and erosion of Watermouth Bay (Halcrow, 2002). The various defences within individual embayments serve to reduce the impact of these storm events on coastal erosion by reducing the risk of recession locally.

Flood defences along the rivers that discharge along parts of this section, such as at Combe Martin and Lynmouth, also serve to restrict the supply of sediment to the shoreline by reducing the risk of flash flood events that have historically delivered significant, albeit infrequent, amounts of sediment to the shoreline. This may also have an impact upon shoreline evolution in the future.

Existing Predictions of Shoreline Evolution

For an 'unconstrained' scenario, Futurecoast (Halcrow, 2002) predicted that the future evolution of this section of coast will continue to be controlled by the geological resistance of the bedrock, resulting in a continuation of the low rates of cliff recession observed historically. Local rock falls will supply limited amounts of sediment to local beaches. It is uncertain whether or not this supply of sediment will be sufficient to maintain the overall form of the foreshore as sea levels rise, and so these beaches would narrow or even disappear in places as they are constrained by steeply rising, resistant geology. 'Negligible/no change' (less than 10m over the next century) in cliff position was therefore predicted by Futurecoast.

The Futurecoast (Halcrow, 2002) prediction for a 'with present management' scenario is for this scenario to be largely as for the unconstrained scenario due to the pre-dominantly undefended natural cliffs located along this section of coast. Where existing defences are maintained for flood defence purposes, such as at Lee, Ilfracombe, Hele Bay, Watermouth, Combe Martin and Lynmouth, they may also serve to continue to restrict cliff erosion locally in these areas, potentially reducing the supply of sediment to local beaches. However, Futurecoast suggested that the continued presence of these defences locally would not have wider implications on the rest of the coast.

SMP1 (Halcrow, 1998) predicted that between Morte Point and Bull Point retreat rates would be approximately 1m/year, but that elsewhere cliff retreat would be less than 10m over a 50 year timeframe, except at Holdstone Down where rates may increase to 0.5 to 1.0m/year. It also noted that at Lee there would be an increased flood risk if the defences were not maintained.

There is also a likelihood that occasional flash flood events at places such as Lynmouth and Combe Martin could provide infrequent additional inputs of sediment to the shoreline if defences were not maintained (Environment Agency, 2009).

LOCAL SCALE: Foreland Point to Gore Point

Interactions

This section of coast lies between the two headlands of Foreland Point and Gore Point and consists of undefended cliffs of steeply dipping sandstones with mudstones that form the pre-dominant 'hogs back' cliff form along much of its length with sea cliffs below upper slopes. There are also some localised areas of head deposits present. These cliffs are mantled in places by landslip deposits that are generally inactive. However these can contribute to the local shoreline sediment stock where they become reactivated by cliff toe erosion (Halcrow, 2002).

The foreshore is characterised by a narrow shingle beach at the cliff toe. Between Foreland Point and Glenthorne small beaches are present at the back of pocket beaches, whereas to the east of Glenthorne there is a shingle beach present, almost continuously to Gore Point.

The dominant wave-driven longshore sediment transport is from west to east along this section. It is likely that this transport may once have been a (post-ridge formation) source of sediment supply for the gravel ridge within Porlock Bay further to the east, although the ridge itself is believed to have formed around 6,000 years BP as a result of the seaward transport of sediment as sea levels rose following the last glaciation (Jennings *et al*, 1998). However, contemporary erosion rates along this section of coast are too low to sustain a continuous supply of sediment for transport via Gore Point to Porlock Bay (Halcrow, 2002).

Movement

Due to the resistant nature of the cliffs, there have been low rates of cliff recession along this section of coast historically, although local scale events can cause a few metres of erosion, as a result of long term wave undercutting at the toe and rock slides. Futurecoast (Halcrow, 2002) suggests that cliff failure events along this section occur with a frequency of between 100 and 250 years, resulting in less than 10m of cliff top recession in any one event.

From appraisal of historical Ordnance Survey maps, Futurecoast (Halcrow, 2002) suggests that the foreshore position has also changed little, although some landward movement of the mean low water mark may have occurred near Culbourne, although this change may lie within the error limits of the maps.

Existing Predictions of Shoreline Evolution

For an 'unconstrained' scenario, Futurecoast (Halcrow, 2002) predicted that this undefended section of cliffed coastline would continue to erode slowly, as has been the case historically, and as such will maintain its present form over the next 100 years whilst continuing to provide limited amounts of sediment to the shoreline. 'Negligible/no change' (less than 10m) was therefore predicted over the next century.

Futurecoast (Halcrow, 2002) did, however, identify that the ongoing erosion of the base of the marine cliffs could result in instability of the relict landslide deposits that lie above them in the upper parts of the cliffs. Where this occurs there would be rapid, localised, short term retreat followed by long term stability as the failure debris protects the toe of the cliff until such time as it is removed by marine action. Future sea level rise may accelerate this process in the future, particularly if the foreshore narrows and steepens as sea levels rise and there is insufficient sediment supply to counter this effect.

LOCAL SCALE: Porlock Bay

Interactions

The dominant feature of Porlock Bay is the gravel barrier system (Porlock Ridge) that fronts a low-lying area covered by river terrace and salt marsh deposits. Stretching 5km in length it is the longest continuous coastal gravel barrier system on the western coast of Britain (Orford, 1993). Porlock Bay lies within an open valley formed from soft marine clays and mudstones, and is bounded on both sides by sandstone cliffs (Halcrow, 2002).

The present gravel barrier form has a variable crest height of between 7m and 12m. The western part of the barrier has a single crest with gentle seaward slope and a wide cobble/boulder beach: this boulder platform dissipates wave energy, but does not protect the barrier during high tides and surges (Orford, 2003). Towards the eastern end the barrier becomes more complex with a series of swash-aligned ridges that form a steeper, narrower and more reflective seaward face (Halcrow, 2002).

There is little or no contemporary supply of sediment to the barrier. Orford (2003) reported a 'recent' increase in sediment supply from landslides and suggested that landslides will have supplied sediment episodically in the past history of the feature. He noted, however, that the increase in sediment supply had not alleviated the net trend of sediment deficient.

Longshore sediment transport is from west to east along the shoreline of Porlock Bay, driven by swell and locally derived waves. The rate of potential transport is dependent upon the degree of exposure of each part of the bay, which in turn is controlled by the bounding cliffed headlands and gradient of the sub-tidal region (which is shallower in the western part of the bay). Estimates of longshore drift range from 250m^3/year to 2,000m^3/year (Pethick, 1992; Bray & Duane, 2001; Cope, 2004). Beach drift rates increase towards Hurlstone Point, with a local resident reporting a noticeable increase in the size of the ridge in this area in recent years. Some sand sediment may also be transported around this headland under favourable conditions, although it is likely to be a complete barrier to gravel transport. However, overall rates of actual littoral drift are generally low along this frontage due to a combination of factors including the partial swash alignment of the updrift barrier (Cope, 2004), a shortage of new material entering the system and the presence of a range of defences that partly intercept drift, including artificial maintenance of the ridge, between Gore Point and Porlock Weir, and groynes, seawall and harbour breakwater arm at Porlock Weir (Bray & Duane, 2001; 2005, Halcrow, 2002).

The development of the permanent 1996 breach in the barrier introduced a new longshore sediment drift boundary along the shoreline and localised sediment drift reversal, resulting in material being transported eastwards along the barrier entering the breach mouth before being flushed seawards via an inlet channel, to be deposited in a small ebb tidal delta. As such the supply of sediment to the shoreline further east is affected by the presence of the breach. The seaward flushing of sediment itself is a function of the strong ebb currents that are generated as a result of the tidal prism of the lagoon. These currents, combined with low rates of littoral sediment drift along this frontage, are also why the breach has remained and not been re-sealed by littoral drift processes (Cope, 2004; Bray & Duane, 2005).

Movement

The barrier is thought have formed as a drift-aligned spit, which developed eastwards until reaching Hurlstone Point, which acts as a natural groyne. The source of the sediment contained in the gravel barrier is uncertain, but Orford (2003) suggests that the west-east Exmoor coastal slope was probably the main source of gravel, due to marine erosion of debris fans at the foot of the coastal slopes as sea level rose during the Holocene marine transgression. This material was then moved by longshore drift.

As the rate of sea level fell, sediment supply fell and the barrier entered a phase of reworking (Orford et al., 1996). Since this time Porlock Ridge has experienced a cycle of build-up and break-down, largely controlled by the rate of sea level rise and the rate of input of new sediment from further west. The pattern of barrier breaching and subsequent 'healing' has not therefore been caused by man (Orford, 2003), although intervention to maintain the barrier as a fixed feature may have exacerbated this process and thereby increased its vulnerability to storm events (Cope, 2004). Sediment transport from the west is believed to have now virtually ceased, therefore the barrier can be considered as a largely relict feature.

Porlock Ridge is undergoing overall shoreline retreat as it naturally migrates landward in response to rising sea levels via overwashing and breaching. In October 1996 a section of the gravel barrier breached during a severe storm event, and formed an intertidal lagoon landward of the barrier crest.

In terms of morphological behaviour, the barrier can be divided into a number of partially dependent 'sub-cells' that behave slightly differently (Bray & Duane, 2005). Bray & Duane (2005) analysed historical maps to determine rates of change along these various sections of the barrier. The barrier to the west of the 1996 breach retreated at an average rate of 0.83m/year between 1988 and 2000, which compares to a rate of 0.42m/year between 1888 and 1988, due to a lack of reprofiling works being undertaken. Between New Works and the War Memorial there was a retreat of between 10m and 20m between 1888 and 1928, followed by a period of stability up to 1988. Between 1988 and 2000 there was then around 10m erosion in the vicinity of New Works. To the east of the War Memorial there was between 10m and 20m retreat between 1888 and 1928, but since then this section has remained relatively stable.

At the breach itself, the barrier has been allowed to evolve naturally since the breach event; spits and a proto-type ebb tidal delta have since formed at the mouth of the breach. The breach remains open as the tidal prism is large enough to produce strong ebb-tidal velocities that flush away any material that could otherwise block the breach (Cope, 2004). This flushing has been enhanced since 2000/1, since headward erosion of the breach resulted in connection with the main drainage dyke. The breach is, however, enlarging and extending (Bray &

Duane, 2001) and is gradually shifting eastwards along the coast (Bray & Duane, 2005) as a result of longshore drift; whereby the western spit is extending into the breach channel whilst the eastern spit is retreating away from the breach. The flooded back barrier areas have been infilling, with subsequent salt marsh colonisation. Bray & Duane (2005) suggested that there was a net loss of barrier volume associated with the breach; with coarse material being moved into the ebb tidal delta and fine core material becoming lost as the barrier is reworked.

Analysis of recent beach surveys undertaken for this SMP suggests that landward retreat of the ridge is currently occurring at an annual average rate of about 0.1m/year.

The net length of the barrier has increased; prior to the breach this was due to the barrier migrating into the Bay, and following the breach there has been a further increase in length due to the development of spits at the mouth of the breach (Bray & Duane, 2005). This means that there is a thinning of the available material along the beach.

The low cliffs at Porlockford are cut in solifluction deposits and are therefore fairly easily eroded by marine action. Bray & Duane (2005) estimated that these cliffs were eroding at an average rate of between 0.5 and 0.6m/year between 1888 and 1972, but that since this time although they remain active, the rate of recession has slowed. Here the beach is relatively sheltered by the coast immediately to the west and the timber groynes along this stretch help trap material.

Existing Predictions of Shoreline Evolution

For an 'unconstrained' scenario, Futurecoast (Halcrow, 2002) predicted that without defences and other human intervention, there would be natural retreat of the entire shoreline onto the low-lying land behind, resulting in an overall reduction in the flood protection afforded to this low-lying land by the gravel barrier. This would be likely to occur as a result of overwashing and further breaching of the ridge during storm events. Breaches would be permanent due to the lack of sediment input to the system from further west to provide material to re-seal them. Roll back of the ridge would be constrained by high ground at Porlockford. A 'high' net retreat was predicted (between 50 and 100m over the next century).

In term of the overall barrier, Orford (2003) predicted that the barrier will continue its trend of retreat as a function of the height reached by extreme run-up of breaking waves; this could increase with future sea level rise and any increase in storminess. Without reintroduction of management activities, the barrier will be more responsive to forcing and should adjust its form accordingly by retreat, flattening and widening such that the barrier form becomes more dissipative so reducing the risk of catastrophic barrier breakdown. There is, however, a risk of hinterland flooding, although the barrier will prevent wave action. However, Bray & Duane (2005) also identified that there is a risk that the barrier will continue to reduce in volume, due to the formation of the ebb-delta at the breach and the net loss of 'core' finer sediments as the barrier is reworked.

It is uncertain as to how long the present tidal inlet will remain. Pethick (2001) suggested that as salt marsh development continues, as a result of sedimentation occurring at a rate of about 20mm/year, the level of the salt marsh will increase and so the tidal prism of the lagoon will decrease, resulting in an associated reduction in ebb current flow which may be sufficient to allow longshore sediment processes to eventually re-seal the mouth of the inlet. Bray & Duane (2005) also suggested that the developing salt marsh appears to be able to accrete vertically in line with, or even exceeding predicted sea level rise. Cope (2004), however, looked at the potential for the breach to be closed on due to longshore transport and determined that for the breach to become unstable, longshore drift would have to increase from between 250 and 2,000m^3/year to between 4,000 and 7,000 m^3/ year, but for the breach to close completely, drift rates would have to increase to 24,000m^3/year. Cope (2004) also concluded that sea level rise would be likely to strengthen inlet stability by increasing the tidal prism.

Although, as stated above, the salt marsh should be able to accrete vertically with sea level rise, its lateral extent may be squeezed, should sea level rise accelerate the rate of barrier roll back, as the backing field boundaries would restrict landwards marsh development.

At the breach mouth, Bray & Duane (2005) predicted that the western spit would remain relatively stable as it is not exposed to direct wave action, but that the eastern spit could be vulnerable to overwashing and breaching, should its volume become depleted to a critical level. The ebb tidal delta was predicted by this study to grow in the future as gravel is moved into the breach channel. However, Bray & Duane (2005) suggested that there could be two possible outcomes: (1) the delta could store gravel at the expense of the barrier, thereby resulting in depletion in volume, or (2) the delta accretion could build-up foreshore levels and therefore improve wave dissipation and reduce the pressure on the barrier locally.

Bray & Duane (2005) concluded that there was uncertainty regarding the role of the groynes to the east of New Works as these may have already 'anchored' parts of the barrier. As these defences fail, there could be increased sediment drift resulting in the barrier becoming depleted in volume and rapid crest recession occurring.

Bray & Duane (2005) predicted that the barrier to the east of the breach would remain fairly stable because it has a high barrier 'inertia' that provides buffering against changes. The study did, however, identify that there was a risk of 'catastrophic breakdown' and proposed four locations where the barrier integrity could be at risk: (1) along the eastern spit at the mouth of the breach, (2) at Porlockford Barrier, where the barrier joins the cliffs, due to a negative sediment budget, (3) between New Works and the war memorial, where there is a risk that a breach could form if the barrier becomes depleted and (4) at the war memorial, where the crest has thinned and the barrier is still to react to the cessation of active management.

Orford (2003) also proposed that there is potential for further breaching to the immediate east of New Works; however he suggested that inlet efficiency could be reduced if more breaches occur, which would actually limit the potential for breaches to become permanent.

LOCAL SCALE: Hurlstone Point to Minehead

Interactions

This section of coast extends from Hurlstone Point in the west to Minehead Harbour breakwater in the east, and is comprised of high, extensively vegetated cliffs formed from heavily faulted and folded sandstones. At Greenaleigh Point and towards Minehead the cliff toe forms a low slope behind the foreshore rather than steep cliffs. The foreshore is mostly comprised of a narrow gravel beach that grades to fine-grained sub-tidal sands towards seawards, although there are some areas of exposed bedrock and boulder debris also present (Halcrow, 2002).

The slow erosion of the cliffs along this section supplies a very limited amount of sediment to the foreshore that is then available to be transported eastwards by the dominant west to east wave-driven longshore sediment transport along this section of coast. The main exposure of beach-building deposits is at Greenaleigh Point, where glacial deposits are exposed (Halcrow, 1998). There is little or no sediment input to this section from further west around Hurlstone Point. Sediment is inhibited in its ability to move along the shoreline by exposures of foreshore bedrock and boulders, and to the immediate west of Minehead, by a combination of groynes, a concrete seawall and the Minehead Harbour breakwater.

Movement

The heavily faulted and folded sandstones along this section are prone to frequent rock falls (Black & Veatch, 2006a). However the overall rate of recession is low, with Futurecoast (Halcrow, 2002) suggesting that cliff failure events at along this section occur with a frequency of between 100 and 250 years, resulting in 10m to 50m of cliff top recession in any one event around Minehead Bluff, and more than 50m of cliff top recession in any one event around Culver Cliff. Black & Veatch (2006a) also concluded that the coastline has been relatively stable.

The gravel storm ridge between Greenaleigh Point and Minehead is steep and narrow and shows signs of lowering towards the east (Halcrow, 2002; Black & Veatch, 2006a). Analysis of historical Ordnance Survey maps undertaken for Futurecoast (Halcrow, 2002) suggests that there has been a general trend of retreat of the mean low water mark and associated foreshore steepening. Black & Veatch (2006a) also determined, from historical admiralty charts, that the offshore (approximately one kilometre from the coast) has steepened and become shorter over time, at a rate of approximately 1.4m/year. They did not, however, agree with the Futurecoast suggestion that mean low water has changed over the last century.

Existing Predictions of Shoreline Evolution

For an 'unconstrained' scenario, Futurecoast (Halcrow, 2002) predicted that the cliffs along this section of coast will continue to experience low rates of recession as have occurred historically. As sea levels rise the beaches along this section would become narrower and steeper, resulting in the cliff toe becoming increasingly exposed to wave action during storm events which in turn could potentially accelerate cliff recession in the longer term. Futurecoast also suggested that without defences at Minehead, combined with the narrowing and steepening of the foreshore in response to rising sea levels, there would be increased risk of erosion of the low slope and cliffs that are present behind the gravel storm ridge in this area.

The Futurecoast (Halcrow, 2002) prediction for a 'with present management' scenario is for this scenario to be largely as for the unconstrained scenario along the majority of this undefended, natural section of cliff coast. The exception is in the area at Minehead, where the continued presence of defences will inhibit the longshore drift of sediment from reaching the shoreline further east, but will maintain protection of the land behind the defences.

SMP1 (Halcrow, 1998) suggested that the coastline to the west of Greenaleigh Point is relatively stable, although some foreshore steepening may occur, and the cliffs were generally continue to erode as historically.

C.1.10 Minehead to Hinkley Point

LARGE SCALE

Interactions

This section of coast extends from Minehead Harbour breakwater in the west to Hinkley Point in the east and is a predominantly cliffed coastline fronted by intertidal platform. These cliffs reach a height of about 75m between Blue Anchor and Watchet before gradually reducing in height towards the east and disappearing altogether to the east of Hinkley Point. Differential erosion of these cliffs, as a result of varying wave exposure and bedrock geology, has resulted in the present coastline form characterised by small bays that indent the coast separated by more resistant headlands. These headlands are formed from resistant Devonian Sandstones and Carboniferous Limestones whilst the small bays that indent the coast are cut into the relatively softer Jurassic mudstones (Halcrow, 2002).

The erosion of the cliffs along this section is a key sediment input to the coast, although this provides mostly fine material and only some coarser sand and gravel material. The fine material is lost offshore where it enters the Bridgwater Bay mudbelt. This mudbelt is an extensive depositional feature that has developed in Bridgwater Bay as a result of its relative sheltering from wave action (compared to the coast further west) and low tidal currents, combined with high suspended sediment concentrations derived from the Severn Estuary and Bristol Channel. The influence of the mudbelt is seen in the widening and shallowing of the nearshore zone towards the east of this section (Halcrow, 2002).

The western part of this section, between Minehead and Blue Anchor, is low-lying with an extensive area of former salt marsh and river terrace deposits that developed following enclosure by a gravel storm ridge. The source of material for this gravel ridge was erosion of cliffs to the west of Minehead as sea levels rose following the last glaciation. This remains a source of sediment, although the rate of supply is dependent upon the frequency of cliff falls and is affected by coastal structures. Coarse sediment is prohibited from being transported along the shoreline by the various defences and other structures at Minehead, although some sand sediment is transported in the nearshore zone and provides sediment inputs as it moves onshore having been deposited in the embayments along this section (Black & Veatch, 2006a). Between Warren Point and Dunster, the ridge is backed by dunes that are believed to have formed prior to the development of the gravel ridge (Halcrow, 2002). The sand source for these dunes is thought to have originally come from both the Bristol Channel sweeping sediment towards the shore after the last glaciation, and also erosion of the cliffs to the west. Sand sediment that is transported in the nearshore zone may provide a small contemporary input to parts of the shoreline (Black & Veatch, 2006), although it is thought that there is little or no coarse sediment exchange from offshore to inshore (Halcrow, 2002). This low-lying area is backed by cliffs of Triassic and Jurassic shales and mudstones with additional head deposits in the east (Halcrow, 2002).

Erosion of the cliffs to the west of Minehead was also the source of gravel to the shoreline in Blue Anchor Bay, with material being transported from west to east by wave driven littoral drift along this section, leading to the accumulation of gravel at the down-drift end of Blue Anchor Bay in the form of a gravel ridge. The contemporary supply of sediment is, however, currently prevented by the various structures along the shoreline at Minehead (Black & Veatch, 2006a; Halcrow, 2002).

Movement

Erosion of the cliffed parts of this coastline since the last glaciation has resulted in the formation of wide intertidal platforms along much of this section. A number of embayments have also developed, controlled by both local geological variations (embayments formed largely in relatively softer Jurassic mudstones) and the degree of exposure to wave energy from the North Atlantic (Halcrow, 2002).

Warren Point is a ness feature that formed as a result of deposition of coarse cobble/shingle material that was transported to this area following erosion of the cliffs further to the west of Minehead. The Warren frontage faces into the prevailing wind and wave conditions and, being also a more prominent shoreline feature, is subject to a high degree of storm wave energy. This has resulted in erosion of the ridge over the past several decades (Black & Veatch, 2006a).

Within Blue Anchor Bay, the width of the nearshore zone is increasing with the 5m bathymetric contour moving seaward by about 500m since 1982 (Halcrow, 1998), suggesting that this is an area of sediment accumulation, probably linked to the Bridgwater Bay mudbelt; this is causing shallowing of the seabed, particularly in the eastern part of the bay, which in turn is likely to result in reduced wave action at the shoreline (Halcrow, 2002).

Modifications

Whilst most of this cliffed section of coast is undefended, there are several areas that have been subject to significant human intervention and modification, namely Minehead, Blue Anchor, Watchet, Lilstock and Doniford.

At the western end of this section is Minehead Harbour which has a breakwater and groyne that projects seaward from the main harbour arm. This provides both shelter to the harbour but also prohibits the supply and distribution of sediment from the occasional cliff erosion to the west to beaches to the east (Black & Veatch, 2006a). The harbour is frequently infilled by sand and shingle and annual dredging is necessary to remove the material and allow harbour operations to continue. The dredged material is placed on the shoreline to the east of the Red Lion slipway.

Other defences in Minehead Bay include concrete seawalls and groynes that have been constructed and maintained over many decades. The most recent construction took place in 1998 when a wave return wall was constructed in combination with the placing of 183,000m^3 of sand beach recharge. New groynes were also constructed to hold the beach in place and thereby help stabilise the shoreline (Black & Veatch, 2006a). This scheme followed a flood event caused by wave overtopping of the previous defences during a storm in October 1996, which caused the old seawall to collapse and resulted in flooding of a significant number of assets located on the low-lying hinterland (Black & Veatch, 2006a).

Groynes extend from Minehead around to the western side of Warren Point (the eastern extent of Minehead Bay). Beyond the eastern-most groyne of the 1998 Minehead scheme, the shoreline of Warren Point that fronts the golf course is subject to severe erosion; here it has been necessary to build up beach levels since 1998 (Black & Veatch, 2006a), although information provided for the SMP from local land owners suggests that the accretion of sand to the east of Warren Point (fronting Dunster Beach) has increased since 1998, when the beach at Minehead was recharged. From information provided to the SMP through the consultation process by a local resident, material to recharge the eroding beach is understood to have been sourced from several large borrow pits, which were dug in 2009 on the eastern side of the easternmost Minehead boulder ridge (see local scale Minehead to Blue Anchor for a description of the Minehead Boulder ridges). It has also been suggested that the boulder ridges provide significant protection to Warren Point foreshore from long-period westerly swell and storm waves. If they are destroyed by abstraction then the erosion of Warren Point will accelerate.

Within Blue Anchor Bay, a masonry and concrete seawall, rock armour and stone groynes are present at the eastern end of the bay fronting Blue Anchor; these were upgraded between 2002 and 2005, although the majority of the bay is protected by the gravel storm ridge, which is subject to management to maintain its function as a sea defence (Halcrow, 2002). At the Warren there has been a number of beach management schemes, including rock 'sausage' groynes, beach recharge (using shingle derived from the lower foreshore) and sand fencing (Black & Veatch, 2009).

Along the Dunster caravan site, timber groynes have been constructed along the upper foreshore over a length of approximately 800m, to hold beach material (Garrard *et al*, 2006). Black & Veatch (2009) report that analysis of LiDAR data shows that at present this groyne system appears to be stabilising the beach in front of the Dunster Beach Chalets.

Towards the eastern end of this section, defences such as those at Watchet, Lilstock and Doniford provide localised protection against flooding and erosion. At Lilstock a 305m long gabion wall was constructed in the 1960s to the rear of the natural shingle ridge in order to increase the standard of protection provided by the ridge against tidal flooding. This structure is, however, nearing the end of its design life (Jacobs Babtie, 2005).

At Watchet defences include a concrete seawall, augmented with rock armour in places, which also has a culvert through it to allow the River Washford, that flows through Watchet, to discharge to the sea. Despite these defences, Watchet has a history of flooding, with notable flood events having occurred five times since the 1960s, and the area around the tidal basin, located immediately upstream of the harbour culvert, is particularly vulnerable to flooding (Royal Haskoning, 2004). There are also structures associated with Watchet Harbour, which is also subject to annual dredging by the local authority. The dredged material is either placed in the nearshore zone to the immediate east of the harbour, or allowed to disperse with the tide (depending upon the dredge method used).

Towards Doniford, there is a range of structures including a seawall, rock revetment and embankments, which protect a range of assets along the shoreline, including the coastal railway line. These localised defences also reduce cliff erosion locally; however, the adjacent, undefended cliffs also erode only very slowly due to erosion of the cliff toe and so the small variations in recession rates that are caused by the defences have a negligible impact on adjacent lengths of coast (Halcrow, 2002).

At Hinkley Point, construction of Hinkley Point A Power Station started in 1957. Much of the site was built out onto the foreshore and is probably underlain by made ground. Hinkley Point B Power Station is also underlain by up to 5m of made ground, largely composed of Lias limestones and shales excavated from the deeper foundations (Royal Haskoning, 2008). The site is protected by a seawall.

LOCAL SCALE: Minehead to Blue Anchor

Interactions

This section comprises two embayments: Minehead sits within a natural embayment bounded by hard Devonian cliffs in the west (Culver Cliff) and the prominent headland of Warren Point in the east, whilst Blue Anchor Bay lies between Warren Point and an exposed wave-cut platform in the east (Black & Veatch, 2006a). These embayments are backed by low-lying land, which is reclaimed salt marsh.

The embayments are largely sheltered from large North Atlantic swell waves and this has created conditions favourable for sediment deposition (Black & Veatch, 2006a). The foreshore along this section varies from Minehead Bay, where a mud/sand upper foreshore becomes progressively more sand/shingle-rich seawards, to Blue Anchor Bay, where the wide upper foreshore (fronting the gravel storm ridge) is comprised of sand and shingle, which becomes more mud/sand-rich seawards. This difference is related to the amount of wave exposure, which is less in Blue Anchor Bay than in Minehead Bay due to the increasing influence of the Outer Severn Estuary.

Warren Point is a ness feature, which is believed to have formed as a result of deposition of coarse cobble/shingle material eroded from the cliffs to the west as sea levels rose following the last glaciation. Currently, this supply is much reduced due to less frequent cliff falls and the impact of coastal structures at Minehead. The current beach ridge is backed by a series of ancient (now vegetated) shingle ridges and sand dunes which demonstrate the historic evolution of this feature and show that the ridge has fluctuated many times in the past and has previously existed several metres landward of its current position (Black & Veatch, 2006a). The Warren frontage forms as small promontory which faces into the prevailing wind and wave conditions, which means that it is subject to a higher degree of storm wave energy than the embayments either side. This has resulted in erosion of the ridge over the past several decades and makes this area particularly vulnerable to overtopping and breaching (Black & Veatch, 2006a).

Located between the mid-tide and low spring tide position of the beach north of Butlins holiday centre are two liner boulder ridges orientate north-south, that separate Minehead Bay from Madbrain Sands. Information from a local resident provided to the SMP via the consultation process suggests that the morphology of the 'Minehead ridges' were deposited in two stream channels cut in coastal deposits that have since been removed by erosion and shoreline retreat during the past few thousand years.

There are limited inputs of sediments to the system from offshore as offshore sand resources are much depleted (Black & Veatch, 2006a; Halcrow, 1998). Longshore drift is from west to east, but there has been a long term effect of structures along the coast, particularly the harbour arm breakwater at Minehead, which have interrupted the supply of shingle from the Culver Cliff areas to frontages further east.

Movement

To the west of the Harbour Arm breakwater the shoreline has remained relatively stable, with the slow eastward longshore transport of sediment being constrained by the groyne system and breakwater (Black & Veatch, 2006a).

At Minehead, the coastline has been stabilised through the construction of a concrete seawall and groyne scheme. Beach recharge was also undertaken along the beach within Minehead Bay in 1998; a review of recent beach profile data as part of this SMP suggests that the beach has been more or less stable, with a slight trend of erosion, since this recharge event. Black & Veatch (2006a) did, however, note that in the west of the Bay, near the end of esplanade, the shoreline has moved landward by between 10m and 20m over the last 30 years, equating to approximately 0.6m/year retreat. This study also concluded that mean low water has moved inshore at an average rate of up to 3.5m/year. Black & Veatch (2006a) also stated that the range of sediments within the Bay has changed; with an increase in sand to shingle ratio, both due to beach recharge and the reduction in coarse sediment supply due to the harbour structures.

At the Warren, Black & Veatch (2009) noted that there has been a slight increase in the height of the dunes at the western end of the area, behind the terminal rock groyne on Minehead Beach. This trend was, however, observed to be only affecting a very short stretch of dune, with the majority of the shingle ridge being in fair to poor condition, with wave erosion of the ridge face occurring. Black & Veatch (2009) suggested that erosion is occurring at a rate of 0.3m/year, which would mean that the crest of the dune could be eroded within 20 years. It was, however, noted that, due to the higher land behind, there was not a risk of breach.

The gravel storm ridge is narrowing and degrading in the area of Dunster Beach, where in the recent past there has been significant erosion of the foreshore berm. This erosion prompted the construction of groynes between the late 1990s and 2003. Since the groynes were installed, the upper beach has increased in height by between 2m and 3m, whilst the foreshore has been relatively stable since 2001, with only a small change in levels due to sand accretion following the installation of the groynes (Garrard, 2006). Along the western, undefended end of the beach, the coastline has eroded at a rate of around 0.6m/year since the 1970s (Black & Veatch, 2006a).

Along this Warren and Dunster frontage, there is a limited supply of sediment due to the construction of the Minehead Harbour breakwater and other shoreline control structures along the Minehead frontage (Black & Veatch, 2009). This reduction in sediment supply has also resulted in the narrowing of the shingle ridge in Blue Anchor Bay, with particular degradation of the ridge occurring along Dunster Beach compared to the eastern beach within the Bay, due to the net eastward drift of sediment. Black & Veatch (2009) suggest that the whole area could become depleted of shingle, due to the limited new supply of shingle material to the area. The low-lying land at Dunster Beach is already subject to periodic flooding (Garrard, 2006). As a result of both sea level rise and the net loss of sediment, the risk of an extreme storm event causing breaching of the shoreline between Warren Point and Blue Anchor is increasing. Should such an event occur along the Dunster Marshes section of Blue Anchor Bay, there would be a risk of backdoor flooding of Minehead (Black & Veatch, 2006a).

Within Blue Anchor Bay as a whole, the width of the nearshore zone is increasing, suggesting that this is an area of sediment accumulation, probably linked to the Bridgwater Bay mudbelt. This is causing shallowing of the seabed, particularly in the eastern part of the bay, which in turn is likely to result in reduced wave action at the shoreline (Halcrow, 2002). This increase in the nearshore zone width is in contrast to the upper foreshore and beach, which in general has retreated by between 100 and 300m over the past century and been associated with lowering beach levels at the same time (Halcrow, 2002), both of which also contribute to the shallowing of this part of the shoreline. It has been reported that beach levels reduced by 4m over 20 years in the early part of this century, with more recent reports of 0.6m drop between 1973 and 1983 (Halcrow, 1998).

Existing Predictions of Shoreline Evolution

For an 'unconstrained' scenario, Futurecoast (Halcrow, 2002) predicted that overall there would be a trend of shoreline retreat along the length of this section. This would mean the extensive low-lying areas that form the hinterland along this section would be at risk of flooding from the sea over the next 100 years due to overtopping and breaching of the beaches and gravel ridges that front shoreline. For this area, Futurecoast (Halcrow, 2002) proposed a 'high' net retreat (50 to 100m) over the next century.

To the west of the Harbour Arm breakwater, Black & Veatch (2006a) predicted that there would be a risk of minor flooding, but that the area would only be affected during the peak of the tide as water would be able to drain quickly once the tide has receded. No backdoor flood route to Minehead from this side was identified, for the next century.

At Minehead, Black & Veatch (2006a) assumed that the recent seawall would remain, but identified that the current trend of landward migration of mean low water would place increasing pressure on the existing defences, particularly at the western end of the frontage, where there has been a recent erosional trend.

To the east of Minehead, Futurecoast (Halcrow, 2002) predicted that there would be landward migration of the gravel storm ridge, and narrowing and lowering of the ridge crest, which would result from the combination of rising sea levels and insufficient input of new sediment from erosion of cliffs to the west.

Breaching of the ridge during storm events would most likely occur first along the western Dunster Beach where it is relatively more degraded compared to the beach in the eastern part of the bay. However, a breach in the western part of the bay would inhibit transport of sediment to the beach in the eastern part of the bay, which in turn would be likely to increase erosion of beaches towards Blue Anchor. Futurecoast (Halcrow, 2002) suggests that the greatest pressure will, however, occur at Warren Point due to the more prominent position of this feature along the shoreline. Rollback of the ridge in this area will occur due to overtopping and breaching, which in turn would result in the re-creation of tidal marshes behind a mud/sand foreshore.

However, Black & Veatch (2006a; 2009) suggested that the sand dunes that back the ridge in this area would be likely to prevent breaching of the ridge from causing the complete breakdown of the barrier. Based on an estimated erosion rate of around 0.5m/year, Black & Veatch (2009) estimated that it would take approximately five years to erode through the existing crest at its weakest point, but that overtopping would occur before this time, although this would not cause flooding to properties. The study did note, however, that should a breach occur, there would be a risk to four properties at the golf course and clubhouse.

At Dunster Beach, Black & Veatch (2009) predicted that there would be landward migration of the high water mark with sea level rise, resulting in a continued narrowing and lowering of the beach foreshore. This could have an impact on the existing defences, as larger waves will reach the defences on a more frequent basis. Black & Veatch (2009) predicted that the first breach would occur at the southern end of Minehead Golf Course and that hinterland flooding would affect a large number of properties. Black & Veatch (2009) also identified that the presence of a palaeochannel could rapidly convey flood water from an overtopping or breach in the defences all the way to Minehead.

The Futurecoast (Halcrow, 2002) prediction for a 'with present management' scenario is for the continued maintenance of the Minehead Harbour breakwater arm to continue to limit the natural supply of sediment from the cliffs to the west to the beaches to the east by littoral drift processes. The beaches to the east of this structure in Minehead and Blue Anchor Bay would therefore become increasingly dependent upon beach management activities and beach recharging to maintain the integrity of the defence function of the shoreline to reduce the risk of flooding of the extensive low-lying hinterland. In areas where there are no hard structures, the ridge would be subject to roll-back and breaching during storm events, though intervention would restore these and so limit the extent of flooding that is caused. The continued presence of defences along Minehead and Blue Anchor prevents the natural retreat of the shoreline and may also serve to interrupt longshore sediment transport.

In their recent Warren Point to Dunster Beach Coastal Defence Study, Black & Veatch (2009) suggested that if coastal defences remain fixed in position, narrowing of the intertidal zone could also occur as sea levels rise, increasing the amount of wave energy that reaches the defences.

LOCAL SCALE: Blue Anchor to St Audrie's Bay

Interactions

This is a pre-dominantly cliffed section of coast with the cliffs incised into Triassic shales and limestones and Jurassic mudstones. Towards the eastern end of this section, the cliffs are covered in parts by Quaternary head deposits, these are glacial deposits which typically consist of coarse rock fragments contained within a sandy-clay matrix. Near vertical cliffs are present towards Blue Anchor Point, where they give way to higher cliffs that are affected by frequent, but small, landslips occurring when the cliffs become unstable due to the local geology (see explanation in 'Movement' below). The cliffs then decrease in height towards Watchet.

This section is fronted by wide intertidal rock platforms that are covered by varying amounts of mud, sand and gravel. These platforms vary in width from 120m to over 500m (May, 2003b). The geology of the bedrock along this section forms the dominant control on shoreline evolution along this frontage (Halcrow, 2002).

The mudstone forms cliffs and intertidal platforms at Blue Anchor, Watchet and St Audrie's Bay. Erosion of this relatively softer bedrock has resulted in the development of small embayments as well as providing a source of sediment to the foreshore. In St Audrie's Bay, the cliff is fronted by a steep sand/gravel beach. The more resistant shale and limestone cliffs are typically fronted by narrow storm ridges comprised of limestone pebbles at the base of the cliff. Erosion of the cliffs topped by Quaternary head deposits between Watchet and Doniford provide a source of sandier sediment to the foreshore in this area (Halcrow, 2002).

The sediment from the erosion of the cliffs along this section is subject to longshore transport from west to east driven by wave action. However, due to the indented nature of this coast, sediment is typically trapped within individual embayments and so this littoral drift is mostly constrained to being a re-distribution of sediment within each embayment (Halcrow, 2002).

Movement

The bedrock along this section is extensively folded and faulted, and as such landslips are common within the shale and limestone cliffs, such as at Grey Rock near Watchet. Geological fractures in the cliffs at Watchet are the main reason for cliff failure – at the Watchet Fault there can be up to 400m of shift, and large rock slides are common at Daw's Castle (information provided during SMP consultation). The amount of recession along this section of coast is also affected by human intervention. Located within the cliffs at Watchet are seams and nodules of white gypsums, also called Alabaster. Alabaster was formerly taken by boat to Bristol to make Plaster-of Paris in the Victorian years, however, this process continues on a much smaller scale, with the material being used by local artists to create sculpture and household objects, such as ash trays (information provided during SMP consultation). Between Blue Anchor and the western side of Watchet the cliffs are undefended. The cliffs here recede as a result of cliff fall events, with a recent large cliff fall having occurred at Grey Rock in 1995. Typically, these cliffs are prone to events with a frequency of between 10 and 100 years, resulting in 10m to 50m of cliff top recession in any one event (Halcrow, 2002). A more recent event occurred in 2006, causing the loss of part of the play area of the Blue Anchor Hotel. This was associated with the loss of stone gabions at the base of the cliff which has resulted in the cliff toe becoming exposed to wave action (Corns, 2006).

There are a wide range of structures between Watchet and Doniford that encompass Helwell Bay and reduce the rate of erosion of the cliffs locally. Despite this, cliff recession does occur, albeit at a lower rate compared to the adjacent coast. Recession along this section is as a result of debris flows and rotational slides within the head deposits, with a notable event having occurred in 1978 in Helwell Bay. Cliff recession events in this area typically occur with a frequency of between 1 and 10 years, resulting in less than 10m of cliff top recession in any one event (Halcrow, 2002).

The cliffs in the eastern part of this section in St Audrie's Bay are also unprotected and retreat as a result of large scale debris sliding that cause the retreat of less than 10m of cliff top recession in any one event, with events typically occurring at a frequency of between 1 and 10 years (Halcrow, 2002).

Existing Predictions of Shoreline Evolution

For an 'unconstrained' scenario, Futurecoast (Halcrow, 2002) predicted that the future evolution of this section of coast would continue to be controlled by the geology of the bedrock. This would involve ongoing recession at rates similar to those observed historically, although rates could increase in the area from Watchet to St Audrie's Bay over the next 100 years. This could result in deeper embayments forming in this area bounded by more pronounced headlands of more resistant limestone and shales. The lack of defences at Watchet would result in inundation by the sea of the low-lying area of land here, although a tidal inlet is unlikely to form due to the steeply rising topography inland. The beach would be expected to retreat in line with the backing cliffs which would provide continued sediment inputs to the foreshore to enable this to remain stable. The extensive intertidal rock platforms would continue to provide protection to the backing cliffs. A 'moderate' rate of retreat (10 to 50m) was therefore predicted for the next century.

The Futurecoast (Halcrow, 2002) prediction for a 'with present management' scenario is for the undefended parts of this section of coast to respond largely as for the unconstrained scenario. Where defences are maintained between at Watchet and Doniford, these areas are likely to become more prominent features along the shoreline as adjacent cliffs erode back. However it is unlikely that these would become large enough over the next 100 years to significantly interrupt the natural west to east littoral drift of sediment.

SMP1 (Halcrow, 1998) predicted that rates of erosion would vary along this frontage, due to differences in the cliff geology. Between Blue Anchor and Watchet a rate of 0.5 to 1.0m/year was predicted, with higher rates predicted for between Watchet and Doniford of more than 1m/year. Within St Audrie's Bay the SMP1 concluded that the cliffs are relatively more stable, although retreat of up to 0.5m/year was predicted.

LOCAL SCALE: St Audrie's Bay to Hinkley Point

Interactions

This section of coast is comprised of low cliffs formed from Triassic shales and limestones, which are typically fronted by a narrow gravel storm ridge and an intertidal rock platform that is up to 500m wide in places. Much of the cliff is near-vertical. Between Lilstock and Hinkley Point, in the eastern part of this section, the intertidal area is comprised of extensive mud and sand flats that lie within an embayment that has developed as a result of differential erosion of the softer mudstone bedrock (Halcrow, 2002).

The low cliffs are interrupted by small areas of lower land at Kilve Point and Lilstock, which are fronted by gravel storm ridges. Despite the natural protection afforded by the ridges, these areas are still at risk from flooding during extreme events, with defences having been constructed at Lilstock in the 1960s to reduce the flood risk (Jacobs Babtie, 2005).

This section of coast is more exposed to wave action, compared to the coast further west, due to its orientation relative to prevailing waves. At Kilve Point waves propagating from the North Atlantic are comparable in size to locally generated waves, whereas locally generated waves are more dominant at Lilstock. Wave-induced currents result in a west to east longshore sediment transport regime towards Hinkley Point. Tidal currents are also significant here, with an east to west transport of sand occurring close to the shore along this section. Where these two opposing transport regimes (eastward wave currents versus westward tidal currents) meet at Lilstock, offshore transport of sediment occurs (Halcrow, 2002). This site also shows a stronger relationship between the coastal morphology and the prevailing direction of wave attack; in both the alignment of the shingle beach on the eastern side of St Audrie's Bay and in the alignment of the cliffs to the north-east of Kilve Pill (May, 2003b).

Movement

The majority of this section is comprised of undefended cliffs that are subject to recession primarily as a result of debris flows or rotational slides. The rate of recession is very low due to the resistant nature of the geology, with little change having occurred in the cliff top position over the past century. May (2007) noted that there have been very few measurements of cliff recession and that the retreat is far from uniform, with little change apparent at some locations, whilst at others up to 1.2m/year can be observed. May (2007) proposed that the most active parts of the cliffs coincide with more exposed locations in terms of wave attack, for example to the west of Lilstock. From an appraisal of the cliffs, Futurecoast (Halcrow, 2002) proposed that between Quantoxhead and Hinckley Point cliff recession typically occurs at a frequency of between 1 and 10 years, resulting in less than 10m of cliff top recession in any one event.

Within the embayment to the east of Lilstock, the position of the mean low water mark appears to have moved landwards (from analysis of Historical Ordnance Survey maps) suggesting that the foreshore in this area is steepening (Halcrow, 2002).

At Hinkley Point, there has been land reclamation as part of the Power Station development, with the current shoreline position now over 100m seaward of the shoreline position in the 1880s.

Existing Predictions of Shoreline Evolution

For an 'unconstrained' scenario, Futurecoast (Halcrow, 2002) predicted that cliff recession would continue to occur only very slowly in the future, at rates similar to those that have occurred historically. These continued low rates of cliff recession would occur due to the resistant nature of the geology as well as the protection afforded to the base of the cliff by the wide intertidal rock platforms along this section. These low rates of cliff recession will provide only small amounts of sediment to the foreshore, although it would be expected that this input will be sufficient to allow the foreshore to remain stable as it retreats in response to rising sea levels. 'Negligible/no change' (less than 10m over the next century) in cliff position was therefore predicted.

The gravel storm ridges at Kilve Point and Lilstock would roll back naturally onto the small areas of low-lying land that they protect. Breaching of these barriers would also be likely to occur during storm events resulting in flooding of the low-lying land behind. However, Futurecoast proposed that sediment supply by longshore drift from the erosion of cliffs further to the west could eventually re-seal the breach. As a whole the shoreline was therefore predicted to remain generally stable.

The Futurecoast (Halcrow, 2002) prediction for a 'with present management' scenario is for this scenario to be largely the same as the unconstrained scenario as this is a largely undefended, natural shoreline. The exception being at Lilstock, where continued maintenance of defences would reduce the risk of flooding to the low-lying land behind the beach. As the defence line is provided to the rear of the gravel storm ridge, Futurecoast concluded that this is unlikely to have a significant impact upon the behaviour of this frontage, although it may constrain the ability of the gravel storm ridge to roll back landwards as sea levels rise in the future.

C.1.11 Hinkley Point to Brean Down

LARGE SCALE

Interactions

This section comprises the north and west facing shorelines of Bridgwater Bay and incorporates the Parrett Estuary. It is bounded by two cliffed headlands, Hinkley Point in the west, which is comprised of Jurassic lias cliffs, and Brean Down in the north, which is comprised of Carboniferous limestone. These headlands, along with intertidal rock platforms at Hinkley Point and Stolford, are geological hard points within an otherwise soft geological area, and so provide important controls upon the evolution of the bay. Brean Down is a significant barrier to the exchange of littoral sediment with the coast to the north in Weston Bay, whilst sediment can be moved around Hinkley Point (Halcrow, 2002). This section also fronts the extensive low-lying area of the Somerset Levels.

Bridgwater Bay was formed during the Holocene marine transgression when marine and estuarine sediments infilled the broad Pleistocene valley of the Brue and Parrett rivers as sea levels rose to about their present level around 4,000 years BP (Halcrow, 2002).

Offshore of Brean Down is the island of Steep Holm, which sits in the middle of the Bristol Channel. This is comprised of Carboniferous limestone and was once part of a limestone ridge that would have been attached to the mainland at Brean Down (see also Section C.1.11). This demonstrates that the long term processes of erosion have in the past eroded through this limestone ridge and this is something that could happen in the future at Brean Down, most likely at the thinnest point where the headland attaches to the mainland, to eventually link Bridgwater and Weston Bays with Brean Down itself becoming an island. This is unlikely to occur permanently during the next 100 years, although there is a risk that a temporary breach through to the River Axe could occur towards the end of the 100 year period considered by the SMP, if a large storm event occurred, though this would be expected to re-seal naturally within these timescales (Halcrow, 2002).

Bridgwater Bay itself is a sink for fine sediment, and a thick layer of mud (the Bridgwater Bay mudbelt) has accreted here, with sediment derived from a range of sources including re-working of intertidal muds, fluvial inputs from rivers discharging into the bay, and mud from cliff erosion to the west that has been transported around Hinkley Point. An exchange of mud occurs between the intertidal and offshore sections of the mudbelt, with erosion of intertidal areas putting mud into suspension which is then transported offshore to be deposited on the seaward face of the mudbelt (Halcrow, 1998).

This section of coast is exposed to both open-ocean and local waves from the west and north-west. Offshore of Bridgwater Bay is Culver Sand, a sandbank that is thought to reduce the incident wave energy at the coast, especially for waves from the north and north-west because of its own east-west orientation (Halcrow, 2002), The asymmetry of sand waves that cover part of Culver Sand indicate a westwards direction of transport of the bank which is supportive of evidence of the migration of the bank in this direction into deeper water; the occurrence of this westward migration, combined with a low bank crest level, means that the protection it provides to the coast against wave attack is minimal (HR Wallingford, 2002).

Due to the different orientations of the coast along this section, the wave induced sediment transport generated occurs in different directions. Along the west facing coast, to the north of the Parrett Estuary, sediment transport is generally from north to south towards the mouth of the estuary. Along the north facing coast from Hinkley Point to the Parrett Estuary, sediment transport is generally from west to east towards the mouth of the estuary (Black & Veatch, 2008).

These two shoreline sediment transport directions form part of two circulation cells that occur within Bridgwater Bay, with offshore transport of sediment occurring in the vicinity of the mouth of the Parrett Estuary and sediment returning to shore in the vicinity of Hinkley Point and Brean Down (Black & Veatch, 2008). Gore Sand may act as a transport pathway for sand sediment between the intertidal and offshore zones, aided by ebb flows along the Parrett Estuary channel that are strong enough to enable seaward sediment transport (Halcrow, 2002).

A key influence on the sediment transport that occurs within Bridgwater Bay is the Parrett Estuary, which can be described as a prograding sedimentary environment with deltaic characteristics. The location of the mouth of the estuary is particularly important for the long term stability of the adjacent shoreline, and has often altered its position in the past. Over recent centuries the Parrett channel has taken a more northerly route, and this is currently influenced by the presence of Steart Point along the western edge of the estuary mouth (Halcrow, 2002). However, borehole evidence suggests that the mouth of the Parrett once existed much further west in the low area of Wall Common between Steart and Stolford (Ravensrodd, 1996; cited in Black & Veatch, 2008).

Movement

Whilst the headlands of Hinkley Point and Brean Down are composed of hard geology and have therefore experienced little cliff recession over the long term, there have been significant changes in the morphology of Bridgwater Bay, which have resulted from changes in the tidal discharge of the Parrett Estuary; tidal flows within the Bristol Channel; and the net eastward drift of sediment (Environment Agency, 2009).

In the northern part of the Bay, the shoreline along the southern side of the headland at Brean Down is thought to have retreated to its present position over the past 3,000 years, with dunes migrating eastward in line with this shoreline retreat (Halcrow, 2002). It is thought likely that this recession would occur much more rapidly if it were not for the wide area of intertidal mudbelt within Bridgwater Bay and the wide beach at Berrow Flats that limit the impact and frequency of storm events that cause recession from reaching the shoreline (Black & Veatch, 2008).

The mouth of the Parrett has also migrated towards Burnham-on-Sea due to the eastward movement of sand and shingle along the upper shore (Environment Agency, 2009). This report also identified that the outer estuary and tidal delta has moved westwards due to both a reduction in flow due to a decrease in the tidal prism of the Parrett Estuary and the strong ebb-dominant tidal flow in the Bristol Channel.

Modifications

Human modification of the coast along this section has occurred in several areas, notably around the large developed areas of Burnham-on-Sea, Bridgwater (within the Parrett Estuary) and at Hinkley Point to protect the nuclear power station that is situated here.

Defence of the low cliffs at Hinkley Point (and the coast further to the west) has resulted in a reduction in cliff recession locally but also has reduced the alongshore supply of sediment to the gravel ridges to the east. This reduction in sediment supply has contributed to the diminishing ability of the gravel ridges to provide flood protection to the low-lying land behind which is below the annual flood level (i.e. below the level of the highest tide of the year) (Halcrow, 2002; Babtie Brown & Root, 2002).

Human intervention has therefore been undertaken along these gravel ridges between Stolford and Steart Point in order to enhance flood protection. This has been in the form of an earth embankment between Stolford and Wall Common, with additional gabions installed at Wall Common. However, in introducing defences here, it has constrained the natural tendency of the gravel ridges to migrate landwards (Halcrow, 2002). These defences are unsustainable and so currently only maintained to a minimum standard whilst a policy of Managed Realignment is being developed (Babtie Brown & Root, 2002).

Along the west facing coast of this section, defences located at Burnham-on-Sea have been present since the early part of the 20th century, and include a wave return wall, masonry seawall, concrete revetment and gabions. The wall extends south to the River Brue, beyond which embankments extend along the full length of the Parrett Estuary to the flood wall defences in Bridgwater town centre. There is also a rock revetment that extends immediately southwards from Brean Down, with an older seawall that extends for a further kilometre south of this. The purpose of all of these defences is to protect low-lying land behind from flooding, although flood events have occurred in the past, with flood events in 1981 and 1990 during storms causing overtopping and breaching of the defences along the Burnham-on-Sea to Brean frontage (Halcrow, 2002; Black & Veatch, 2008).

Embankments within the Parrett Estuary date back to the 14th century, with the first reclamations of the Somerset Levels and Moors, although historically, periodic flooding was probably accepted and prior to the 1970s the raised tidal embankments were traditionally maintained at a level consistent with the previous highest flood event, with no freeboard (Environment Agency, 2006). In the early 1970s embankments on both banks of the River Parrett (from Bridgwater t the mouth of the estuary) and a short distance up both banks of the Brue Pill were improved. Following a storm surge event in 1981, further schemes were implemented to improve flood protection (Environment Agency, 2006).

LOCAL SCALE: Hinkley Point to River Parrett

Interactions

A complex of mixed sand and gravel ridges has developed between Stolford and Wall Common, passing eastwards into a shingle ridge between Wall Common and Steart Point. These mixed sand and gravel ridges, which are fronted by salt-marsh and intertidal mud and sand flats, are comprised of a series of variable height ridges made up mostly of limestone derived from the erosion of lias cliffs between Lilstock and Stolford to the west, although some sand is also derived from erosion of head deposits. Sediment transport along these ridges is driven by wave-induced currents. Sediment transport is from west to east between Stolford and Wall Common, as evidenced by the form of the gravel ridges, though the currents reduce in strength and so sediment transport further east is negligible (Halcrow, 2002). In typical conditions the transport of gravel along the ridges occurs along the beach face. As the tide level rises and exceeds the beach crest level, overwashing occurs and transport becomes more cross-shore with overwash deposits resulting on the landward side of the ridge (White, 2009).

A review of historic Ordnance Survey mapping, undertaken as part of this SMP, confirms the longer term eastward movement of sediment along this section towards the mouth of the estuary, with Fenning Island having once been detached from what is presently the Steart Peninsula. This joining of Fenning Island to the Steart Peninsula is also related to the migration northwards of the mouth of the Parrett and the River Parrett channel.

Movement

The gravel ridge system along this shoreline is experiencing overall retreat due to insufficient input of new sediment from further west, which is needed to sustain the ridge system in the long term (Halcrow, 2002). Review of recent beach profile data at Steart as part of this SMP, suggests that the beach has changed very little over the past five years, although a slight trend of erosion is observed. Some steepening of the beach also occurred over this period.

The salt marsh that fronts this section has experienced long term erosion since the 1960s with sediment generally being lost from the Steart area as a whole (Long *et al*, 2002).

Existing Predictions of Shoreline Evolution

For an 'unconstrained' scenario, Futurecoast (Halcrow, 2002) predicted that there would be an overall 'high' (50 to 100m) retreat of the shoreline along this section over the next 100 years. At Hinkley Point and Stolford, the lack of defences would result in the shoreline retreating to a less exposed alignment, although the rock platforms fronting these areas would continue to provide some protection. The low-lying area between Hinkley Point and Stolford would, due to its low-level, be likely to experience breaching and inundation of the hinterland during storm events over the next 100 years, with these breaches becoming permanent if there is insufficient sediment supply. If a permanent breach were to develop between Hinkley Point and Stolford, then a tidal inlet would become established which would alter sediment transport patterns in this area.

Between Stolford and Steart, landward migration of the gravel ridges and backing salt marsh would occur in response to rising sea levels. Low sediment supply could result in narrowing of the ridges and an increased risk of breaching and inundation of the extensive area of low-lying hinterland during storm events; any breach could become permanent if there were insufficient sediment available to re-seal it. This would result in the stability of the adjacent sections of gravel ridge being reduced and sediment being drawn into the newly formed tidal inlet as part of an ebb and flood tidal delta system.

Futurecoast (Halcrow, 2002) also identified that it is possible that the Parrett Estuary channel could alter course over the next 100 years, with the channel potentially breaking through the Steart Peninsula. If this were to occur, then the hydrodynamic and sedimentary regime of the entire area would be significantly altered, although there is a good deal of uncertainty as to what the impact of such changes would be, either for this section or the section to the north between Burnham-on-Sea and Brean Down.

The Futurecoast (Halcrow, 2002) prediction for a 'with present management' scenario is for the continued defence of Hinkley Point to result in this headland becoming even more of a promontory along the shoreline as the adjacent sections of coast slowly retreat over the next 100 years. The growth of this headland would further restrict the amount of sediment reaching this frontage from further west. Defences and maintenance of the gravel ridges along this section would continue to provide protection against inundation of the backing low-lying land during storm events, although with a reduction of natural sediment input from the west, this would become increasingly more difficult to achieve without beach recharge. The continued maintenance of the gravel ridges would also prevent natural roll back of the ridges and fronting salt marsh, resulting in the steepening and narrowing of the foreshore and coastal squeeze of the salt marsh.

SMP1 (Halcrow, 1998) predicted that under 'do nothing', tidal inundation of large areas would occur within the next 50 years and probably within the next 10 years if 'significant return period' storms are experienced.

LOCAL SCALE: River Parrett

Interactions

The Parrett Estuary is a filled river valley type estuary that is almost full to capacity with sediment and, without alteration to the estuary extent (i.e. removal of defences in some parts) is only likely to be a weak sink for mud in the future (Halcrow, 2002). It is a strongly flood-dominant estuary (Environment Agency, 2009). The estuary mouth opens to extensive tidal mudflats and sand banks in Bridgwater Bay, but is constrained along its western side by the presence of the Steart Peninsula. There is a large ebb-tidal delta, known as Steart Flats, which is composed of intertidal muds.

Within the estuary, the meandering channel is narrow and muddy, and is constrained in its ability to adjust by flood defences that have been constructed along its entire length. Very large areas of former marshes have also been reclaimed over the centuries, whilst existing intertidal areas are steep and narrow (Halcrow, 2002).

The estuary is tidal for about 25km inland from the sea to Oath Sluice (Sedgemoor District Council, 2008), and flood-dominated during periods of low fluvial flow, but reverts to a river at low water springs (Halcrow, 2002). Along this length is the town of Bridgwater where raised defences protect around 11,000 homes from tidal flooding (Black & Veatch, 2006c), although there is still a risk of tidal flooding under a 1:200 year event even with these defences in place (Sedgemoor District Council, 2008).

The main Parrett Estuary is also fed by discharge from the River Brue at Highbridge and via the Huntspill River. The Huntspill River is a man-made channel that controls drainage of the lower Brue catchment into the Parrett Estuary via a controlled sluice structure. These sluice gates on the River Brue at New Clyce Bridge control the risk of flooding upstream (Sedgemoor District Council, 2008). There is however still a risk of sea flooding to this area from overtopping and/or undermining of the defences along Brue Pill (to the south of Burnham-on-Sea to the Huntspill River) that could result in breaching of the defences and extensive flooding of the low-lying land in this area (Jacobs Babtie, 2006).

Movement

As the estuary has infilled there has been a reduction in the tidal prism and the delta extent has reduced, resulting in a landward migration of the delta front.

The mouth and channel of the Parrett Estuary has migrated significantly in the past as a result of changes in flow and sediment movements (Halcrow, 2002; Environment Agency, 2009). There has also been extensive erosion of the upper intertidal area of the Steart Flats over the past 70 years, with a vertical decrease of 3m reported over this period (Black & Veatch, 2008).

According to regime analysis, the present morphology of the estuary is mostly stable, although some parts of the estuary are experiencing erosion or deposition (Black & Veatch, 2006b; Environment Agency, 2009). Environment Agency (2009) stated that analysis of LiDAR data showed that there is considerable instability in the route of the low water channel within the Parrett Estuary.

Existing Predictions of Shoreline Evolution

For an 'unconstrained' scenario, Futurecoast (Halcrow, 2002) predicted that there is a possibility that the Parrett Estuary channel could alter course over the next 100 years, and this could possibly result in the channel breaking through the Steart Peninsula. If this were to occur, then the hydrodynamic and sedimentary regime of the entire area would be significantly altered.

Black & Veatch (2006b) recognised that there is uncertainty about the future sediment supply to this coast which would have a significant impact upon the stability of the current estuary regime, particularly the Parrett Estuary channel and the salt marshes, dunes and mudflats within the estuary, and indeed the wider Bridgwater Bay.

Pethick (2002) (cited in Environment Agency, 2009) proposed that sea level rise would result in an increase in the tidal prism of the Parrett Estuary, causing the outer low water channel (to the north of Steart Point) to swing clockwise, while the inner channel (south of Steart Point) would swing anti-clockwise. This movement would have significant implications for the coastline around Burnham Beach.

The Flood Risk Management Strategy Report for the Parrett (Environment Agency, 2009) looked at the potential impact of sea level rise. Assuming the current defences remain, this study concluded, from regime analysis, that sea level will would have a 'marginal' impact on the existing estuarine regime, with sediment deposition in the lower reach as a result of higher water levels, an increase in tidal prism and an increase in tidal flow. The study also looked at the impact of realignment options. In general, it concluded that for all the options considered, the estuary would remain a strongly flood-dominant estuary, but the impact of ebb flow could increase. The largest realignment option considered, along the west bank at Cannington, was found to have a potential impact on the adjacent coastline as the increased tidal flow could result in a anti-clockwise swing of the inner channel, which would increase the rate of erosion along Stert Island. This, in turn, could increase the vulnerability of the beach at Burnham-on-Sea to erosion.

The Futurecoast (Halcrow, 2002) prediction for a 'with present management' scenario is for the continued presence of defences within the estuary to continue to constrain the river channel, resulting in increased pressures on parts of the estuary to erode, with narrowing and loss of intertidal areas resulting. However, this would be dependent upon the wider evolution of the estuary.

LOCAL SCALE: River Parrett to Brean Down

Interactions

This section of coast extends north from the mouth of the Parrett Estuary to the hard, cliffed headland of Brean Down. Onshore winds have resulted in the development of a series of longitudinal dunes that extend along this shoreline for about 8km from the northern end of Burnham-on-Sea to almost Brean Down, ending about 1.4km south of Brean Down where they are replaced by rock revetment defences. These dunes are characterised by a series of ridges, some up to 450m wide and up to 10m high, that, together with man-made defences, help to protect the low-lying Somerset Levels from flooding (Black & Veatch, 2008; Halcrow, 2002). This low-land area is, however, also at risk of backdoor flooding from the left bank of the Axe Estuary that discharges to the north into Weston Bay (Black & Veatch, 2008). These dunes are narrow at the northern and southern ends, widening in the central part around Berrow.

The dunes are fronted by a sandy upper foreshore that changes abruptly to mud to seaward; and the intertidal Berrow mudflats extend for some 4km offshore of Berrow (Halcrow, 2002).

Offshore of Burnham-on-Sea, the intertidal mudflats are dissected at low water by the Parrett Estuary channel, the seaward limit of which is marked by the sandbank at Gore Sand. Currently this low water channel runs to the south of Gore Sand, although this position is not fixed and could change in the future.

The width of these mudflats helps to reduce the incident wave energy that reaches the shoreline, which is reduced by Culver Sand; a sand bank which lies further offshore. Culver Sand is migrating into deeper water and therefore its influence is likely to reduce in the future; should this occur the shoreline between Burnham-on-Sea and Brean Down would experience higher wave energy events and would be at risk from greater erosion and potential longshore sediment transport than observed historically (Halcrow, 2002).

Black & Veatch (2008) identified two principal sediment circulations associated with the Parrett Estuary: the first is along Berrow Flats, where shoreline transport is moved by short-period waves from north to south, but nearshore transport is south to north, due to long-period waves, i.e. a clockwise circulation. The second circulation is counter-clockwise, along Steart Flats, driven by a combination of ebb currents from the Parrett and westerly waves along the coast. Due to the Berrow Flats sediment circulation, any change in the pattern of erosion and accretion along Berrow Flats could have significant consequences for the beach at Burnham.

This coast is west facing and therefore exposed to westerly and north-westerly waves. Waves from the west result in the largest waves at the coast that therefore are believed to be responsible for erosion of the dune face, with a strong relationship identified between periods of westerly wave action and erosional phases (Black & Veatch, 2008).

Movement

The shoreline along this section has experienced complex changes over the past century, although there has an overall trend for shoreline retreat and foreshore steepening.

At Burnham-on-Sea, historical maps indicate little change in shoreline position since the earliest maps, dating from around 1802 (Black & Veatch, 2008). The Bridgwater to Burnham-on-Sea Flood Management report (Environment Agency, 2006) noted, however, that there has been concern that the beach level of the beach at Burnham-on-Sea has dropped, with debris from the construction of the seawall during the 1980s becoming exposed. This study did however, conclude that there was insufficient trend data to confirm whether or not beach level have actually been dropping.

Historically there has been slight erosion of the shoreline and dune ridge around Berrow; estimated to be at an average rate of between 0.4 to 0.8m/year (Black & Veatch, 2008). Black & Veatch (2008) also concluded that in the area around Berrow, the beach is narrowing and lowering at a rate of about 0.6m/year and reported that residents have stated that along north Burnham and Berrow dune erosion has been around 0.5m/year.

The area around Berrow Marshes is more complex. It was formerly an intertidal area, backed by high, well developed dunes, and connected to the sea by a series of creeks. These marshes formed as a result of shoreline accretion, of around 275m, which occurred in the early 20th century. Since the 1960s the marshes have become disconnected from the sea due to the development of a series of fore dunes. These fore dunes formed after 1967 and have advanced seaward at a rate of between 3 and 5m/year. Black & Veatch (2008) found, however, that since 2001 this pattern of accretion has reversed and now there is evidence of erosion and landward migration of the shoreline at a rate of around 2m/year. The dunes are also subject to frequent overtopping and breaching during storm events. The higher, older dunes that back this area do, however, maintain flood protection to the extensive area of low-lying land behind (Black & Veatch, 2008; Halcrow, 2002).

Review of recent beach profile data as part of this SMP suggests that the shoreline along this section is retreating at an annual average rate of between 0.07 and 0.2m/year, supporting the findings of Black & Veatch (2008) and that the foreshore is continuing to both steepen and lower, particularly towards Brean.

Futurecoast (Halcrow, 2002) suggests that typically cliff failure events at Brean Down could occur with at frequency of between 10 and 100 years, resulting in less than 10m of cliff top recession in any one event.

Existing Predictions of Shoreline Evolution

The future evolution of this entire section of coast is highly dependent upon the future evolution of the mouth of the Parrett Estuary and the estuary channel alignment and also changes to adjacent stretches of coast (Halcrow, 2002; Black & Veatch, 2008), all of which could affect sediment transport patterns along this section of coast. Currently the low water channel of the Parrett Estuary runs to the south of Gore Sand, although if this position were to move to the north of Gore Sand as part of a clockwise rotation in the channel position, then this would result in significant erosion of the Burnham-on-Sea beach and Huntspill foreshore such that the coastal defences along these areas could fail by 2028 (Halcrow, 2009; Atkins, 2009).

For an 'unconstrained' scenario, Futurecoast (Halcrow, 2002) predicted that the coast at Burnham could be susceptible to erosion and inundation of the low-lying land in this area and that ultimately, this could result in a new coastal alignment with a new shoreline forming some distance inland, where higher ground is present. The study did however that whilst this was dependent upon the future evolution of the Parrett Estuary, it would be unlikely over the next century. SMP1 (Halcrow, 1998) also suggested that falling foreshore levels at Burnham could result in loss of frontage assets within the timeframe of SMP1 (50 years) under a 'do nothing' scenario. Assuming defences did remain, the Futurecoast (Halcrow, 2002) prediction for a 'with present management' scenario is for lowering of the foreshore to be exacerbated by the defences as they limit the ability of the beach here to adapt naturally. This, in turn, would lead to greater exposure of the defences to storm waves and so greater armouring of them would likely to be required, although they would continue to protect the low-lying land behind from eroding.

Along the Berrow frontage, Futurecoast suggested that there would be continued erosion of the dunes, with resultant re-distribution of sediment to the adjacent shoreline. A breach in the dunes was considered unlikely over the next 100 years, and this was also predicted by SMP1 (Halcrow, 1998). Black & Veatch (2008) also concluded that whilst there was a risk of breach along the frontal dunes during a 1:5 year flood event or less at Berrow, due to the low crest and severe erosion experienced near Berrow Marsh, the coastal belt behind would be sufficient to prevent large scale inundation.

Further north, where the dunes are narrower and eventually disappear, Futurecoast (Halcrow, 2002) predicted that there would be foreshore narrowing and lowering, and possibly even loss of the dune belt, making this part of the coast especially vulnerable to future erosion and flooding as a result of overtopping and breaching during storm events. A high retreat rate (50 to 100m over the next century) was predicted. The study also suggested that it is probable that, given rising sea levels, a breach in this area would occur in the next 100 years causing flooding of the low-lying land behind, although it is unlikely that this would become permanent due to erosion of adjacent dunes providing material to re-seal the breach.

Black & Veatch (2008) identified that between Brean Down and Brean a breach anywhere along the defences could result in a rapid and deep flooding of a larger hinterland area.

C.1.12 Brean Down to Anchor Head

LARGE SCALE

Interactions

This section encompasses the dune-backed embayment of Weston Bay between the two resistant headlands of Brean Down in the south and Anchor Head (also known as Worlebury Hill) in the north, and fronts a large lowland area that forms part of the Severn Levels. These headlands are comprised of Carboniferous limestone and act as strong geological controls on the evolution of Weston Bay, with the embayment formed in a depression in the underlying Triassic mudstone, which infilled with marine and estuarine sediments as sea levels rose to their present position during the Holocene.

A major source of fine-grained sediment within the Bay is the erosion of the upper intertidal zone, a trend observed along much of the shoreline of the outer Severn Estuary. The River Axe also discharges into the southern part of the Bay, providing additional (although very small) inputs of fine-grained sediment to the coast, which is likely deposited in salt marsh areas located around the mouth of the estuary. There is relatively little contemporary sediment input from cliff erosion due to the resistant nature of the geology. Any erosion that does occur is a result of marine action at the toe, and weathering of the cliff face.

The headland of Brean Down is part of a limestone ridge that once extended seaward to what is now the island of Steep Holm that lies offshore within the Bristol Channel. This headland forms a complete barrier to littoral transport of non-cohesive sediment from south to north, and broadly corresponds to the limit of the Bridgwater Bay mud deposits (refer to Section C.1.9). Although some suspended sediments are transported around Brean Down headland into Weston Bay and on to Sand Bay to the north (being also transported around Anchor Head), Weston Bay can be considered as a largely self-contained embayment.

Movement

Weston Bay is exposed to high swell wave activity from the west and this drives the littoral transport of sand within the embayment, which is related to the seasonal variations in wave activity rather than being driven by tidal currents (Halcrow, 2002). Sediment transport alongshore within Weston Bay appears to be from north to south, with beach levels fronting Weston-super-Mare being lower than those fronting the sand dunes in the southern part of the bay. Annual recycling of about 16,000m^3 of sand from south to north is undertaken to counter this effect. The central part of Weston Bay, between the pier and the southern end of Marine Parade, appears to be relatively stable by comparison (Black & Veatch, 2004).

The cliffs along the northern side of Brean Down headland (the southern side of Weston Bay) erode very slowly due to the resistant nature of the limestone from which it is formed. Futurecoast (Halcrow, 2002) suggests that cliff failure events at Brean Down could occur with a frequency of between 10 and 100 years, resulting in less than 10m of cliff top recession in any one event. This would be expected to continue to be the case in the future, although future sea level rise may lead to exposure and erosion of raised beach deposits that occur at a level of about 12 to 14mOD along this length in the longer term.

Modifications

Defences within Weston Bay are concentrated along the northern part of the bay and have been present, in some form for over a century, associated with the development of the town of Weston-super-Mare during the late 1800s as a popular tourism destination (Royal Haskoning, 2007). These defences provide both flood and coastal erosion protection, but have been associated with the trend of foreshore lowering and steepening observed within this northern part of the bay. This may be due to the defences maintaining the shoreline in a more seawards position than would be expected naturally. Annual beach recycling, which involves the transport sand from the dune area in the south of the bay back to the northern beach, is undertaken to address this trend of foreshore erosion (Futurecoast, 2002; Black & Veatch, 2004).

The current defences provide a variable standard of protection against flooding, with only about a 1:25 year standard north of the pier (i.e. defences would only withstand an event that statistically occurs once every 25 years; an event larger than this would begin to cause damage and flooding), and a 1:110 year standard to the south (Black & Veatch, 2004), although Royal Haskoning (2007) suggests this is much lower, suggesting a standard of between 1:5 and 1:10 along the frontage. The low standard of protection in the northern part of

Weston Bay has been demonstrated a number of times in the past, where storm waves combined with high water levels have resulted in overtopping of the defences and flooding of the low-lying parts of Weston-super-Mare behind. Recent flood events occurred in:

- 1981, when gale force westerly winds caused severe damage at Marine Lake (an artificial enclosure of Glenworth Bay) and seafront properties were flooded;
- 1990, when overtopping of defences led to flooding of the northern part of Weston-super-Mare; and
- 1996, when flooding of about 2 hectares of the town occurred, flooding around 50 properties and many roads within the town (Black & Veatch, 2004).

If the defences were not upgraded then flooding during high water level events would occur more frequently in the future, as a result of sea level rise which would result in the extreme 1:200 year still water level being higher than the defence crest level (Black & Veatch, 2004; Royal Haskoning, 2007). However, upgrading of the defences is currently ongoing along the Weston-super-Mare frontage, which once completed will minimise future flood risk through providing a standard of protection in excess of 1:200 (about 1:300), which will then reduce to a 1:200 standard over the 100 year scheme life (Royal Haskoning, 2007).

Around Anchor Head a seawall provides protection against localised cliff erosion.

There are very few defences along the southern part of the bay, where a largely natural dune system protects the low-lying land behind from marine inundation. The exception here is at Uphill, where defences have constrained the natural landward migration of the dune system and dune management activities are undertaken here to counter the effects of this (Halcrow, 2002).

A seawall extends south from Uphill into the Axe Estuary. The Axe Estuary itself has a long history of embanking associated with land reclamation activities. The Walborough realignment site was implemented in 2004 and involved improved flood defence, reduced flood defence costs and the creation of 3.5ha saltmarsh, 0.2ha of mud flats, and 0.2ha of saline lagoon. Tidal exchange is regulated into the area through the installation of gabion mattresses at two locations. The method of breach had the additional benefit of maintaining the existing footpaths (OMReG database). Along both sides of the estuary the height of the existing embankments were raised to provide flood protection to the large areas of low-lying land located behind the defences. These embankments extend all the way to the tidal limit of the estuary, which has moved downstream over the years as a result of sluicing upstream.

LOCAL SCALE: Brean Down to Anchor Head (Weston Bay)

Interactions

Due to the strong geological control exerted on the evolution of Weston Bay by the two resistant limestone headlands that bound it to the north and south, sediment transport is largely self-contained within the embayment and there is little interaction with adjacent shorelines, except for some limited transport of suspended sediments from Bridgwater Bay northwards up into the Severn Estuary.

The foreshore comprises a wide sandy beach that grades to mud on extensive tidal flats that reach some 2km offshore. This is backed in the southern part by a largely natural dune system that is migrating landwards. This in turn fronts an extensive lowland area that forms part of the Severn Levels which is linked beyond this to the Levels south of Brean Down by the flood plain of the River Axe.

Within the nearshore zone of the bay there is a net seaward movement of sand, with sediment eroded from the dune face in particular likely being re-deposited within the embayment. However, the closed nature of this system means it is unlikely that this sediment would be transported out of the bay (Halcrow, 2002; Royal Haskoning, 2007).

There is a net southward longshore drift of sand within Weston Bay, with beach levels in the north being artificially maintained by annual beach recycling of sand from the southern part of the bay, where it accumulates in front of the natural dune system. The amount of material recycled is reported to be around 16,000m^3/year (Black & Veatch, 2004).

Movement

The cliffed headlands at either end of Weston Bay are fronted by intertidal rock platforms. Along the northern side of Brean Down there appears to have been an increase in the extent of intertidal platform exposure, suggesting that the foreshore in this area has lowered over the past century, although the position of Mean High Water has changed little due to the resistant nature of the bedrock (Halcrow, 2002).

The resistant nature of the limestone bedrock that forms the cliffs along the southern part of the bay means there has been very low rates of recession observed historically, and Futurecoast (Halcrow, 2002) suggests that cliff failure events along this section could typically occur at a frequency of between 10 and 100 years, but would probably result in less than 10m of cliff top recession in any one event.

Historical maps indicate that there has been very little change along the Weston-super-Mare frontage; the shoreline here has remained fixed since construction of the promenade prior to the first maps of 1887. Minor changes can be observed for the rest of the shoreline; early maps suggest that dunes originally stretched as far north as Winter Gardens.

A review of recent beach survey data as part of this SMP suggests that the beach is generally stable, with a small amount of net accretion occurring at a rate of about 0.07m/year.

Existing Predictions of Shoreline Evolution

For an 'unconstrained' scenario, Futurecoast (Halcrow, 2002) predicted that the strong geological control exerted by the two resistant headlands of Brean Down and Anchor Head would continue to influence the broad scale configuration of Weston Bay by constraining the movement of sand out of the bay and providing a degree of stability to the bay that enables the ongoing existence of a swash-aligned shoreline between them. Rising sea levels would drive the retreat of the beaches eastwards over the backing low-lying land and the dune system in the southern part of the bay would be likely to breakdown due to a lack of sediment supply. A 'high' rate of change was predicted (50 to 100m over the next century). This would eventually lead to a breach of the dunes and extensive inundation of the lowland areas to both the north and south of the dunes, possibly even extending to the Levels south of Brean Down.

The headland cliffs were predicted to continue to erode very slowly as observed historically, although in the long term erosion through the narrowest part of Brean Down could link Weston Bay with Bridgwater Bay. This would leave Brean Down as an island and could result in the relocation of the mouth of the Axe Estuary.

The Futurecoast (Halcrow, 2002) prediction for a 'with present management' scenario is for the ongoing defence of Weston-super-Mare to prevent the permanent flooding of the lowland areas behind. However, this could lead to increased pressure on the defences during storm wave events in the long term as rising sea levels cause further narrowing and steepening of fronting beach levels. This continued defence of the northern part of the bay could also limit supply of sediment to the dune area in the southern part of the bay, making it increasingly difficult to sustain dune defences at Uphill which prevent the landward migration of the dunes.

From studies undertaken as part of the ongoing upgrading of defences along the Weston-super-Mare frontage, Royal Haskoning (2007) concluded that, although these defences would be expected to result in further lowering and narrowing of the fronting beach as sea levels rise, in terms of flood risk, the resulting deeper water at the seawall during high water level events would only serve to increase the significant wave height at the seawall by a few centimetres during storm wave events.

C.2 Defence Assessment

C.2.1 Overview

The Table below provides a summary of the existing defences along the SMP2 frontage together with an assessment of residual life. The information in this table is based upon the information that has been collected as part of the National Flood and Coastal Defence Database (NFCDD) update (Halcrow, May 2009), which Halcrow was commissioned by the Environment Agency to undertake in parallel to the development of the SMP2. This update involved surveying defence levels along the shoreline, noting the type of defence structures present and assessing the condition of the defences. It ensures that the most current information has been utilised in the development of this SMP2.

Additional information contained in both of the two first round SMPs for (1) Hartland Point to Brean Down, and (2) the Severn Estuary, has also been utilised to supplement the NFCDD update data in the appraisals of 'No Active Intervention' and 'With Present Management' presented in Sections C.4 and C.5 of this report, to cover areas of private defences or other non-coastal defence structures.

For all defences assessed the 'overall condition' and 'residual life' have been defined.

Overall condition is a description of the state of the defences and has appraised been using the Environment Agency's National Sea and River Defence Survey's Condition Assessment Manual (1998), which is summarised in Table C.2.1 below.

This condition assessment, along with the type of defence, has then been used to determine an estimate of when defences are most likely to fail under a 'no active intervention' scenario (i.e. in the short, medium or long term), using Table C.2.2 below as a guide. *Note, that the values in Table C.2.2 differ from those presented within the NFCDD summary table below due to different requirements on how this information is stored in the NFCDD.*

Rating	Condition	Description	Extent of Defect and Estimated Life
1	**Very Good**	Good condition. Fully serviceable. Maintenance to continue as present. No remedial work required.	No significant defect. Estimated life typically more than 30 years.
2	**Good**	In reasonable condition. Minor defects. Minor routine or increase in routine maintenance required.	Not more than 5% of area, length or height affected by defect. Estimated life typically 15 to 30 years.
3	**Fair**	Average Condition. Requires careful monitoring. Some minor repairs needed and significant improvements in maintenance.	Moderate defects affecting 5% to 20% of area, length, or height. Replacement typically likely within 5 to 15 years.
4	**Poor**	Some major repairs needed but not urgent. Structurally unsound now or in the near future.	Extensive defects affecting 20% to 50% of area, length or height. Replacement typically needed within the next 1 to 5 years.
5	**Very Poor**	Complete failure or derelict. Major urgent repairs or replacement without delay.	Severe and/or extensive defects over 50% of area, length or height. Replacement typically likely to be required within the next year.

Table C.2.1 Guide to assessing condition grade (based upon Environment Agency, 1998)

Defence Description	Estimate of residual life (years) under a no active intervention policy				
	Existing Defence Condition Grade:				
	Grade 1	**Grade 2**	**Grade 3**	**Grade 4**	**Grade 5**
Seawall (concrete/ masonry)	40 to 50	25 to 35	15 to 25	10 to 15	5 to 7
Revetment (rock)	40 to 50	25 to 35	15 to 25	10 to 15	5 to 7
Timber structures	20 to 30	15 to 25	10 to 20	8 to 12	2 to 7
Gabions	15 to 25	10 to 15	6 to 10	4 to 7	1 to 3

Table C.2.2 Guide to estimating residual life of defences

NFCDD Reference Number	Location	Primary Defence *(i.e. main defence line)*	Secondary (seaward) Defence *(e.g. additional defences that support the main defence line)*	Secondary (landward) Defence *(e.g. additional set-back flood bank behind main defence)*	Foreshore Type	Overall Condition	Residual Life (years)
NEW_ASSET_37_1	West of Prom, Westward Ho!	Concrete Seawall with Recurve	Rock Armour Revetment		beach - cobble	1	
113GCS7100601C01	Maritime Station Car Park, Westward Ho!	Concrete Seawall	Rock Armour		beach - mixed	3	6 - 10
113GCS7100302C04	Amusement Arcade, Westward Ho!	Concrete Seawall	Rock Armour		beach - cobble	2	>20
113GCS7100302C03	Amusement Arcade - Holiday Village, Westward Ho!	Masonry Seawall			beach - mixed	2	0
113GCS7100302C02	Holiday Village - Promenade, Westward Ho!	Complex Seawall	Concrete Apron		beach - cobble	3	0
113GCS7100302C01	Promenade, Westward Ho!	Concrete Seawall		Concrete Splash Wall	beach - cobble	3	11 - 20
113GCS7100901C01	Skern, Northam Burrows	Rock Armour Revetment			beach - sandy	2	>20
113GCS7100601C06	North End Northam Burrows, Appledore	Rock Armour Revetment			beach - cobble	2	>20
113GCS7101502C05	The Quay, Appledore	Concrete Quay Wall			beach - sandy	1	11 - 20
113GCS7101502C06	Churchfield Road Slipway, Appledore	Concrete Revetment			beach - sandy	2	>20
113GCS7101502C04	Churchfield Road Car Park, Appledore	Concrete Revetment			beach - mixed	1	11 - 20
113GCS7101502C03	Irsha Street - Slipway, Appledore	Complex Seawall			beach - mixed	2	11 - 20
113GCS7101502C01	Appledore, North	Masonry Seawall			shore platform	3	11 - 20
113GCS7101502C00	Jubilee Road, Appledore	Concrete Seawall			shore platform	3	11 - 20
113GCS7101201C05	Western Hill, Appledore	Concrete Seawall			shore platform	2	>20

NFCDD Reference Number	Location	Primary Defence *(i.e. main defence line)*	Secondary (seaward) Defence *(e.g. additional defences that support the main defence line)*	Secondary (landward) Defence *(e.g. additional set-back flood bank behind main defence)*	Foreshore Type	Overall Condition	Residual Life (years)
113GCS7101501C01	Marine Court, Instow	Concrete Seawall with Recurve			beach - sandy	1	11 - 20
113GCS7102701C03	Bath Terrace, Instow	Masonry Seawall			beach - sandy	2	>20
113GCS7103604C02	North Devon Cricket Ground, South, Instow	Masonry Seawall	Concrete Apron		beach - sandy	3	11 - 20
113GCS7103604C03	North Devon Cricket Ground, North, Instow	Earth Embankment	Rock Armoured Revetment	Masonry Wall	beach - gravel	2	11 - 20
113GCS7103604C05	West of Jetty, Instow Marsh Barton, Yelland	Earth Embankment	Rock Armoured Revetment		beach - sandy	2	>20
113GCS7103604C06	Instow Barton Marsh, Yelland	Earth Embankment			estuarine mudflat	3	6 - 10
113GCS7103604C07	Electricity Sub Station, Yelland	Earth Embankment	Gabions		estuarine mudflat	2	>20
113GCS7103604C08	Estuary Business Park, Yelland	Earth Embankment	Rock Armoured Revetment		estuarine mudflat	2	11 - 20
NEW_ASSET_32_1	Home Farm Marsh, Yelland	Masonry Wall			beach - gravel	2	
113GCS7103601C03	Tarka Trail Car Park, Fremington	Masonry Seawall			beach - mixed	3	6 - 10
113GCS7103601C02	Fremington Quay, Fremington	Masonry Quay Wall			beach - sandy	2	11 - 20
113GCS7103602C01	Fremington Pill					3	6 - 10
113GCS7103602C03	Fremington - Muddlebridge cottages						
113GCS7103602C04	Fremington - Muddlebridge cottages						
113GCS7103601C01	East of Fremington Pill, Fremington	Masonry Revetment			beach - sandy	2	>20
113GCS7103604C13	Salt Pill Duck Pond,	Earth Embankment	Masonry		beach - gravel	2	11 - 20

NFCDD Reference Number	Location	Primary Defence *(i.e. main defence line)*	Secondary (seaward) Defence *(e.g. additional defences that support the main defence line)*	Secondary (landward) Defence *(e.g. additional set-back flood bank behind main defence)*	Foreshore Type	Overall Condition	Residual Life (years)
	Home Farm Marsh, Yelland		Revetment				
113GCS7103303C01	Allen's Rock - Salt Pill Duck Pond, Home Farm Marsh, Yelland	Earth Embankment			beach - gravel	2	>20
113GCS7103604C14	Home Farm Marsh, Yelland	Earth Embankment			beach - gravel	3	11 - 20
113GCS7103604C12	Home Farm Marsh West, Yelland	Earth Embankment			beach - gravel	2	11 - 20
113GCS7103604C11	Isley Marsh Nature Reserve, Yelland	Earth Embankment			estuarine mudflat	2	>20
113GCS7103604C10	East Yelland Marsh, Yelland	Earth Embankment			estuarine mudflat	2	11 - 20
NEW_ASSET_30_3	West of Tarka Inn, Braunton	Earth Embankment	Masonry Revetment		shore platform	3	
NEW_ASSET_30_2	Braunton Pill - Jetty, Braunton	Earth Embankment	Rock Armour Revetment		River Bed	2	
NEW_ASSET_30_1	Marstage Quay & Slipway, River Caen	Earth Embankment			estuarine mudflat	3	
113GCS7104201C02	Velator Road - Braunton Pill, Braunton	Earth Embankment			estuarine mudflat	3	11 - 20
113GCS7104201C04	Shooting Range, Chivenor Airfield	Concrete Seawall	Concrete Revetment		beach - mixed	3	6 - 10
113GCS7104201C03	Chivenor Ridge, Chivenor	Earth Embankment	Concrete Revetment	Earth Embankment	beach - mixed	3	6 - 10
113GCS7103902C04	Industrial Estate, Heanton Punchardon	Earth Embankment			beach - mixed	2	>20
113GCS7103902C02	Heanton Court Farm, Braunton	Earth Embankment	Masonry Revetment		shore platform	2	>20

NFCDD Reference Number	Location	Primary Defence *(i.e. main defence line)*	Secondary (seaward) Defence *(e.g. additional defences that support the main defence line)*	Secondary (landward) Defence *(e.g. additional set-back flood bank behind main defence)*	Foreshore Type	Overall Condition	Residual Life (years)
113GCS7104202C05	Marstage Quay - Marstage Farm, River Caen	Earth Embankment			estuarine mudflat	3	11 - 20
113GCS7104202C04	U/S Marstage Quay, River Caen	Earth Embankment	Masonry Quay Wall		estuarine mudflat	3	11 - 20
113GCS7104202C02	Velator Bridge - Marstage, River Caen	Earth Embankment			estuarine mudflat	2	>20
113GCS7104202C01	River Caen Weir, West Bank	Masonry Wall	Earth Embankment		estuarine mudflat	3	11 - 20
NEW_ASSET_29_1	Crow Beach House, River Taw	Earth Embankment	Rock Armour Revetment		beach - sandy	3	
113GCS7104502C01	Crow Point, River Taw	Rock Armour Revetment			beach - sandy	2	>20
113GCS7104202C08	Crow Beach House - Crow Point, River Taw	Gabions			beach - mixed	3	11 - 20
113GCS7104202C09	Crow Point Toll Road, River Taw	Earth Embankment			flood plain	2	11 - 20
113GCS7104202C07	Horsey Island, River Taw	Earth Embankment	Rock Armour Revetment		beach - sandy	3	11 - 20
113GCS7104801C01	Southern Side of Slipway, Saunton Sands	Gabions			beach - sandy	2	0
113GCS7104801C03	Ice-Cream Shop Seawall, Saunton Sands	Blockwork Wall			n/a - slipway	2	0
113GCS7104801C04	Beach Shop Seawall, Saunton Sands	Blockwork Wall			n/a - slipway	2	0
113GCS7104801C06	Surf Life-Saving Club, Saunton Sands	Gabions			beach - sandy	2	0
113GCS7150501C05	Beach Road, Croyde Bay	Masonry Wall			beach - sandy	2	0

NFCDD Reference Number	Location	Primary Defence *(i.e. main defence line)*	Secondary (seaward) Defence *(e.g. additional defences that support the main defence line)*	Secondary (landward) Defence *(e.g. additional set-back flood bank behind main defence)*	Foreshore Type	Overall Condition	Residual Life (years)
113GCS7150501C06	Beach Road, Croyde Bay	Masonry Seawall			beach - sandy	2	0
113GCS7150501C07	East of Kiln, Moor Lane, Croyde Bay	Masonry Seawall	Concrete Apron	Sand Dune	beach - sandy	2	0
113GCS7150501C08	West of Kiln, Moor Lane, Croyde Bay	Masonry Seawall		Earth Embankment	shore platform	3	0
113GCS7151001C02	East of Moor Lane Steps, Croyde Bay	Masonry Seawall			shore platform	3	0
113GCS7151001C03	Moor Lane Steps, Croyde Bay	Masonry Seawall	Concrete Apron		shore platform	2	0
113GCS7151001C04	West of Moor Lane Steps, Croyde Bay	Masonry Seawall			shore platform	2	0
113GCS7151001C05	Moor Lane Houses, Croyde Bay	Masonry Seawall			shore platform	2	0
NEW_ASSET_26_2	South of Slipway, Putsborough Sand	Concrete Seawall			beach - sandy	2	
NEW_ASSET_26_1	North of Slipway, Putsborough Sand	Masonry Seawall			beach - sandy	2	
113GCS7152501C03	Vention, Putsborough Sand	Concrete Revetment		Sand Dune	beach - sandy	1	
113GCS7152501C02	Putsborough Sand	Concrete Seawall			beach - sandy	3	
113GDS7201502C03	Lee Bay				0	2	11 - 20
113GDS7201502C02	Lee Bay				beach - mixed	2	11 - 20
113GDS7201502C01	Lee Bay				0	2	11 - 20
113GDS7202005C05	Wrath Rock to Wilder's Mouth				shore platform		
113GDS7202005C06	Wilder's Mouth				shingle ridge		
113GDS7202001C01	Cheyne Beach				0	2	>20
113GDS7202002C01	Ilfracombe – The				0	2	6 - 10

NFCDD Reference Number	Location	Primary Defence *(i.e. main defence line)*	Secondary (seaward) Defence *(e.g. additional defences that support the main defence line)*	Secondary (landward) Defence *(e.g. additional set-back flood bank behind main defence)*	Foreshore Type	Overall Condition	Residual Life (years)
	Quay						
113GDS7202002C02	Ilfracombe Quay				0		
113GDS7202002C03	Ilfracombe Quay				0		
113GDS7202003C03	Ilfracombe Quay				0		
113GDS7202003C04	Ilfracombe Quay				0		
113GDS7203001C03	Hele Beach				shingle ridge	2	>20
113GDS7203001C04	Hele Bay				shingle ridge	2	>20
113GDS7205001C06	Combe Martin				shingle ridge	2	>20
113GDS7205001C05	Combe Martin				shingle ridge	2	>20
113GDS7205001C04	Combe Martin				shore platform		
NEW_ASSET_20_2	Blacklands Wood, Lynmouth	Masonry Seawall			beach - gravel	2	11 - 20
NEW_ASSET_20_1	East Bank, River Lyn, Lynmouth	Masonry Seawall	Masonry Revetment		shore platform	3	>20
113GDS7206001C01	The Esplanade, Lynmouth	Masonry Seawall			beach - cobble	3	>20
113GDS7206001C02	Lynmouth Street Pier - The Esplanade, Lynmouth	Masonry Seawall	Rock Armour Revetment		beach - mixed	2	>20
113GDS7206001C03	Lynmouth Street Pier, Lynmouth	Masonry Harbour Arm			beach - sandy	2	>20
113GDS7206001C04	Lynmouth Street, Lynmouth	Masonry Seawall			beach - sandy	2	>20
113GDS7206001C05	Riverside Road Pier, Lynmouth	Masonry Harbour Arm			River bed - cobbles	2	#N/A
113GDS7206001C06	Riverside Road, Lynmouth	Masonry Seawall			River bed - cobbles	2	>20
113GDS7206002C01	River Lyn - Blacklands Wood, Lynmouth	Masonry Seawall			beach - gravel	2	11 - 20

NFCDD Reference Number	Location	Primary Defence *(i.e. main defence line)*	Secondary (seaward) Defence *(e.g. additional defences that support the main defence line)*	Secondary (landward) Defence *(e.g. additional set-back flood bank behind main defence)*	Foreshore Type	Overall Condition	Residual Life (years)
NEW_ASSET_19_1	North Harbour Wall, Porlock Weir	Masonry Seawall			beach - mixed	3	11 - 20
112GDS7252001C01	South Harbour Wall, Porlock Weir	Masonry Seawall			beach - mixed	3	11 - 20
112GDS7252002C01	Car Park, Porlock Weir	Earth Embankment			beach - cobble	4	6 - 10
112GDS7252501C01	Porlock Beach					2	1 - 5
112GDS7252502C02	Porlock Bay Marshes					2	6 - 10
112GDS7252502C03	Last 300m of Porlock Bay at Hurlestone Point End (Eastern end)					2	6 - 10
NEW_ASSET_17_3	Quay West, Minehead	Concrete Seawall			beach - cobble	2	0
NEW_ASSET_17_2	Outer Wall, Minehead Harbour, Minehead	Concrete Seawall with Recurve			beach - sandy	2	0
NEW_ASSET_17_1	Esplanade - Harbour, Minehead	Concrete Seawall with Recurve	Rock Armour Revetment		beach - mixed	1	0
112GDS7301002C01	Breakwater - Quay West, Minehead	Shingle Ridge		Wall	beach - cobble	3	6 - 10
112GDS7301501C01	Inner Wall, Minehead Harbour, Minehead	Masonry Seawall			beach - sandy	2	11 - 20
112GDS7301502C01	Warren Point - Esplanade, Minehead	Concrete Seawall with Recurve	Stepped Concrete Revetment		beach - sandy	2	11 - 20
112GDS7301502C02	Golf Course Car Park, Minehead	Masonry Seawall	Sand Dune		beach - sandy	5	<1
112GDS7302001C01	Minehead Golf Club, Minehead	Earth Embankment			beach - gravel	2	6 - 10
112GDS7302501C01	Sea Lane End to the Hawn, Dunster	Earth Embankment			beach - sandy	2	11 - 20
112GDS7303001C01	Blue Anchor Railway	Shingle Embankment		Earth	shingle ridge	5	6 - 10

NFCDD Reference Number	Location	Primary Defence *(i.e. main defence line)*	Secondary (seaward) Defence *(e.g. additional defences that support the main defence line)*	Secondary (landward) Defence *(e.g. additional set-back flood bank behind main defence)*	Foreshore Type	Overall Condition	Residual Life (years)
	Station to Sea Lane End, Dunster			Embankment			
112GDS7303501C01	Blue Anchor Railway Station	Earth Embankment			beach - gravel	4	6 - 10
112GDS7303502C01	TCB to Railway Station, Blue Anchor	Concrete Seawall	Concrete Revetment		beach - gravel	2	11 - 20
112GDS7303502C02	Near TCB, Blue Anchor	Concrete Seawall	Concrete Seawall with Recurve		beach - gravel	2	11 - 20
112GDS7303502C03	Pill Copse, Blue Anchor	Concrete Seawall	Concrete Revetment		beach - gravel	2	11 - 20
112GDS7303502C04	Caravan Park, Blue Anchor	Concrete Seawall	Masonry Wave Return Wall		beach - gravel	2	>20
112GDS7303503C01	Pill Bridge - Slipway, Blue Anchor	Concrete Seawall	Rock Armour Revetment		beach - mixed	3	11 - 20
112GDS7303503C02	Slipway, Blue Anchor	Concrete Seawall	Concrete Splashwall		beach - sandy	3	6 - 10
112GDS7303503C03	Blue Anchor Hotel - Slipway, Blue Anchor	Concrete Seawall with Recurve			beach - mixed	3	11 - 20
112GDS7303503C04	Blue Anchor Hotel, Blue Anchor	Concrete Seawall	Gabions		beach - mixed	4	1 - 5
NEW_ASSET_13_5	Inner Wall, Western Pier, Watchet	Concrete Blockwork Seawall			beach - sandy	2	
NEW_ASSET_13_4	Eastern End of Eastern Pier, Watchet	Masonry Seawall			shore platform	2	
NEW_ASSET_13_3	Outer Wall, Eastern Pier, Watchet	Concrete Seawall with Recurve			shore platform	2	
NEW_ASSET_13_2	Inner Wall, Eastern Pier, Watchet	Sheet Pile Quay Wall			beach - sandy	2	
NEW_ASSET_13_1	West Street Beach, Watchet				beach - mixed	2	

NFCDD Reference Number	Location	Primary Defence *(i.e. main defence line)*	Secondary (seaward) Defence *(e.g. additional defences that support the main defence line)*	Secondary (landward) Defence *(e.g. additional set-back flood bank behind main defence)*	Foreshore Type	Overall Condition	Residual Life (years)
112GDS7304501C01	Cliffs Fronting Allotment Gardens, West Street Beach, Watchet	Rock Armour Revetment			beach - mixed	2	11 - 20
112GDS7304501C02	Cliffs Fronting Allotment Gardens, West Street Beach, Watchet	Concrete Seawall			beach - mixed	2	11 - 20
112GDS7304501C03	West Street Beach, Watchet	Masonry Seawall			beach - mixed	3	6 - 10
112GDS7304501C04	West of West Street Slipway, Watchet	Concrete Seawall			beach - cobble	2	11 - 20
112GDS7304501C05	Bottom of Slipway, West Street Beach, Watchet	Masonry Seawall	Rock Armour Revetment		beach - cobble	2	6 - 10
112GDS7304501C06	West Street Slipway, Watchet	Masonry Seawall	Concrete Revetment		beach - shingle	2	6 - 10
112GDS7304502C01	Western Pier, Outer Seawall, Watchet	Masonry Seawall			n/a - submerged	3	>20
112GDS7304502C02	Slipway to Inner Harbour, Watchet	Rock Armour Revetment			beach - sandy	3	11 - 20
112GDS7304502C03	Inner Harbour Wall, Watchet	Blockwork Seawall			beach - sandy	2	11 - 20
112GDS7304502C04	Harbour to Eastern Pier, Watchet	Masonry Seawall			beach - sandy	3	11 - 20
112GDS7304502C05	East of Eastern Pier, Watchet	Masonry Seawall		Rock Armour Revetment	shore platform	2	11 - 20
112GDS7305003C10	Coastguard Lookout, Watchet	Rock Armour Revetment			shore platform	2	11 - 20
112GDS7305003C12	East of Coastguard	Rock Armour			beach - mixed	2	6 - 10

NFCDD Reference Number	Location	Primary Defence *(i.e. main defence line)*	Secondary (seaward) Defence *(e.g. additional defences that support the main defence line)*	Secondary (landward) Defence *(e.g. additional set-back flood bank behind main defence)*	Foreshore Type	Overall Condition	Residual Life (years)
	Lookout, Watchet	Revetment					
NEW_ASSET_12_1	Doniford Farm West, Helwell Bay, Doniford	Rock Armour Revetment			beach - mixed	3	#N/A
112GDS7305501C01	Helwell Bay West, Doniford	Rock Armour Revetment			beach - mixed	3	6 - 10
112GDS7305501C14	Helwell Bay Centre, Doniford	Rock Armour Revetment			beach - mixed	3	11 - 20
112GDS7305501C15	Doniford Farm, Helwell Bay, Doniford	Rock Armour Revetment			beach - mixed	3	11 - 20
112GDS7306002C01	Caravan Park, Doniford	Rock Armour Revetment			beach - mixed	4	6 - 10
112GDS7351001C02	Gabion Baskets, Lilstock	Gabions			beach - cobble	4	1 - 5
112GDS7351001C01	Rock Revetment, Lilstock	Rock Armour Revetment			beach - cobble	2	11 - 20
112GDS7352001C01	Hinkley Point Power Station, western end				shore platform	3	1 - 5
112GDS7352001C02	Hinkley Point Power Station				beach - cobble	2	>20
112GDS7352001C03	Hinkley Point Power Station, eastern end				beach - cobble	3	11 - 20
112GDS7352501C01	Hinkley Point Power Station to Stolford, west				beach - mixed	2	11 - 20
112GDS7352501C02	Hinkley Point Power Station to Stolford, east				beach - mixed	2	11 - 20
112GDS7352502C01	Stolford, western end				beach - cobble	2	11 - 20
112GDS7352502C02	Stolford, Chapel Cottages				beach - cobble	2	11 - 20

NFCDD Reference Number	Location	Primary Defence *(i.e. main defence line)*	Secondary (seaward) Defence *(e.g. additional defences that support the main defence line)*	Secondary (landward) Defence *(e.g. additional set-back flood bank behind main defence)*	Foreshore Type	Overall Condition	Residual Life (years)
112GDS7352502C03	Adjacent to Chapel Cottages					2	11 - 20
112GDS7352502C04	Stolford				beach - cobble	2	11 - 20
112GDS7353001C05	Steart Peninsula, Catsford Common				beach - gravel	3	1 - 5
112GDS7353001C01	Steart Peninsula, Catsford Common					2	6 - 10
112GDS7353002C01	Steart Peninsula, Wall Common, western end					3	11-20
112GDS7353002C05	Catsford Common East					2	1 - 5
112GDS7353002C04	Steart Peninsula, Wall Common					2	11 - 20
112GDS7353002C02	Steart Peninsula, Wall Common to Catsford Common				beach - gravel	3	1 - 5
112GDS7353002C03	Steart Peninsula, Wall Common					2	11 - 20
112GDS7353003C01	Steart 1					5	6 - 10
112GDS7353003C02	Steart					2	6 - 10
112GDS7354001C01	South of Huntspill Sluice (was part of Huntspill 1)					2	6 - 10
112GDS7354001C02	Huntspill Sluice to River Brue					2	6 - 10
112GDS7354001C03	North of Huntspill Sluice - Concrete access track with saltings to front.					2	6 - 10

NFCDD Reference Number	Location	Primary Defence *(i.e. main defence line)*	Secondary (seaward) Defence *(e.g. additional defences that support the main defence line)*	Secondary (landward) Defence *(e.g. additional set-back flood bank behind main defence)*	Foreshore Type	Overall Condition	Residual Life (years)
112GDS7354001C05	North of Huntspill Sewage Works Outfall					2	6 - 10
112GDS7354002C01	Huntspill 2. Mouth of the River Brue					3	11 - 20
112GDS7354002C02	Mouth of River Brue Left Bank.					2	6 - 10
112GDS7400502C01	Burnham-on-Sea, South Esplanade to Pavilion	Concrete Seawall with Recurve	Concrete Stepped Revetment		beach - sandy	2	>20
112GDS7400501C01	Burnham-on-Sea, South Esplanade, Slipway	Concrete Seawall	Concrete Stepped Revetment		beach - mixed	2	>20
112GDS7401001C01	Burnham-on-Sea, Esplanade, Pavilion	Concrete Revetment		Concrete Splash Wall	beach - sandy	3	6-10
NEW_ASSET_6_2	Burnham-on-Sea, Maddocks Slade slipway	Concrete Seawall			beach - sandy	2	>20
NEW_ASSET_6_1	Burnham-on-Sea, Esplanade, northern end	Concrete Seawall			beach - sandy	2	>20
112GDS7401001C02	Burnham-on-Sea, Esplanade	Concrete Seawall with Recurve	Concrete Stepped Revetment		beach - sandy	2	>20
112GDS7401002C10	Burnham-on-Sea, Atlanta Key	Sloped Masonry Seawall			beach - sandy	2	6-10
112GDS7401002C09	Burnham-on-Sea, Belfield Court	Sloped Masonry Seawall			beach - sandy	2	6-10
112GDS7401002C08	Burnham-on-Sea, Poplar Road	Sloped Masonry Seawall		Masonry Splash Wall	beach - sandy	2	6-10
112GDS7401002C07	Burnham-on-Sea, north of Poplar Road	Sloped Concrete Seawall		Brick Splash Wall	beach - sandy	2	6-10

NFCDD Reference Number	Location	Primary Defence *(i.e. main defence line)*	Secondary (seaward) Defence *(e.g. additional defences that support the main defence line)*	Secondary (landward) Defence *(e.g. additional set-back flood bank behind main defence)*	Foreshore Type	Overall Condition	Residual Life (years)
112GDS7401002C06	Burnham-on-Sea, Grove Road steps	Sloped Masonry Seawall		Brick Splash Wall	beach - sandy	2	>20
112GDS7401002C05	Burnham-on-Sea, south of Allandale Road	Sloped Masonry Seawall		Masonry Splash Wall	beach - sandy	2	11 - 20
112GDS7401002C04	Burnham-on-Sea, Allandale Road	Masonry Seawall			beach - sandy	2	11 - 20
112GDS7401002C03	Burnham-on-Sea, north of Allandale Road	Concrete Seawall			beach - sandy	2	11 - 20
112GDS7401002C02	Burnham-on-Sea, the Colony	Rock Armoured Revetment				2	11 - 20
112GDS7402002C01	Brean - Southern end of rock armour from flood gate to 2nd bungalow.					2	11 - 20
112GDS7402002C02	Brean - Armour section north of the vehicular access flood gates.					2	11 - 20
112GDS7402002C03	Brean Down - between vehicular flood gates and pedestrian flood gate, includes west wall of cafe.					2	11 - 20
112GDS7402002C04	Brean Down - short section immediately north of cafe pedestrian flood gate.					2	11 - 20

NFCDD Reference Number	Location	Primary Defence *(i.e. main defence line)*	Secondary (seaward) Defence *(e.g. additional defences that support the main defence line)*	Secondary (landward) Defence *(e.g. additional set-back flood bank behind main defence)*	Foreshore Type	Overall Condition	Residual Life (years)
112GDS7402002C05	Brean Down - short section to cliff and District Council Gabions					2	>20
112GES8100501C01	Brean Down Farm					2	11 - 20
112GES8100501C02	Brean Down Farm					2	6 - 10
112GES8100501C03	Brean Down Farm, 150m U/S					2	6 - 10
112GES8100501C04	Brean Down Fm, 250m U/S to Flap Outfall/Drain					2	>20
112GES8100501C05	Flap Outfall/Drain to Ferry Point					2	>20
112GES8100501C06	Ferry Point to Uphill Great Rhyne					2	>20
112GES8100501C07	Uphill at Rhyne to Stone at Hook Pill					2	>20
112GES8100501C08	Hook Pill, Immediately D/S					2	>20
112GES8100501C09	Hook Pill					2	>20
112GES8100501C10	Hook Pill, Immediately U/S					2	11 - 20
112GES8100501C11	Between Two Lengths of Rock Revetment					2	>20
112GES8100501C12	Last Rock Revetment to Before Sluice					2	>20
112GES8100501C13	Rock Revetment On Cs to Brean Sluice					2	>20
112GES8100502C06	Brean Cross Sluice					2	11 - 20

NFCDD Reference Number	Location	Primary Defence *(i.e. main defence line)*	Secondary (seaward) Defence *(e.g. additional defences that support the main defence line)*	Secondary (landward) Defence *(e.g. additional set-back flood bank behind main defence)*	Foreshore Type	Overall Condition	Residual Life (years)
112GES8100502C05	Brean Sluice, 500m D/S to Brean Sluice					2	>20
112GES8100502C04	L/B Stroud Pill					2	>20
112GES8100502C03	Stroud Pill					2	>20
112GES8100502C02	Lagoon Outfall to Stroud Pill, Uphill					2	>20
112GES8100502C01	Behind Lagoon Saltings					2	>20
112GES8100504C03	River Bank South of Uphill Boatyard Pond to High Ground					2	6 - 10
112GES8100506C09	Uphill Golf Course					2	0
112GES8100506C08	Uphill Caravan Park					2	0
112GES8100506C08	Uphill Caravan Park					2	0
112GES8100506C07	Coastal Sand dunes, under Links Road, to Caravan Park Building, Uphill					2	11 - 20
112GES8100506C06	Slimeridge Farm, Links Road, Uphill					2	6 - 10
112GES8100506C05	Behind Slimeridge Farm, Links Road, Uphill					2	6 - 10
112GES8100506C04	Gate on new embankment to tidal sluice, Uphill					2	>20
112GES8100506C03	North of Uphill Sluice					1	>20
112GES8100506C02	Uphill Sluice					1	>20
112GES8100506C01	Uphill boat yard entrance					1	>20

NFCDD Reference Number	Location	Primary Defence *(i.e. main defence line)*	Secondary (seaward) Defence *(e.g. additional defences that support the main defence line)*	Secondary (landward) Defence *(e.g. additional set-back flood bank behind main defence)*	Foreshore Type	Overall Condition	Residual Life (years)
112GES8051502C03	Weston-Super-Mare Golf Club, Weston-Super-Mare					2	11 - 20
112GES8051001C01	South of Quantock Road, Weston Super Mare					2	6 - 10
112GDS8051502C02	Quantock Road to Harbour, Weston Super Mare				beach - sandy	2	>20
112GDS8051503C01	Northern end of Weston Super Mare up to high land opposite Manilla Crescent.					2	11 - 20
112GES8051504C03	Marine Lake, Weston-super-Mare					2	>20

C.3 Climate Change and Sea Level Rise

C.3.1 Introduction

The global climate is constantly changing, but it is generally recognised that we are entering a period of change. The anticipated implications of climate change, and in particular sea level rise, present a significant challenge to future coastal management. Over the last few decades there have been numerous studies into the potential impact of future changes. However, there remains considerable uncertainty in future climate modelling science and future global development patterns.

The UK Climate Impacts Programme (UKCIP) was established in 1997 to co-ordinate scientific research into the impacts of climate change. UKCIP publishes (on behalf of the UK Government) predictions of how the UK climate may change this century for a range of scenarios. UKCP09, the most recent predictions, were released in June 2009. This is the fifth generation of climate information for the UK, and provides probabilistic projections of climate change. UKCP09 comprises a package of information including, publications, key findings, user support and customisable output: this is primarily available on-line at: http://ukclimateprojections.defra.gov.uk/.

It should be noted, that although UKCP09 presents the latest and most accurate projections, for the purpose of land use planning, planning applications in areas prone to flood risk, shoreline management planning and the design of coastal defences, predictions for future rates of sea level rise, wave heights, river flow, rainfall should be sourced from Policy Planning Statement 25 (PPS25), or Defra's Supplementary Note to Operating Authorities October 2006 (Defra, 2006) until new guidance on the use and application of the UKCP09 scenarios is released. It is recommended that the UKCP09 website is consulted for more detailed information and guidance on how the projections data should be used.

However, although climate change projections may differ, the nature of shoreline change and response to management policies remain valid, it is simply the precise magnitude and timing of such changes that remain uncertain. This is recognised in the assessments made throughout the rest of the SMP.

The text below provides a summary of latest climate change projections relevant to shoreline management along the SMP frontage.

C.3.2 Sea level rise

Sea levels on the West coast are believed to have largely reached their present levels around 4,000 years BP, having risen rapidly during the Holocene marine transgression following the end of the last glacial period about 10,000 years BP. There is now concern over human-induced acceleration in sea level rise due to climate change. Relative sea level change depends upon changes in global sea level (eustatic change) and in land level (isostatic change).

Isostatic change is the change in land level as the crust slowly readjusts to unloading of the weight of the ice since the last Ice Age c.125, 000 years BP (this phenomenon is also known as crustal forebulge). Therefore, areas which were covered by ice, i.e. northern England and Scotland, have been experiencing a rise in land levels over the last few thousand years, whereas the south-west coast of England has been subsiding at a rate of between 0.5 to 1.2mm/year (UKCIP, 2005).

Eustatic change can be influenced by climatic changes (e.g. increased temperature causes an increased volume of water through thermal expansion and melting ice). Evidence suggests that global-average sea level rose by about 1.5mm/year during the twentieth century; this is believed to be due to a number of factors including thermal expansion of warming ocean waters and the melting of land (alpine) glaciers (Hulme *et al*, 2002*)*, but after adjustment for natural land movements, it has been calculated that the average rate of sea level rise during the last century around the UK coastline was approximately 1 mm/year.

Over the last 2,000 years sea level rise has continued but at much lower rates, resulting in ongoing, but less dramatic, changes at the shoreline. However, we are now entering a period of accelerating sea level rise, which will result in changes to the present coastal systems.

Global sea level is believed to have risen by between 10cm and 20cm during the past century and best estimates predict approximately 50cm sea level rise over the next 100 years (i.e. an increase by a factor of 3). Rising sea levels are a consequence of thermal expansion of the oceans, melting of low latitude glaciers (Alps, Rockies etc.) and many other factors, each of which are reviewed every few years by the Intergovernmental Panel on Climate Change (IPCC). However, how this change in global sea level translates to relative sea level along the coast depends upon both local changes in vertical land movements (due to Glacial Isostatic Adjustment (GIA)) and regional factors such as ocean circulation.

Work completed for the Copenhagen Diagnosis study (The Copenhagen Diagnosis, 2009) compares tide gauge data and satellite observations of sea level from around the world, with IPCC sea level rise projections for the time period 1970 to 2010. It is strongly evident from the graph that sea levels are rising, and at an accelerating rate.

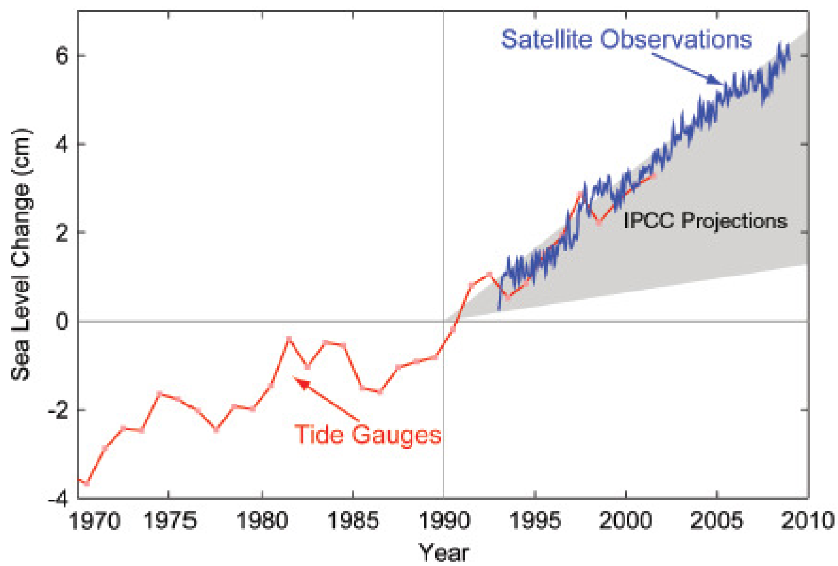

Figure C.1 *Sea level change during 1970-2010. The tide gauge data are indicated in red (Church and White 2006) and satellite data in blue (Cazenave et al. 2008). The grey band shows the projections of the IPCC Third Assessment report for comparison. Sourced from The Copenhagen Diagnosis (2006).*

Analysis of tide gauge data collected by Proudman Oceanographic Laboratory (POL) (POL website) for Avonmouth, which is located in the Bristol Channel, clearly shows an increasing trend in sea level rise (see

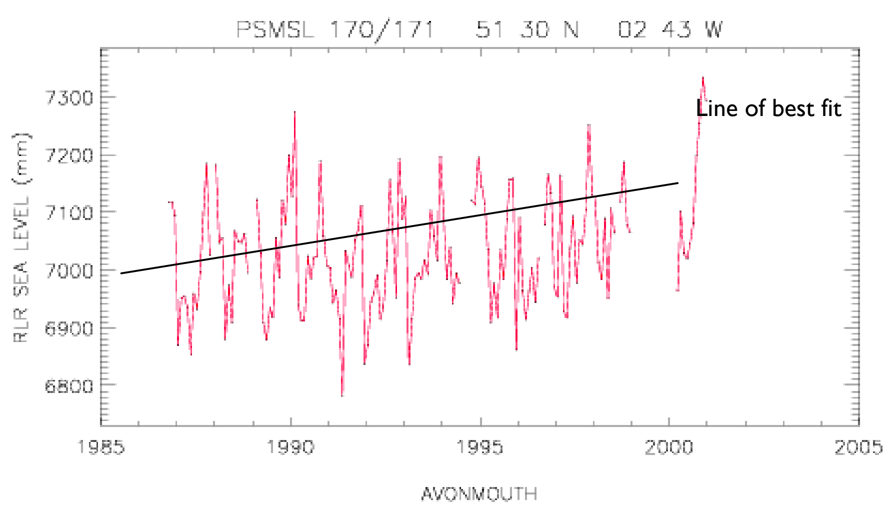

Figure C.2).

Figure C.2 ***Sea level change between 1986-2000 at Avonmouth (from POL website).***

Current Defra flood guidance (Defra, 2006) which provides advice on climate change allowances and sensitivity ranges, in support of Planning Policy Statement 25 (PPS25) 'Development and Flood Risk', is based on the maximum of the global sea level range given for the high (SRES A1F1) climate scenario in the IPCC Third Assessment Report, along with vertical land movement estimates based on geological data. In the Defra guidance, rates of relative sea level rise are given for three large-scale UK sub-regions and for four time intervals which span the 21st century (see Table C.3 for the allowances for this SMP area). A criticism of these allowances was that whilst the Defra allowances are precautionary in nature, they do not reflect the uncertainties associated with the projections of sea level rise UKCIP (2005).

Administrative or Devolved Region	Assumed Vertical Land Movement (mm/yr)	Net Sea Level Rise (mm/yr)				Previous allowances
		1990 - 2025	2025 - 2055	2055 - 2085	2085 - 2115	
South West and Wales	-0.5	3.5	8.0	11.5	14.5	5mm/yr constant*

Table C.3 Sea level rise predictions from the latest Defra guidance on climate change (Defra, 2006). **Updated figures now reflect an exponential curve and replaces the previous straight line graph.*

More recently, UKCP09 have updated the UKCIP02 projections in a number of ways, primarily through using results from the most recent IPCC Fourth Assessment Report and newer estimates of UK vertical land movement.

The methodologies used to generate sea level ranges for the UK in the UKCP09 report differ from current Defra guidance, using improved methods to estimate vertical land movement and models constrained by a range of observations, informed by the most recent IPCC Fourth Assessment Report (IPCC, 2007). The IPCC Fourth Assessment Report estimates that approximately 70% of global sea level rise over the 21st century will be due to thermal expansion, with the remainder due to melting of glaciers, ice caps and a combined contribution from the Greenland and Antarctic ice sheets. Outputs from UKCP09 are available from the website and include:

- Absolute sea level rise time series for the UK for high, medium and low emissions scenarios (central estimate, and 5th and 95th percentile).
- Relative sea level rise around the UK, combining absolute sea level rise and vertical land movement, at user specified coastal locations.

One component of future sea level rise is from the melting of large ice sheets; however, there is a lack of current scientific understanding of some aspects of ice sheet behaviour and as such there are known limitations to including this component in sea level projections. UKCIP02 did not take any account of catastrophic changes, such as the collapse of the Thermohaline Circulation or the collapse of the West Antarctic Ice Sheet, whereas UKCP09 provides a low probability, high impact range for sea level rise around the UK, known as the High-plus-plus (H++) scenario, in addition to their main scenarios. This provides some indication of the impact of large-scale ice sheet melting on sea level rise. The scenario takes its bottom value from the maximum global mean sea level rise given by the IPCC Fourth Assessment Report, and its top value is derived from indirect observations of sea level rise during the last interglacial period, where the climate was comparable in some ways to today, and from estimates of maximum glacial flow rate. The H++ scenario prediction of sea level rise around the UK coast is between 0.93m and approximately 1.9m by 2100. UKCP09 state that the top of this range is very unlikely to occur in the 21st century and that improvements in models and continued monitoring may, in the future, help to estimate the likelihood of this type of event, or rule it out completely.

The above projections of future sea level rise also do not take any account of catastrophic changes, such as the collapse of the Thermohaline Circulation (THC) which UKCIP02 did not consider. The Thermohaline Circulation is a massive circulation of water in the world's oceans, which brings considerable amounts of heat to Western Europe; the Gulf Stream is one element of the circulation. This circulation is primarily driven by changes in water density, but other process, such as winds and tides, also contribute. It is frequently referred to in scientific literature as the meridional overturning circulation (MOC) particularly when focussing on the component of the THC which takes place in the North Atlantic. Any change is this circulation could result in cooling in North West Europe even whilst most of the world experiences warming.

There has been some concern that climate change could trigger this circulation to shut down, which in turn could lead to significant cooling in north-west Europe, even whilst most of the world warms up. Over the next century, total collapse of the Thermohaline Circulation is considered unlikely (IPCC Fourth Assessment Report 4, Working Group I); and even under a scenario of the circulation weakening over the next 100 years, which would mean that the Gulf Stream would bring less heat to the UK, increased greenhouse gas heating would greatly exceed this cooling effect (UKCIP02 report: Hulme et al., 2002). The effects of the gradually weakening MOC on UK climate are included in the UKCP09 climate projections.

C.3.3 Storminess and storm surge

Along much of this shoreline, a key risk will be future changes in tidal surges, winds and storms. The combination of high tides and strong westerly and south-westerly winds, increasing wave height and tidal surges, is a significant threat in terms of future coastal erosion and flooding.

Wind climate is a particularly important variable in the evolution of sand dune systems. As well as affecting frontal dunes, wind speed and direction also affects the stability of the system, affecting dune migration rates and the effect of wind stress on vegetation cover (Pye and Saye, 2005). UKCP09 has not, however, provided probabilistic projections for future changes in wind speed or direction.

A report by UKCIP (2009) (available from the UKCP09 website), which reviewed historical trends, stated that whilst severe wind storms around the UK have increased in recent decades, they are not above those observed in the 1920s. This report concluded that although there is considerable interest in possible trends in severe wind storms around the UK, these are difficult to identify, due to low numbers of such storms, their decadal variability, and by the unreliability and lack of representation of direct wind speed observations. The report also stated that there continues to be little evidence that the recent increase in storminess over the UK is related to man-made climate change.

As part of UKCP09, changes in storm surge levels for return periods of 2, 10, 20 and 50 years (the level predicted to be exceeded on average once during the return period) were examined. The trends found were physically small everywhere around the UK, with projections suggesting that the surge level expected to be exceeded on average once every 2, 10, 20 or 50 years would not increase by more than 9cm by 2100 anywhere around the UK coast (not including mean sea level rise), although the largest trends were found in the Bristol Channel and Severn Estuary. This suggests that the surge component of extreme sea level will be much less important than was implied by the previous projections presented in UKCIP02. Further information can be obtained from the UKCP09 website.

The UKCP09 report concludes that in most locations the trend in storm surge levels cannot be clearly distinguished from natural variability; therefore, although this is recognised as an uncertainty within the predictions, no detailed analysis of potential impacts has been undertaken. It is not within the remit of the SMP to undertake an analysis of extreme still water levels; which should be undertaken when assessing defences during strategy or scheme development. A joint Defra/ EA flood and coastal erosion risk management research and development project entitled 'Development and Dissemination of Information on Coastal and Estuary Extremes (SC060064)' is currently underway, due to be completed in spring 2010. This will provide a consistent set of extreme still water levels around the coast of England, Wales and Scotland, replacing POL Report 112.

UKCP09 projections suggest some significant changes in the UK wave climate by 2100. The main statistically significant result, based on a mid climate sensitivity version of the Met Office wind forcing for a medium emissions scenario, is a projected increase in winter wave heights along the south and south-west coast of the UK for both mean and extreme wave heights. Changes in the winter mean wave height are projected to be between –35cm and +5cm. Changes in the annual maxima are projected to be between –1.5m and +1m. Changes in wave period and direction are rather small and more difficult to interpret. Further work is needed to fully interpret the wave projections in the light of predicted changes in weather patterns.

C.3.4 Precipitation

In addition to sea level rise and storminess, another factor of climate change that is important to coastal evolution is precipitation. Analysis of existing UK precipitation records presented in UKCIP08 (2007) indicated that all regions of the UK have experienced an increase in winter rainfall contribution from heavy precipitation events, although the rainfall seasonality experienced across the UK has changed little over the past 50 years.

UKCP09 concluded that there was unlikely to be a significant change in annual mean precipitation by the 2050s, with the central estimate of change being 0% under medium emissions (with an uncertainty range of -5% to +6%). Under medium emissions, it was suggested that there could be an increase in winter rainfall (with a central estimate of +14%; and uncertainty range of 0% to +31%). Conversely a decrease in summer mean rainfall was proposed (with a central estimate of -16%; and uncertainty range of -38% to +13%). Further information can be obtained from the UKCP09 website.

Although many of the cliffs along this frontage are relatively resistant there are a few locations where the cliffs are more susceptible, due to either their geology or structure. Along these sections, any change in precipitation patterns could have an impact through potentially increasing the likelihood of slope failures. Dunes systems are also potentially susceptible to changes in precipitation through limiting sand transport through wetting of beach and dune surface and influencing dune vegetation growth (Pye and Saye, 2005). However, due to uncertainty in the exact impact of precipitation change and due to the fact that it is the intensity of the rainfall, rather than the total amount of rainfall that is the key factor, for which there is no information, although precipitation changes are recognised as an uncertainty this has not been directly taken into account in the shoreline evolution predictions. Given the nature of this coastline, any effects are also likely to be localised.

Changes in precipitation patterns could also have implications for river flows, which in turn could affect meandering patterns, alignment of intertidal channels, development and breaching of sand spits, fluvial discharge and flood risks within the inner estuaries. Although this is recognised as an uncertainty and a potential risk, no further analysis has been undertaken as part of this SMP.

C.4 Baseline Case 1 – No Active Intervention (NAI)

C.4.1 Introduction

This section of the report provides analysis of shoreline response conducted for the scenario of 'No Active Intervention'. This has considered that there is no expenditure on maintaining or improving defences and that therefore defences will fail at a time dependent upon their residual life (see Defence Assessment, Section C.2) and the condition of the beaches.

The analysis has been developed using the understanding of coastal behaviour from the baseline processes understanding (see Section C.1), existing coastal change data (see Section C.4.4) and information on the nature and condition of existing coastal defences (see Section C.2).

Maps illustrating potential flood and erosion risk are included at the end of the appendix.

C.4.2 Summary

The following text provides a summary of the analysis of shoreline response, with details specific to each location and epoch contained within the Scenario Assessment Table.

C.4.2.1 Short Term (to 2025)

Large stretches of this shoreline are undefended or contain only very localised, short stretches of defence and here there would be a continuation of current trends. In places, this would mean that beaches would continue to narrow due to the lack of new sediment inputs and there would be continued cliff erosion at a range of rates, dependent upon the local geology, although along much of this coastline, the cliff erosion rates are low.

Where the coast is defended by hard defences, such as seawalls and rock revetments, these would remain along the majority of frontages, but there could be failure of a number of short lengths of defence that are in poor condition or are at risk from undermining, during this period. At these locations, where defences have tended to slow erosion, there could be an initial acceleration in retreat rates as they fail, although rates are likely to remain relatively low as have occurred historically along adjacent lengths of undefended cliffs. Where defences remain, beaches would continue to narrow as exposure increases due to continued transgression of the coastal system and deeper nearshore areas.

Under this scenario it is assumed that beach management activities would cease and wooden groynes could fail during this period. The impact of this could start to be seen during this period under this scenario, but in most places it is likely that the beach would remain in place. However, any beach narrowing would increase exposure of any backing defences and could accelerate their failure.

A number of beaches along this section, such as within Porlock Bay, are also likely to become increasingly vulnerable to overtopping, overwashing and even breaching during this period, resulting in increased flooding to low-lying areas behind. However, any breaches are likely to be repaired naturally during this epoch as there should be sufficient sediment within the system to allow this to occur.

There is unlikely to be any significant changes to the sediment regime during this period as this is generally a poorly connected coast, in terms of littoral drift, due to natural barriers. Also, the slow erosion rates of the predominately resistant cliffs mean that there will be a limited input of new sediment.

The Taw/Torridge Estuary would not be expected to change significantly and so would maintain its current form during this period and defences would be expected to remain, even without maintenance. However, embankment defences in the outer Parrett Estuary could fail by the end of this epoch, which may contribute to changes in the course of the Parrett low water channel, which in turn could have implications for defences fronting Burnham-on-Sea, if the channel rotates clockwise and encroaches further upon the Burnham frontage.

C.4.2.2 Medium Term (to 2055)

There would be increased pressure on the coastal system due to accelerating sea level rise. During this period many of the remaining defences will fail, accelerated by narrow beaches and increased exposure along the open coast. This could result in an initial acceleration in retreat rates as defences fail at these locations, where shoreline position has been held in place for over 120 years in some cases. The erosion is likely to remain rapid for 5 to 10 years before returning to rates more similar to those pre-defences, commensurate with shoreline energy, although overall rates will remain relatively low, as experienced along the adjacent undefended natural cliffs along this coast.

At a limited number of locations the defences may remain. Here beaches and shore platforms are likely to narrow and become increasingly submerged and may even disappear in places (particularly given the lack of beach management assumed under this scenario), due to rising sea levels and therefore greater exposure to wave action. These conditions would not be conducive to beach retention and any sediment arriving on these frontages could be rapidly transported offshore again.

Along undefended sections of coastline, erosion of softer areas of cliffs such as those between Blue Anchor and Watchet will accelerate in response to sea level rise, periodic cliff failures and landslides occurring to provide occasional inputs of new sediment to the local beaches, some of which will then undergo longshore sediment transport to adjacent frontages. Harder, more resistant rock cliffs, which characterize much of this coastline, would be unlikely to be affected by sea level rise and are expected to continue to retreat at historical rates, failing only as a result of infrequent, geologically controlled events. Where beaches front cliffs that contain sufficient coarse sediment, such as parts of the coast between Hartland Point and Westward Ho!, they could be maintained as narrow beaches despite sea level rise. Where there is insufficient coarse sediment supply to beaches from local cliff erosion, and where beaches are unable to roll landwards due to being backed by higher ground, there would be an increased tendency for sediment to be drawn-down the beach during storms and through this process the beaches could gradually become denuded of sediment and so the beaches would narrow further as sea levels rise and could disappear in places along with shore platforms. This is particularly likely in locations where there are small, pocket type beaches.

Where beaches are backed by low-lying land, then the tendency will be for these to roll landwards as sea levels rise, becoming more swash aligned and vulnerable to overtopping, overwashing and breaching due to a lack of new sediment inputs to the beaches as this roll back occurs. There would therefore be an increased risk of flooding of low-lying areas behind these beaches, with breaches becoming less likely to re-seal naturally due to reducing amounts of available sediment during this epoch.

The mouth of the Taw-Torridge estuary could attempt to widen during this epoch in response to rising sea levels. This will result in increased erosion pressure in the areas around the estuary mouth. Embankment defences within the estuary would fail in this epoch under this scenario, resulting in uncontrolled flooding of previously protected low-lying areas. Where this occurs in the outer part of the estuary, this increase in area that can be inundated will significantly impact the tidal and sedimentary regime of the estuary and adjacent coastal areas.

Similarly, further changes in the regime of the Parrett Estuary resulting from both sea level rise and failure of defences within the estuary, will likely impact upon the evolution of the open coastal areas adjacent the estuary mouth. There is much uncertainty about both the open coast and estuary interactions and the potential impacts on these of changes in estuary regimes. Therefore it is not possible at the present time to be able to provide a quantified assessment of potential impacts.

C.4.2.3 Long Term (to 2105)

The vast majority of defences will have failed or deteriorated by the end of this period, and even where defences remain, they are likely to have a reduced effectiveness due to a combination of a lack of maintenance under this scenario, rising sea levels and increased wave exposure. As such, the influence and impacts of human intervention upon the natural system would be largely diminished along most of the SMP frontage.

As a result there would be reactivation of previously defended cliffs. The rate of retreat of both these and undefended cliffs will be dependent upon the local geology, which controls both the response of the cliff to wave action and also whether sediment would be supplied to the system which could potentially reduce the rate of erosion. Harder, more resistant rock cliffs, which are predominant along this coastline, would be unlikely to be significantly affected by sea level rise and are expected to continue to retreat at historical rates, failing only as a result of infrequent, geologically controlled event. Any fronting beaches could be lost or significantly diminished during this period due to rising sea levels combined with insufficient inputs of new sediment as a result of the low rates of cliff recession.

Erosion of the softer areas of cliff will accelerate in response to sea level rise, periodic cliff failures and landslides occurring to provide occasional inputs of new sediment, particularly where head and raised beach deposits are eroded such as around parts of Croyde and Morte Bay. Along these frontages, there could be a supply of sediment to the beaches as the cliffs erode and if the cliffs erode back at a sufficient rate beaches could be retained in front.

Where beaches are backed by low-lying land, then the tendency will be for these to continue to roll landwards as sea levels rise, becoming more swash aligned and vulnerable to overtopping, overwashing and breaching due to a lack of new sediment inputs to the beaches as this roll back occurs. There would therefore be increased risk of inundation of low-lying areas behind these beaches with rising sea levels, with any breaches potentially becoming permanent during this epoch.

The evolution of both the Taw/Torridge and Parrett estuaries as sea levels rise will continue to have a significant influence on the evolution of the adjacent coastal areas. There is much uncertainty about both the open coast and estuary interactions and the potential impacts on these of changes in estuary regimes. Therefore it is not possible at the present time to be able to provide a quantified assessment of potential impacts.

C.4.3 NAI Scenario Assessment Table

Location	Predicted Change for 'No Active Intervention'		
	Short Term (to 2025)	**Medium Term (to 2055)**	**Long Term (to 2105)**
Lundy	Undefended cliffs apart from at Landing Bay, where defences include a concrete seawall with masonry splash wall, concrete breakwater and stone gabion revetments. Without further maintenance these would be expected to begin to fail by the end of this period.	Undefended cliffs apart from at Landing Bay, where the effect of defences, including concrete seawall with masonry splash wall, concrete breakwater and stone gabion revetments, would gradually diminish during this period as they fail and are lost due to lack of maintenance.	Undefended cliffs apart from at Landing Bay. There would be no defences at Landing Bay during this period as they would have failed during the medium term.
	The resistant granite cliffs have historically been eroding very slowly. In the future it is predicted that recession will continue to occur at similar historic rates such that there would be negligible change along most of this coastline during this epoch. Along the south-east of the island, soft slates are exposed and these are more prone to erosion, with up to 10m of recession possible due to infrequent rock falls. Erosion of these softer cliffs will provide material to the small pocket beaches, which are predicted to remain relatively stable. The defences in Landing Bay would deteriorate due to a lack of maintenance during this period, which may increase the risk of cliff erosion, where the soft slates are exposed, i.e. along the coast road. Between 0 and 10m of erosion could therefore occur once defences fail.	Erosion of the granite cliffs will continue to occur at very low rates, with negligible change expected around the majority of the island; in isolated areas, where softer slates are exposed, up to 10m of recession is possible as a result of small scale, infrequent rock falls. Although sea level rise will increase exposure of the cliffs, the resistant nature of the granite cliffs means that it is unlikely to affect the erosion rate. Where small pocket beach lie at the toe of these cliffs these could become submerged and lost as sea levels rise. Where the softer slates outcrop, sea level rise could potentially increase erosion rates slightly, although sediment would be supplied to the fronting beaches, which could provide some toe protection. The loss of defences at Landing Bay will allow coastal erosion to occur naturally by the end of this period. Here the cliffs are cut into soft slates, which can collapse easily and erosion rates could	The resistant granite cliffs have historically been eroding very slowly. In the future it is predicted that recession will continue to occur at similar historic rates such that this frontage would change very little during this epoch, with up to 10m of recession possible in isolated areas, where softer slates are exposed, as a result of small scale, infrequent rock falls. Sea level rise may cause erosion rates along the softer slate cliffs to increase as the cliffs become increasingly exposed to wave action. Material supplied from this erosion may be retained locally as small beaches.

Location	Predicted Change for 'No Active Intervention'		
	Short Term (to 2025)	Medium Term (to 2055)	Long Term (to 2105)
		increase as the effect of the defences diminishes.	
Hartland Point to Westward Ho!	Undefended cliffs apart from localised defences at Clovelly (breakwaters, groynes and seawall) and Buck's Mill (gabions and seawall).	Undefended cliffs apart from localised defences at Clovelly (breakwaters, groynes and seawall) and Buck's Mill (gabions and seawall). These may fail towards the end of this epoch.	Any defences remaining would be expected to fail within this epoch.
	The cliffs along this coastline are generally cut into interbedded sandstones and shales, which have been subject to faulting and folding in the geological past. As a result, the cliffs are subject to different rates of erosion, with some stretches being fairly resilient to erosion and other stretches prone to large landslips. The shales tend to be more easily eroded than the sandstones but rates of erosion also depend upon the bedding and the degree of faulting and folding. Overall, this coastline has generally experienced low rates of erosion and this trend is expected to continue in the future, such that generally this frontage will maintain a similar form during this epoch. Along much of this coastline erosion is likely to be less than 10m over the next 20 years. However, certain stretches may be prone to landslip events, which could cause between 10 and 50m through a single event. Narrow cobble and gravel beaches are present at the toe of the cliffs. To the west of Chapman Rock these tend to be confined to small pocket beaches, but to the east they become more continuous, forming a barrier beach. Much of this	Much of this coast will continue to erode, with less than a total of 25m expected by year 50. However, there is a risk of localised landslide events, which could result in up to 10 to 50m of erosion during a single event. Areas where shales outcrop and previous landslips are evident are most at risk. Sea level rise is predicted to increase erosion rates along these softer cliffs as the cliffs come under increasing attack due to higher water levels. The frequency of landslips may also be affected by any increase in rainfall resulting from future climate change; however, due to uncertainty in the possible future changes in precipitation, no direct account has been taken of this in the predictions. Erosion of the cliffs will supply some sediment to the beaches, although much of the material that makes up these cobble and gravel beaches is essentially relict. Finer material will be transported westwards and either deposited on the intermittent beaches or transported west beyond Hartland Point to be recirculated within the Bideford Bay circulatory system. The pocket beaches along the frontage to the	Continual slow erosion of the cliffs is expected along much of this frontage; although there is a risk of isolated landslips where softer rocks outcrop. Here the risk of landslips will increase due to sea level rise and any change in precipitation patterns. Where the coast is backed by resistant cliffs, sea level rise is unlikely to affect the rates of erosion. Between 10 and 50m may be expected along much of the frontage, with actual recession dependent upon the local geology, which varies due to the complex pattern of faulting and folding along this stretch of coast. In a single landslip event up to 10 to 50m of erosion could occur. Although the beaches are mainly relict and composed of gravel and cobble, any erosion of the cliffs may contribute to their stability. As sea levels rise, some of the smaller pocket beach along the western end of this frontage may become submerged. Along the rest of the frontage beaches are likely to be retained, but due to the predicted increase in water levels may be narrow and become more volatile as larger waves will be able to reach the upper beach on a more

Location	Predicted Change for 'No Active Intervention'		
	Short Term (to 2025)	Medium Term (to 2055)	Long Term (to 2105)
	material is likely to be relict, but cliffs may input some material to the beaches. The coarser material will tend to remain locally and be moved very slowly along in a net eastwards direction, with the finer sediments transported further eastwards to be recirculated within the Bideford Bay circulatory system. During this period both the barrier beaches and the pocket beaches are likely to remain relatively stable. At Clovelly there is currently a small harbour enclosed by breakwaters and backed by a seawall. These structures are assumed to remain during this period and will therefore continue to afford protection to the enclosed beach and backing infrastructure. The harbour structures will also continue to affect the net eastwards, but are only likely to have a very local effect as Clovelly sits within a natural embayment. At Buck Mills there is a short stretch of seawall and gabions, associated with access to the beach. These structures are assumed to remain during this period and will therefore continue to afford protection to the backing infrastructure.	west of Chapman Rock are self-contained; therefore they are predicted to remain stable during this epoch. At Clovelly, the structures associated with the small harbour are at risk from failure during this period. As the outer harbour arm fails this will allow more throughput of sediment along this frontage, which may improve beaches within the present harbour, but could result in erosion of beaches to the immediate west of the harbour arm. However, due to the slight, natural embayment and the shelter afforded from westerly conditions, a reasonable beach is expected to be retained along this frontage. At Buck Mills failure of the short stretch of seawall and gabions would occur. There could therefore be increased wave action at the toe of the cliffs and a risk that loss of these structures could result in reactivation of the cliffs behind, where a landslip occurred in 1989. The impact would, however, be very localised.	frequent basis. The remains of structures at Clovelly may continue to have some impact, but it is likely that alongshore transport of sediment will have resumed. The frontage may become more exposed to wave attack due to increased sea level rise, but the cliffs backing this frontage are very resistant and therefore unlikely to change.
Westward Ho! to Taw/Torridge Estuary	Westward Ho! is protected by a seawall with additional rock armour toe protection at the northern end. Without maintenance, this wall is likely to begin to deteriorate during the early part of this epoch, with failure of the main wall and	Any remaining structures at Westward Ho! would be expected to fail early during this period. The rest of the frontage is undefended.	The entire frontage would be undefended.

Location	Predicted Change for 'No Active Intervention'		
	Short Term (to 2025)	Medium Term (to 2055)	Long Term (to 2105)
	revetment expected by the end of the period. The rest of the frontage is undefended.		
	The southern end of this frontage is characterised by low cliffs, which turn inland and are replaced by an extensive spit and dune system of Northam Burrows, which has formed at the mouth of the Taw/Torridge estuary. This spit and dune complex is set back about a kilometre from the cliffed coastline to the west. It is fronted by a pebble and cobble beach ridge, known as the Pebble Ridge, which extends from Westward Ho! into the mouth of the Taw/Torridge Estuary. Seaward of the ridge is a wide intertidal sand beach, which merges, to the north, into the tidal flats of the Taw/Torridge Estuary. At the southern end of this frontage the low cliffs are cut into raised beach deposits, which consist of sand and rounded pebbles. These are currently eroding and therefore release some pebbles into the beach system. These low cliffs, where undefended, are expected to continue to erode at a similar rate to present, which is estimated to be between 0.1 and 0.5m/year. Further east there is a seawall and revetment which initially will continue to prevent cliff erosion, but by the end of the period these structures are assumed to fail; leaving the cliffs and backing properties at risk from erosion. The Pebble Ridge currently receives only limited inputs of new sediment and historically it has	At the southern end of this frontage, erosion of the undefended low cliffs would continue (with up to 5 to 25m retreat possible), which would release some sand and cobble sized sediments into the system. It is likely that defences along Westward Ho! would have failed during this period, therefore the risk of flooding and erosion would increase along this frontage. However, any reactivation of the low cliffs would be unlikely to significantly contribution to the beaches along this stretch. Historically the pebble ridge that fronts this section has been realigning towards a swash-aligned position. This has meant that the southern end of the feature has retreated more rapidly than the northern end. This landward roll back of the ridge has been accompanied by a net reduction in volume. This process is expected to continue in the future as it is not thought that the feature has yet attained a swash-aligned position. This trend is expected to continue in the future and it has been postulated that the rate of retreat could increase exponentially in the future, with between 100 and 150m retreat possible by year 50. As material is moved from south to north and is not being replaced in sufficient quantities from further south, the risk of the Pebble Ridge becoming breached will increase during this	The previously defended frontage at Westward Ho! is at risk from flooding and erosion during this epoch (with up to 10 to 50m retreat possible). Retreat, realignment and subsequent break-down of the Pebble Ridge will continue, with greatest rates of erosion at the northern end. The ridge could have retreated over 300m in total by the end of this period. This stretch of low-lying coast will therefore be at high risk from flooding due to breaching and increased overtopping. It is unlikely that breaches, particularly at the southern end, will seal naturally therefore a number of tidal inlets may be present, which may accelerate the rate of barrier breakdown. These inlets may, however, allow sediment incursion into these back-barrier areas allowing accumulation of finer sediments in the long term; however, this is likely to be a slow process (Orford, 2004: Pethick, 2007). There is, however, a small possibility that a pulse of sediment could be supplied to this shoreline, should a large landslip event occur to the west. However, it has been questioned whether sediment would actually reach this frontage, even if such an event occurred, due to the landward retreat of the ridge (Orford, 2004).

Location	Predicted Change for 'No Active Intervention'		
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	been eroding; this erosion is predicted to continue during this epoch, associated with a gradual movement towards swash-alignment from the previous drift-aligned shoreline. The ridge crest is narrowing and lowering and, as such, the risk of overtopping and possibly even breaching is predicted to increase during this epoch. Any breaches during this period would be expected to be re-sealed by littoral processes as there is sufficient material being moved alongshore to achieve this. Sediment eroded from the cliffs to the south will be moved along this frontage, but finer sediments are likely to continue northwards into the mouth of the estuary and from there either be moved into the outer estuary or into the sediment circulation system and eventually back onto these beaches. The transport of coarser sediments is more limited and there is a very limited supply of new sediments; therefore the trend of net volume loss along the Pebble Ridge is expected to continue.	period and it is likely that over time these breaches will not become sealed naturally. This will expose the low-lying area behind and the dunes at Northam Burrows to erosion and flooding. The location of any breach may be significant, for example a breach into Sandymere Lagoon may result in the development of a tidal inlet. Sea level rise will also increase the likelihood of hinterland flooding and breaching of the defences. It is thought unlikely the Taw/Torridge Estuary would cut an alternative route through the low-lying area behind the barrier. There may be increased pressure at the mouth of the estuary, but changes here are expected to be small due to the influence of the cobble ridge at Grey Sand Hill.	It is thought unlikely the Taw/Torridge Estuary would cut an alternative route through the low-lying area behind the barrier. There may be increased pressure at the mouth of the estuary, but changes here are expected to be small due to the influence of the cobble ridge at Grey Sand Hill.
Taw/Torridge Estuary: Outer Estuary	The northern seaward side of Northam Burrows is protected by rock armour where it re-curves into the estuary mouth; this is assumed to remain. Along the northern side of the estuary mouth there is a series of groynes at Airy Point, although their current impact on drift is minimal, and a rock revetment along Crow Neck that protects against erosion: this is assumed to remain,	The rock armour revetments at Northam Burrows and along Crow Neck are assumed to fail towards the end of this epoch. Some embankments may remain in the Taw and Torridge Estuaries.	The outer estuary would be undefended and many of the embankments within the Taw and Torridge are assumed to have failed or will be less effective given sea level rise.

Location	Predicted Change for 'No Active Intervention'		
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	although there is a risk it could be breached.		
	The channel in the outer estuary is characterised by a number of rock outcrops which ultimately constrain channel movement. The mouth of the estuary is also constrained by the high rates of longshore transport, which have resulted in the formation of the two spits. Despite the trend for swash alignment along Braunton Burrows shoreline, during this period little change is anticipated in the rate of longshore drift; therefore this will remain a constraint on the mouth width. The defences will remain similar to today; therefore the current trend of very slow accretion within the estuary is likely to continue. The trend of dune erosion at Crow Neck is expected to continue, but should be controlled by the defences here. There is a risk that defences could be breached at Crow Neck, should an extreme event occur. However, this is not thought likely to fundamentally change the estuarine regime, as it has been suggested (Pethick, 2007) that the dunes sit on top of a sub-aerial feature, which will continue to both provide a sediment pathway into the outer estuary and to dissipate wave energy. The defences within the inner estuaries of the Taw and Torridge are assumed to remain and therefore changes within the inner estuaries will	During this period the impact of accelerated sea level rise and changes in the alignment of the Pebble Ridge, along the open coast to the south, may start to have an impact on the estuary and in particular the outer estuary. Defences with the inner Taw and Torridge estuaries may also start to fail or become less effective during this period, which would potentially open up more areas to flood. The impact of sea level rise will result in the estuary attempting to widen at its mouth. There are geological constraints, but also the strong longshore movement of sand has also been a constraint on the mouth width. As the open coast to the south become swash-aligned, rates of longshore drift will reduce; potentially allow the mouth of the estuary to widen. The cobble ridge along the northern shore will provide some protection; therefore it is possible that the Airy Point shoreline will suffer greater erosion (Pethick, 2007). The failure of the revetment at Crow Point may result in an increase in the erosion of the spit. As areas open up within the inner estuaries, this will also affect the estuary regime. Within the Torridge changes are limited by the geological structure of the estuary and therefore changes are likely to be small. Within the Taw there is	There is a high level of uncertainty with regard to how the estuary will evolve as sea levels rise. In general the trend of slow infilling is expected to continue, with sediments from alongshore and the nearshore being moved into the estuary. Any erosion and/ or breach of Crow Neck is not expected to affect this process, as this dune feature is thought to overlie a sub-aerial one (Pethick. 2007). As the open coast to the south become swash-aligned the longshore drift along the open coast is expected to diminish, allowing greater potential for the estuary mouth to widen, through erosion of the northern and southern shorelines. The channel position, will, however, continued to be partially constrained by the incised rock channel. Changes within the inner estuaries of the Taw and Torridge are likely to enhance this process, due to greater tidal power and increased tidal prism. The estuary will remain a net sink for sediment and as demand for sediment increase; this could result in increased erosion of the open coast shorelines as more sediment is moved into the estuaries. It is, however, very difficult to quantify such impacts, without further study.

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	be small.	greater potential for change. Simply considering sea level rise it is expected that the estuary would remain a sink for sediments and would continue to slowly infill. Any flooding of previously reclaimed areas could reduce this trend, but is unlikely to lead to net erosion (Pethick, 2007). A key change is estuary state could arise from flooding of Horsey Bank, which was formally a lagoon area. This would both increase the tidal power of the estuary, leading a widening of the estuary mouth and also would be a sink for sediments. This would be affected further if the area behind, Braunton Marsh, were also allowed to flood. A sediment pathway into the estuary is expected to remain, with sand and finer sediment being moved into the estuary from alongshore and nearshore open coast areas. Should the demand for sediment increase, e.g. should formed reclaimed areas become flooded, this may be at the expense of the adjacent shorelines (Pethick, 2007)	
Taw/Torridge Estuary: Torridge Estuary	There is a range of flood walls and embankments protecting settlements and reclaimed farmland including Bideford, Hallspill and Appledore, Yelland and Instow. Most of these defences (including all of the flood walls) are assumed to remain for the majority of this period.	Remaining embankments are assumed to fail or become less effective towards the end of this epoch.	Any remaining embankments are assumed be less effective due to sea level rise.

<table>
<tr><th rowspan="2">Location</th><th colspan="3">Predicted Change for 'No Active Intervention'</th></tr>
<tr><th>Short Term (to 2025)</th><th>Medium Term (to 2055)</th><th>Long Term (to 2105)</th></tr>
<tr><td></td><td>During this period, the defences are generally expected to remain in situ and therefore little net change is expected within the Torridge Estuary, with current trends expected to continue. This may place increased stress on the defences at Appledore and Bideford due to the current position of the meanders.</td><td>The failure of defences during this epoch would be expected to result in the inner estuary reverting to a more natural alignment. Therefore more areas will be at risk from flooding.

The impact on the Torridge is likely to be greater than the Taw due to the relative size of the two estuaries (Pethick, 2007). However, the net trend for slow infilling of the estuary is predicted to continue.

Patterns of erosion and accretion will therefore depend upon meander positions: configurations of the low water channel will influence future patterns of erosion, sediment transport and deposition within the intertidal area. There is potential for increased stress along existing defences at Torridge Bridge and Westleigh (Pethick, 2007).</td><td>Future change is difficult to predict due to the uncertainty of estuary development following sea level rise and climate change. The Torridge is extremely confined by its geology, with limited opportunity for salt marsh development, even if sufficient sediments were available. Much of the estuary is therefore likely to undergo limited change.

Where defences fail there will be an increased risk of flooding and this could affect the estuary regime. However, the net impact of both this and sea level rise is unlikely to affect the net trend of slow infilling, although the rate of infilling may decrease (Pethick, 2007).

A key influence on patterns of accretion and erosion will remain the natural meandering of the channel. Again for much of this estuary the position of the channel is constrained by geology and in these areas little change is anticipated. Key areas of risk will be Torridge Bridge, Westleigh and the confluence with the River Yeo (Pethick, 2007).</td></tr>
<tr><td>Taw/Torridge Estuary: Taw Estuary</td><td>There is a range of flood walls and protecting settlements including Barnstaple, Sticklepath and Bishop's Tawton. There are also defences associated with the railway and reclaimed farmland upstream of Barnstaple.

Most of these defences (including all of the flood walls) are assumed to remain for the majority of</td><td>Remaining embankments are assumed to fail or become less effective towards the end of this epoch.</td><td>Any remaining embankments are assumed be less effective due to sea level rise.</td></tr>
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Location	Predicted Change for 'No Active Intervention'		
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	this period.		
	During this period, the defences are generally expected to remain in situ and therefore little change is expected within the Taw Estuary, with current trends expected to continue. Key areas at risk will be at the apex of meanders, such as at Barnstaple. Upstream of Barnstaple, the edge of the floodplain is bordered by a railway embankment on the right bank and by rapidly rising ground on the left bank. Here little or no change is anticipated.	During this period the impact of accelerated sea level rise and failure of defences will become more significant. Overall net, slow infilling of the estuary is expected to continue, but opening up of former reclaimed areas, as defences fail, will affect sediment demand within the estuary and also the tidal prism. This will affect both the Taw and the outer estuary. With sea level rise there would also be potential for erosion at Barnstaple and Sticklepath as the estuary tries to widen in response to a greater tidal prism. This would put increased pressure on defences and accelerate their failure. A key risk will be increased flooding, although the extent of flooding will, for much of the estuary, be confined by the steeply sloping valley sides. A key control on patterns of erosion and accretion will remain the configurations of the low water channel. There is potential for increased stress of existing defences West Ashford, Home Marsh Farm and Bickington (Pethick, 2007) and this may accelerate failure of defences.	Future change is difficult to predict due to the uncertainty of estuary development following sea level rise and climate change. The net trend of sediment infilling is expected to continue, although the supply of muddy sediment is low. Large areas in the estuary downstream from Barnstaple are at risk from flooding as defences fail and this will change the tidal prism of the estuary. A key result could be widening of the estuary mouth and channel widening at Barnstaple and Sticklepath, through bank erosion. Upstream from Barnstaple, the flood plain is ultimately limited by the steeply sloping valley sides. A key control on patterns of erosion and accretion will remain the configurations of the low water channel. There is potential for increased erosion of the shorelines at West Ashford, Home Marsh Farm and Bickington (Pethick, 2007).
Taw/Torridge Estuary to Saunton Down	This frontage is largely undefended apart from a series of groynes at Airy Point and a blockwork wall and gabions at Saunton Sands, which are assumed to remain during this period.	The ineffective groynes at Airy Point, together with the wall and gabions at Saunton Sands, is assumed to fail during this epoch	By this period there are not likely to be any defences remaining.

Location	Predicted Change for 'No Active Intervention'		
	Short Term (to 2025)	Medium Term (to 2055)	Long Term (to 2105)
	This frontage comprises the extensive dune system of Braunton Burrows which is fronted by a wide sandy beach. The beach is controlled by the headland of Saunton Down to the north and the headland of Westward Ho! to the south. As such the beach is predicted to remain generally stable during this epoch, although the southern section will be influenced by any changes in the Taw/Torridge estuary. Any sediment eroded may be returned to the shoreline from offshore stores. The groynes at Airy Point are largely ineffective and thus not considered to have a significant impact on future processes.	Failure of the defences is unlikely have a significant impact on the behaviour of the larger scale dune system, and this system is expected to remain fairly resilient to change. There are likely to be localised areas of accretion and erosion, with the possible development of blow-outs at some locations. Overall the dune system is expected to maintain a net positive budget. If a blow-out were to develop along the central section there is a risk that the backing slack areas could become flooded on every spring tide. The impacts of sea level rise may start to felt during this period; however, the primary driver of dune erosion is likely to be the frequency of storm events and the coincidence of surges with high wave activity, which is when the majority of the dune erosion takes place. Actual erosion and accretion rates along the frontage will therefore be dependent upon the future frequency and strength of storm events. There is, however, currently large uncertainty over whether frequency of storms will increase, or storm tracks change, as a result of climate change. Any sediment eroded from the dunes is expected to remain within the system; therefore the dune system as a whole is, however, likely to remain relatively robust. The future evolution of this frontage is also linked	During this period a key influence on this beach-dune system will be any change in sediment input due to either the change in shoreline orientation along the Pebble Ridge and Northam Burrows to the south or changes in the estuary tidal delta resulting from changes in the Taw/Torridge estuary regime. Although the dune system as a whole is expected to remain fairly resilient to change, this period could be one of shoreline retreat and erosion of the frontal dunes. A primary driver of dune erosion will be the frequency of storm events and the coincidence of surges with high wave activity. There is, however, uncertainty over whether frequency of storms will increase, or storm tracks change, as a result of climate change. Any sediment eroded from the dunes is expected to be moved into the sediment circulatory system, but the return of sediment to this shoreline may be reduced. A breach is considered unlikely due to the width of the dunes, but erosion of the frontal dunes may lead to slacks become flooded on every high tide.

Location	Predicted Change for 'No Active Intervention'		
	Short Term (to 2025)	Medium Term (to 2055)	Long Term (to 2105)
		to changes within the Taw/Torridge Estuary system and in particular the tidal delta, which plays an important role in terms of sediment circulation within the Bay. This delta allows sand to bypass the estuary mouth, while maintaining an open channel to the sea (Pethick, 2007).	
Saunton Down to Baggy Point (Croyde Bay)	This section is largely undefended apart from a seawall protecting the northern end of Croyde Bay, which is assumed to remain during this period.	The seawall at the northern end of Croyde Bay would be expected to fail during this epoch.	No defences.
	Croyde Bay is enclosed by the resistant headlands at Saunton Down and Baggy Point. It is thought to be a 'closed system' in terms of sediment transport, with sediment tending to be internally redistributed. The bay itself is characterised by a wide sandy beach backed by dunes. The headlands of Saunton Down and Baggy Point are characterised by a rock platform and lower cliff composed of resistant shales, overlain by raised beach deposits consisting mainly of sands with pebble layers and some shingle. The headlands are predicted to continue to evolve as historically. The resistant shale deposits will change very little, but where the softer raised beach deposits outcrop there is a risk of erosion though either toe erosion or sub-serial weathering, which could result in a few metres of erosion during a single event. Cliff erosion at the northern end of Croyde Bay will be prevented by	Erosion of the headlands is predicted to continue as historically: Baggy Point is expected to erode very slowly (i.e. less than 5m erosion by year 50), but at Saunton Down there is a risk that isolated landslide events could cause up to 50m erosion. During this period, the resistant rock platform will continue to afford some control on the backing cliffs, but there is a risk of erosion, through sub-aerial processes of the sandy cliffs above. The beach in the centre of Croyde Bay has historically been relatively stable due to the headlands, and it is predicted to continue to remain so during this period, despite sea level rise. There may be localised areas of dune erosion, mainly driven by human activity, but any slight erosion is not predicted to affect the integrity of the beach or the wide dune system backing it, with any sediment eroded from the	Erosion of the cliffs either side of Croyde Bay, will continue as historically, although there is a risk that sub-aerial weathering of the softer cliffs could increase should precipitation increase in the future due to climate change. Baggy Point is expected to erode very slowly (i.e. less than 5m erosion by year 50), but at Saunton Down there is a risk that a landslide events could cause up to 50m erosion at any one location, although along the remainder of the coast change could be less than 10m. At the northern end of the bay, erosion of the low cliffs could occur following failure of the defences and retreat could be in the region of 10 to 40m. Any sediment released by cliff erosion would be added to the beach at Croyde. The beach in the centre of Croyde Bay has historically been relatively stable due to the protective influence of headlands. During this

Location	Predicted Change for 'No Active Intervention'		
	Short Term (to 2025)	Medium Term (to 2055)	Long Term (to 2105)
	the continued presence of defences. The beach in the centre of Croyde Bay has historically been relatively stable due to protection afforded by the headlands, and this trend is predicted to continue during this period. Any sediment eroded from the beach or dune face is likely to be retained and redistributed within the bay.	beach or dune face likely to be re-deposited within the bay. The failure of the seawall at the northern end of the beach may result in some localised cliff erosion and this could be between 0 to 15m. The rock platform along this stretch could provide some protection from wave attack, but not during storm conditions.	period, however, raised water levels, due to sea level rise, may mean that the foot of the dunes is reached more frequently, resulting in erosion. During quiescent times some of this material will be returned to the dunes, but it is possible that a net trend of retreat could be initiated, particularly considering the limited input of new sediment to this system. Actual rates of erosion will be dependent upon the future frequency and strength of storm events, which is when the majority of the dune erosion will take place. There is, however, large uncertainty over whether frequency of storms will increase, or storm tracks change, as a result of climate change.
Baggy Point to Morte Point (Morte Bay)	Most of the frontage is undefended. There are local defences at Putsborough, in the form of masonry walls, and rock revetment which protect the car park to the south and dunes along the northern end of Putsborough. Some of the defences could start to fail towards the end of this period. Currently dune management is carried out, but this is assumed to cease under this scenario.	The local defences at Putsborough are expected to fail during this period.	Residual remains of defences only.
	Morte Bay is controlled by the erosion-resistant headlands of Baggy Point to the south and Morte Point to the north. The bay itself comprises Woolacombe Sand; a wide sandy beach backed by dunes and Woolacombe Down, and Barricane Beach and Grunta Beach; small pocket beaches separated from Woolacombe Sand by smaller	The resistant headlands will change very little during this period, although there is a risk of localised erosion events occurring, which could cause several metres of cliff recession. The primary drivers of dune erosion will be the frequency of storm events and the coincidence of surges with high wave activity, as well as the	There will be very little change along the resistant headlands, although local cliff fall events may occur. Sea level rise is unlikely to significantly accelerate this process. Erosion of the dunes will be driven by storm events; however there is significant uncertainty over whether frequency of storms will increase,

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	headlands. The frontage as a whole is predicted to remain largely stable during this epoch due to the controlling nature of the headlands. The headlands are resistant and are predicted to continue to erode at the very low rates experienced historically; erosion is likely to be in the form of small, infrequent rock falls; therefore negligible erosion is predicted during this period, but the occurrence of very localised events, which are likely to result in less than 10m erosion, is possible. The frequency of storm events will be the key control on the rate of future dune erosion. Any sediment eroded from the dunes will become deposited on the beach, and therefore may return to the dunes during quiescent periods, as cross-shore transport is dominant in Morte Bay. It is also possible that some sediment may be lost offshore. Overall the dune system should change little during this period, but it will be vulnerable to human pressures. The pocket beaches of Barricane Beach and Grunta Beach, to the north of Woolacombe, are predicted to remain stable. At Putsborough there could be issues of cliff erosion along the car park. Defences along the private properties could also start to become less effective during this period; these properties tend	impact of human use of the dunes. Actual erosion and accretion rates along the frontage will be dependent upon the future frequency and strength of storm events, which is when the majority of the dune erosion will take place, and under a scenario of sea level rise, waves will reach the dune toe more frequently. There is, however, uncertainty over whether frequency of storms will increase, or storm tracks change, as a result of climate change. This is essentially a closed sediment system, therefore sediment eroded from the dunes should become deposited on the beach, but there may also be a loss of sediment offshore. The pocket beaches of Barricane Beach and Grunta Beach, to the north of Woolacombe, are predicted to remain stable, although sea level rise could begin to cause narrowing and steepening as a result of coastal squeeze against the backing, erosion resistant cliffs. At Putsborough any remaining defences will become less effective with erosion of the cliffs along the car park and also increased flood risk to the private properties. As the rock revetment fronting the dunes becomes less effective, erosion of the dunes will recommence; this is likely to be mainly during storm events. Erosion along this stretch could be in the region of 5 to 25m by the end of this period.	or storm tracks change, as a result of climate change. Without management of the dunes, any erosion may also be exacerbated by human use of the dunes. Retreat of the dunes through a roll back process is not possible due to the backing topography of Woolacombe Down; therefore it is likely that the dune belt will narrow in the future. Where the dunes narrow sufficiently, for example at Putsborough where the dune belt is narrow already, the relict cliffs may become exposed to the waves and therefore erosion may occur. Erosion along this stretch is expected to be in the region of 10 to 50m by the end of this period. This would add sediment to the system, but it is not predicted that a significant quantity would be released during this period. Barricane Bay, to the north of Woolacombe, is predicted to experience narrowing and steepening as a result of coastal squeeze against the backing, erosion resistant cliffs, as sea levels rise.

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	to be located on more resistant rock outcrops therefore the key risk could be from overtopping during extreme events. To the north, the rock revetment along the dunes may become less effective during this period, which may result in increase erosion of the backing dunes.		
Morte Point to Widmouth Head	Largely undefended cliffs. There are local defences, including a seawall at Lee Bay, sea defences at Ilfracombe and a seawall at Hele Bay. There are also harbour structures at Ilfracombe which may have some defence function. The walls at Lee Bay and Ilfracombe are assumed to be at risk from failure during the latter half of this epoch, although they may continue to have an impact on the coast. The seawall at Hele is assumed to remain.	Largely undefended cliffs. Localised defences at Hele Bay may fail during this epoch. All other defences have failed, although the Ilfracombe structures may continue to have an impact on the coast.	Largely undefended cliffs. Residual defences may continue to have some localised impact on the shoreline.
	This frontage is comprised of hard rock, namely slates, shales and sandstones with heavily indented embayments formed due to differential erosion. These embayments are effectively closed systems which are unconnected in terms of sediment transport. Historically this frontage has only experienced slow rates of recession, in the region of a few hundred metres, since sea levels stabilised approximately 4,000 years ago. Therefore, in general, this coast is expected to experience negligible change over the next 20 years. Any erosion will be in the form of infrequent and small scale events.	As the cliffs are resistant, erosion is likely to be in the form of infrequent and small scale events; therefore, negligible change is anticipated over the next 50 years. Due to exposure of different rock types, there will, however, be slight variations in erosion rates along the coast, with the risk that a rock fall event could cause several metres of erosion; however this will only have implications very locally and for much of the coast the frequency of such of an event is considered to be 'low', i.e. every 10 to 100 years. Morte Point will prevent any sediment supply from the west and the indented nature of this shoreline also means that there is limited	Much of this coastline will remain resistant to change, due to the nature of the geology, with negligible change predicted for this period. Rates of change are also unlikely to be significantly affected by sea level rise. Localised cliff falls will be the main mechanism of retreat, but these will be restricted to very localised areas. The embayments are predicted to continue to narrow due to sea level rise and within the smaller pocket bays beaches may become permanently submerged and disappear. At Ilfracombe, the risk of overtopping and resultant flooding will be high, although ultimately

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	Similar little change is expected to occur within the many embayments, which effectively form a series of closed sediment systems. Storm events may affect beach levels; however it is likely that these will be cyclical changes, with the sediment returning during calmer conditions. At Lee Bay, where the defences will fail or become less effective, the risk of overtopping and flooding will increase. Failure of these defences will only have a localised impact. At Ilfracombe the existing defences and structures are expected to remain, which will continue to minimise the risk of overtopping and associated flooding. These defences do not have an impact on adjacent frontages.	connectivity between the bays. New sediment input to the beaches is therefore dependent upon local cliff erosion, which is generally negligible. Sea level rise may therefore result in some of the smaller pocket beaches becoming permanently submerged, as retreat of the beaches is not possible due to the resistant cliffs to landward, and there is little fresh sediment available. Elsewhere beach narrowing is likely to occur and small beaches may remain at the toe of the cliffs, where fed by rock fall events. At Lee Bay there will be a high risk of overtopping and flooding of the properties where defences have failed. Erosion itself will be limited due to the resistant cliff behind. At Hele Bay failure of defences will be exacerbated by any beach narrowing. There will therefore be an increase risk of flooding and erosion during this period as defences fail. The extent of flooding will ultimately be restricted by the rising topography. The effects of defence failure will only be felt very locally due to the resistant nature of this coastline. At Ilfracombe defences are at risk from failure during this period; this will increase the risk of flooding and erosion of the infrastructure behind. The extent of flooding will be limited by the rising topography behind and ultimately erosion will be limited by the resistant nature of the surrounding geology. A small beach is likely to be retained to	erosion and flooding will be limited by the local topography and nature of the shoreline. A small beach may be retained to the east of Capstone Point, but this is likely to be much narrower during this period, due to sea level rise resulting in higher water levels. Failure of the harbour structures will affect the vulnerability of the inner harbour, and therefore lower part of Ilfracombe, to flooding and erosion.

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		the east of Capstone Point, due to the indented nature of this frontage.	
Widmouth Head to Hangman Point (Combe Martin Bay)	Largely undefended cliffs. There is a localised section of recurved seawall at Combe Martin. There are also harbour structures at Watermouth which may provide some defence function.	The local recurved seawall at Combe Martin is assumed to fail during this epoch. There are harbour structures at Watermouth which may continue to provide some defence.	Any remaining defences are assumed to fail.
	This frontage is comprised of hard rock, namely shale and sandstone, with heavily indented embayments. These embayments are effectively closed systems which are unconnected in terms of sediment transport. Historically this frontage has only experienced very slow rates of recession. Therefore future erosion is expected to be negligible, although there is a risk of localised infrequent and small scale events. The embayments are predicted to remain generally stable during this period; storm events may affect beach levels, however it is likely that these will be cyclical changes with the sediment returning during calmer conditions. Watermouth has historically been eroding and this trend is likely to continue due to the minimal inputs of sediment from cliff erosion.	Along most of this coast there will be negligible change in shoreline position during this period, due to the resistant nature of the cliffs. As a result of sea level rise the small pocket beaches that characterise this shoreline are likely to narrow due to the combination of high water levels, resistant cliffs and lack of new sediment inputs. At Combe Martin, failure of defences during this epoch will result in localised erosion and increased risk of flooding, although ultimately this is be limited by the rising topography behind on either side of the valley and resistant nature of this shoreline. The breakwater is likely to become less effective which will further increase the overtopping and flood risk. Failure of the river training works may also have a local input on beach levels and vulnerability of the backshore to flooding and erosion. This location is also potentially vulnerable to flash flood events.	Negligible change is expected along this shoreline due to the resistant nature of the cliffs; however, many of the smaller pocket beaches may become permanently submerged due to high water levels as sea levels rise and the lack of fresh sediment inputs. The rate of cliff erosion is unlikely to be affected by sea level rise therefore the input of sediment to the system is expected to remain minimal. Elsewhere the beaches are likely to become narrower. At Combe Martin, failure of defences will result in flooding and erosion of the coast locally. This location is also potentially vulnerable to flash flood events which may provide occasional large inputs of sediment as the slate and sandstone bedrock is likely to be eroded during such events.
Hangman Point to	Undefended frontage.	No defences.	No defences.

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Duty Head	The cliffs in this frontage are more uniform than further west and composed of sandstones with alternating slate and shale bands. The cliffs are resistant and any recession is likely to be in the form of very localised and very infrequent events; therefore along the majority of the coast negligible erosion is expected, although locally up to 10m of erosion could potentially result from an isolated cliff fall. Along much of this frontage there is only a small amount of talus at the toe of the cliffs, but pocket beaches are present in the small embayments. There is not thought to be much input to these beaches from alongshore transport, but during this period, the beaches are expected to remain relatively stable.	Negligible erosion is expected during this period, although there is a risk of a small, localised rock fall occurring, which could result in several metres of erosion. However, the frequency of such events is very low and the effects would only be felt at a very local scale. As a result of minimal sediment inputs, resistant backing cliffs and sea level rise, the small pocket beaches may narrow during this period.	The shoreline is not expected to change significantly as the cliffs are resistant to change. There is a risk of a cliff fall event, but the frequency of such events is very low (every 100 to 250 years). It is unlikely that sea level rise will significantly affect this very slow rate of change. Some pocket beaches may become permanently submerged during this period as a result of rising sea levels and the lack of new sediments into the system.
Duty Head to Foreland Point (inc. Lynmouth Bay)	Undefended frontage apart from seawall at Lynmouth and harbour structures (which may provide some defence function). The seawall on the western side of the harbour is fronted by a rock and masonry revetment. These structures are assumed to remain during this period. The cliffs on the west side of Lynmouth are also subject to cliff stabilisation measures to reduce the risk of rock falls. It is thought unlikely that fluvial flash flood events will supply sediment to the shoreline during this period due to continued fluvial defences along the River Lyn.	Undefended apart from the seawall at Lynmouth and harbour structures which may provide some defence function. The seawall on the western side of the harbour is fronted by a rock and masonry revetment. These structures may begin to fail during the latter part of this epoch.	Any remaining defences would be expected to fail in the early stages of this epoch.

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	The cliffs in this frontage are composed of sandstones with alternating slate and shale bands. Along much of the coast the cliffs are very resistant, with negligible change expected over the period. Where softer sandstones are exposed, such as along Foreland Point, slightly greater recession rates as expected, but even here less than 10m would be expected. To the west of Lynmouth, the cliffs tend to be fronted by only narrow talus deposits. To the east of Lynmouth there are narrow linear upper beaches, feed by local cliff erosion; these are expected to remain quite stable during this period. At Lynmouth, the seawall, which runs for over 350m from the harbour westwards along the toe of the cliffs, is expected to remain and will therefore continue to prevent any shoreline retreat. The harbour structures will also afford some protection to the town. The boulder delta at Lynmouth, a legacy of past flash flood events such as that which occurred in 1952, is predicted to remain stable during this epoch. As such, it will continue to provide some protection to the low-lying land behind. The defences along the Lyn River greatly reduce the likelihood of a flash flood event occurring in the short to medium term; these structures are assumed to remain.	To the west of Lynmouth, the cliffs (including where stabilisation works have been carried out) are expected to change very little. Along The Foreland, to the east of Lynmouth, slightly higher erosion rates are expected due to the exposure of softer sandstone deposits. Here between 5 and 25m of erosion may occur by the end of this period. This erosion will supply sediment to the beaches, which should help sustain the narrow beaches present along this stretch. At Lynmouth, the existing defences may start to fail and become less effective during this period. This will result in an increased risk of tidal flooding and erosion to the town behind. The boulder delta is generally expected to remain quite stable and will therefore provide some protection. The defences along the Lyn River greatly reduce the likelihood of a flash flood event occurring and these structures are assumed to remain.	To the west of Lynmouth, the presently undefended cliffs will continue to behave as at present, with only very low rates of retreat anticipated. Further east, along The Foreland, erosion rates will be slightly higher and may be increased further due to sea level rise. Up to a total of 10 to 50m of erosion may occur by year 100. This input of sediment should help to retain narrow beaches along this stretch. At Lynmouth, rising sea levels will reduce the protection afforded by the delta. It is possible that this feature could be rolled landward although it is also possible that it could become submerged by rising sea levels. Failing defences will leave the town vulnerable to tidal flooding and erosion and the cliffs currently protected by the seawall could become reactivated. Unless defences upstream of the Lyn River are maintained during this period, the risk of a flash flood event, which could cause significant damage (such as that experienced in 1952), would significantly increase.
Foreland Point to	There are no defences present along this section.	No defences.	No defences.

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Gore Point	This undefended frontage of sandstone and mudstone cliffs has historically been retreating very slowly and in the future erosion is predicted to occur at similar rates, but with a risk of localised erosion due to wave undercutting at the cliff toe. This may result in the erosion of relict landslip deposits in the upper cliffs, which would erode, but then protect the cliff toe. Sediment transport within this region is limited both due to the resistant nature of the cliffs, and Foreland Point acting as a barrier to drift entering the region from further west.	Negligible change is expected during this period along most of this frontage. Local scale events may cause a few metres of erosion due to long term wave undercutting at the cliff toe and localised rock slides. Sediment transport within this region is limited both due to the resistant nature of the cliffs, and Foreland Point acting as a barrier to drift entering the region from further west. Any sediment movement will be eastwards towards Gore Point, supplying the gravel beaches fronting the cliff and potentially continuing on around into Porlock Bay.	The current trend of very slow retreat is expected to continue and, in general, the form of this frontage is predicted to remain similar throughout all three epochs. There is a risk that the continued undercutting at the toe of the cliffs could result in the erosion of relict landslip deposits in the upper cliffs, which would erode, but then protect the cliff toe. Sediment transport within this region is limited both due to the resistant nature of the cliffs, and Foreland Point acting as a barrier to drift entering the region from further west. Any sediment input through cliff erosion will be transported eastwards towards Gore Point, supplying the gravel beaches fronting the cliff and potentially continuing on around into Porlock Bay; however this is expected to be very small.
Porlock Bay	Defences along the Porlock Bay frontage include a seawall and harbour arm associated with Porlock Weir, and groynes associated with New Works. There is also an earth embankment protecting the car park. These defences are all assumed to fail during the later part of this epoch under this scenario. Under this scenario it is also assumed that beach maintenance works to maintain the ridge between Gore Point and Porlock Weir would cease.	Remaining defences are assumed to fail during this period.	No defences.
	Overall the current trends experienced along the barrier are expected to continue in the future, with the barrier remaining in a state of net	At the large scale the barrier will continue to retreat through a process of overwash; as this is dependent on wave height, it could increase with	The large scale trend of barrier recession and roll back of the gravel ridge via overwashing and

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	retreat. Without any management, the barrier is able to respond naturally and become more dissipative by widening and flattening; however, a continuation of overwashing is predicted during this epoch. Between Gore Point and Porlockford cliffs, Porlock Weir will continue to have an impact on the local sediment drift, with sediment being held on the western side. The defences here also appear to have interrupted the occasional westwards drift of sediment, which has resulted in as lobe of shingle at this location. This area is therefore expected to remain in a similar state to present. Along Porlockford cliffs, cliff recession is likely to continue, albeit at the slow rates experienced recently, i.e. less than 0.5m/year. Overall this stretch will remain quite stable due to the influence of the Porlock Weir and the ebb-tidal at the 1996 breach. The breach is expected to remain open with continued growth of the associated ebb tidal delta. Both spits at the mouth of the breach are likely to remain relatively stable over this period. The area of salt marsh behind the ridge in the vicinity of the 1996 breach is predicted to continue to vertically accrete. The groynes to the east of New Works will continue to have an impact on alongshore drift	future sea level rise. As structures start to fail at Porlock Weir, it is likely that this would allow increased sediment transport along this stretch and may result in quite rapid retreat of the beach barrier along this section. The lobe of shingle will provide some stability to this stretch as it is likely to become cannibalised. Erosion of Porlockford cliffs would continue, but may be at a reduced rate, should sufficient sediment be moved alongshore from the north-west, due to defences failing at Porlock Weir. This may reduce pressure at the Porlockford seawall, which may prolong its life. Failure of this structure would otherwise result in fairly rapid erosion along this short stretch, which stands slightly seawards of the adjacent coast. The 1996 breach is expected to remain open, with continued stability of the western spit and growth of the ebb tidal delta. Growth of this delta could be at the expense of the coast to the immediate west of the breach and here there is a high risk that the barrier integrity could be threatened. Alternatively, it is possible that the delta could afford some protection to the shoreline. The salt marsh behind the breach is expected to continue to vertically accrete, although its lateral extent could start to become squeezed as a result of barrier roll back, as its landward boundary is currently fixed by field	breaching is predicted to continue. Further erosion is expected along the Porlock Weir stretch of coast, following failure of defences along this stretch, with the area to the north at greatest risk due to the limited input of sediment around Gore Point. There will therefore be an increased risk of overwashing and hinterland flooding along this stretch. Erosion of Porlockford cliffs is expected to increase as material released by failure of defences at the weir is transport further eastwards. However, at the large scale, the section of coast to the west of the 1996 breach may start to approach swash-alignment by this time-frame. It is thought likely that the 1996 breach will remain open, due insufficient rates of longshore drift; however, the rate of salt marsh growth behind the breach could decrease the tidal prism sufficiently to allow the breach to reseal. Conversely, an increase in sea level rise would tend to increase the tidal prism; therefore it would depend upon the balance between these two processes. There is therefore a degree of uncertainty associated with this stretch coast and that to the west. It is possible that breaches may occur along other sections of the barrier, particularly to the east of New Works, up to the War Memorial. Despite

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	and should help maintain some beach stability along the barrier along this section; however these groynes do not prevent cross-shore processes and therefore the barrier will still be prone to roll-over as gravel is pushed over the crest. The groynes may therefore start to intercept more sediment during this period, if they do not fail. Further eastwards the barrier is expected to remain generally stable and largely static, as it will continue to be supplied with sediment from the western end of the barrier and is sufficiently robust. Certain sections, are however, likely to become increasingly vulnerable to overwashing and crest narrowing.	boundaries. There is also a risk of breaching along the eastern spit as the breach position moves progressively eastwards. The vulnerability of the barrier along this stretch will also be increased as the remaining groynes to the east of New Works deteriorate and fail or become less effective as the barrier retreats landwards. This would result in increased longshore drift locally and therefore the barrier along this stretch could become reduced in volume and vulnerable to crest recession and narrowing. Here the risk of hinterland flooding would therefore increase. The stretch of coast between New Works and the War Memorial will also be vulnerable to breaching during this period, although up to this point it has remained in a largely static, but oversteepened state. Any sediment released as groynes fail to the east of New Works is likely to continue to moved further eastwards and also the growth of the ebb-tidal delta could result in a diminished input from further west (despite the potential increase in feed due to failure of Porlock Weir). Therefore this stretch could be denuded of volume and in its oversteepened state it is at greater risk of catastrophic breakdown. It is possible that any breaches that form could become permanent, but it has been suggested (Orford, 2003) that inlet efficiency could be reduced, should a number of breaches form,	the increase in sediment being moved alongshore, due to failure of defences, the ebb-tidal delta at the breach could continue to act as a sink for this sediment. There is also a limited supply of sediment in the system as a whole and any sediment moved into this frontage, will continue eastwards towards Hurlstone Point. The frequency of wave overwashing events would also increase with accelerated sea level rise and this coastline would be vulnerable to any increase in storminess or change in wind-wave climate. Any breaches formed, due to catastrophic failure of the barrier, could remain open, but this would be governed by inlet efficiency, which may depend upon the number of breaches forming. It is not thought likely that sediment released by defences updrift failing would be a significant enough to close breaches otherwise. Further east, between Horner Water and Hurlstone Point, the beach will continue to be fed from sediment being moved alongshore; therefore much of this is likely to remain stable and static. Accelerated sea level rise may, however, have an increased impact during this period and it is likely that the boulder foreshore could become less effective in terms of wave dissipation. Therefore during this period, the trend may start to change to net crest recession as the barrier starts to roll landward. The barrier, along most of its length, is likely, however, to

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		which would then limit the permanence of breaches. Further east, between Horner Water and Hurlstone Point, the beach is expected to remain stable and relatively static.	remain robust and provide continued protection to the low-lying hinterland behind.
Hurlstone Point to Minehead	Largely undefended cliffs with some buried groynes immediately west of Minehead, and a terminal groyne associated with the harbour breakwater.	Largely undefended cliffs. The groynes immediately west of Minehead may fail, if exposed, whilst the terminal groyne associated with the harbour breakwater is expected to remain during this period.	Largely undefended cliffs. The terminal groyne associated with the harbour breakwater at Minehead is assumed to remain.
	The heavily faulted and folded sandstones along this stretch of the coastline are predicted to experience low rates of recession as has occurred historically; therefore negligible erosion is predicted by year 20 for most of this coast. However, there is a risk of small frequent rock falls and also larger events occurring at Minehead Bluff, which locally could cause up to 10 to 50m retreat over a short section of cliff. The cliffs are fronted by a narrow gravel beach which is predicted to generally remain stable during this epoch, although trends of beach lowering towards the east may continue. There is little, if any, incoming sediment from updrift areas and therefore beaches rely on local sediment inputs, which are negligible due to the slow rates of cliff erosion. The harbour breakwater at Minehead and associated concrete groyne would continue to	Low rates of erosion are expected to continue, with generally less than 5m erosion predicted by year 50. However, there is a risk of a large landslide at Minehead Bluff, which locally could cause up to 10 to 50m retreat over a short section of cliff. The cliffs are fronted by a narrow gravel beach and beach lowering towards the east may continue. There is little, if any, incoming sediment from updrift and therefore should sediment be lost it would not be expected to be replaced. This trend is predicted to be exacerbated by rising sea levels which will deplete beach sediments further without any significant sources of sediment from updrift areas to replace it. The resistant cliffs means that the beach will be unable to retreat and therefore narrowing is expected. The harbour breakwater at Minehead and associated concrete groyne will continue to trap	The cliffs along this stretch are expected to continue to slowly erode, with less than 10m expected by the end of this period. However, there is a risk of a large landslide at Minehead Bluff, which locally could cause up to 10 to 50m retreat over a short section of cliff. The cliffs are fronted by a narrow gravel beach which is predicted to narrow and continue lowering during this epoch. There is little, if any, incoming sediment from updrift and therefore should sediment be lost it would not be expected to be replaced. This trend is predicted to be exacerbated by rising sea levels which will deplete beach sediments further without any significant sources of sediment from updrift areas to replace it. As long as it remains, the harbour breakwater at Minehead and associated concrete groyne will continue to trap sediment and prevent it

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	trap sediment and prevent it travelling further east around into Minehead Bay.	sediment and prevent it travelling further east around into Minehead Bay. This would help provide some protection to the cliffs immediately north-west of Minehead.	travelling further east around into Minehead Bay. The wider beach that would be retained updrift of the structure would afford some protection to the cliff behind.
Minehead to Blue Anchor	The Minehead urban area is protected by a scheme constructed in 1997-8 consisting of a new recurve seawall, rock revetments and groynes coupled with a large beach recharge. These structures are assumed to remain during this period, although under this scenario no further beach management would take place. Further groynes are found along Dunster Beach protecting the gravel storm ridge. These comprise timber groynes that would be expected to deteriorate and begin to fail by the end of this period. Within Blue Anchor Bay there is a scheme involving a concrete seawall and timber groynes, with the wall reinforced by a rock revetment and T-head rock groynes in the east. These defences are assumed to deteriorate but not fail during this period along this stretch, as they were constructed in the last few years. However, at the very eastern end of Blue Anchor, in the vicinity of the Blue Anchor Hotel, the defences were not upgraded as part of the recent scheme and these defences area expected to fail by the end of this period, under this scenario.	The Minehead urban area is protected by a scheme constructed in 1997-8 consisting of new recurve seawall, rock revetments and groynes; these are expected to remain. Further groynes are found along Dunster Beach protecting the gravel storm ridge, which are all expected to have failed by the middle of this period. Defences along Blue Anchor would continue to influence the coastal evolution throughout this period, though without maintenance, and with accelerated beach narrowing, they will deteriorate further during this period, and would likely begin to fail during this epoch.	The Minehead urban area is protected by a scheme constructed in 1997-8 consisting of new recurve seawall, rock revetments and groynes; these are expected to remain but may become less effective during this period, as this scenario assumes no maintenance or upgrading. Any remaining defences at Blue Anchor will fail as a result of no maintenance or upgrading during this period under this scenario.
	This is a low-lying section of the shoreline fronted	To the west of the Harbour Arm breakwater,	To the west of the Harbour Arm breakwater,

Location	Predicted Change for 'No Active Intervention'		
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	by a gravel and cobble ridge and sandy lower beach. Along some of this stretch the shingle beach forms the main defence, whilst the rest of the coast is protected by seawalls and groynes. At Minehead there have been extensive defence works including a beach recharge. The predominately sandy beach is held in place by large rock groynes. There will be no change in shoreline position due to the defences, and during this period the groynes should maintain beach stability. An overall trend of shoreline retreat is predicted at the Warren due to its exposure to storm wave energy. This area is also vulnerable to overtopping and flooding. It is possible that a breach in the ridge could occur, but the sand dunes that back this area should prevent a total breakdown. To the west, whilst Blue Anchor Bay as a whole has remained quite stable historically, the gravel storm ridge has been eroded, particularly along Dunster Beach, due to the net eastward movement of shingle, but little input from further west. Where groynes have been constructed the beach has remained fairly stable and this trend is expected to continue during this period. Along the undefended stretch net retreat is likely to continue at rate of around 0.6m/year (Black & Veatch, 2006a), with roll back and narrowing of	there could be a risk of flooding, but this would be very minor and there is not a backdoor flood route to Minehead (Black & Veatch, 2006a). Defences are Minehead will remain, fixing the shoreline position at this location. The groynes, whilst reducing longshore losses, will not prevent offshore sediment movement and therefore during this period, under rising sea levels, there may start to be intertidal narrowing. This will put increased pressure on the defences. There is expected to be continued retreat at the Warren with increasing risk of overtopping along this stretch, with associated flooding behind. As the ridge thins the dunes will also become more exposed to wave attack. At Dunster Beach there will be continued erosion, particularly as the groynes start to deteriorate and fail. Under sea level rise, larger wave will be able to reach the shoreline therefore there will be increase pressure on existing defences and increasing risk of breach and flooding. A key risk will therefore be from flooding. There is also an associated risk of backdoor flooding to Minehead (Black & Veatch, 2009). The ridge at Blue Anchor Bay, to the west of the defended area, is also predicted to narrow and roll-back, particularly whilst the defences at Dunster restrict the amount of sediment	there could be a risk of flooding, but this would be very minor and there is not a backdoor flood route to Minehead (Black & Veatch, 2006a). Along the Minehead frontage, defences are assumed to remain fixing the shoreline position, but the net retreat of the beach is expected to continue. There will also be an increased risk of overtopping. Continued shoreline retreat is predicted across the remainder of the frontage. At the Warren, as the ridge becomes increasingly denuded of material the dune behind will become increasingly exposed to erosion and overtopping. Flooding of the hinterland area is therefore a key risk. Between Dunster Beach and Blue Anchor, failure of defences would have resulted in retreat of the ridge along this stretch, with a high risk of breaches. There is a potential backdoor flood route to Minehead (Black & Veatch, 2009).

Location	Predicted Change for 'No Active Intervention'		
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	the ridge. The defences at Blue Anchor itself will prevent roll back of the beach, and thus beach narrowing is expected. The failure of the defences at the eastern end of Blue Anchor itself may lead to rapid erosion of the cliff in this area as the cliff reverts to a more natural position more aligned with the shoreline to the immediate east.	available. To the east, the trend of beach narrowing will continue, which will accelerate failure of defences along this stretch. The failure of the defences at Blue Anchor itself may lead to rapid erosion and roll-back in this area as the beach reverts to a more natural position more aligned with the shoreline to the immediate east.	
Blue Anchor to St Audrie's Bay	Undefended cliffs from Blue Anchor to Watchet and the eastern extent of Doniford Bay to St Audrie's Bay. Watchet is protected by concrete seawalls, and rock groynes and revetments in the harbour area and these are assumed to fail towards the end of this epoch. Between Watchet and Doniford Bay there are localised stretches of defences and small groynes protecting the low-lying land. Doniford Bay is protected by a rock revetment which is also assumed to fail during this epoch.	Defences at Watchet, Doniford and along the coast between Watchet and Doniford are assumed to be at risk of failure by the start of this period.	No defences.
	This frontage mostly comprises Triassic shale and limestone and Jurassic mudstone cliffs fronted by intertidal rock platforms, intersected by small embayments. To the east of Blue Anchor Bay, sandstone cliffs are replaced by mudstones cliffs, which erode via cliff falls, landslips and rotational slides. Such events have resulted in several metres of erosion	The mudstone cliffs along this frontage erode via cliff falls, landslips and rotational slides, which have resulted in significant amounts of erosion at certain locations in the recent past. Along much of the undefended frontage, between 5 and 25m of recession may occur, but a landslide event at any one location could cause up to 10 to 50m of erosion. Differential cliff erosion to the varying geology and continued impact of defences will	Differential erosion of this cliffed frontage will continue, although rates may increase due to sea level rise. Failure will be through both gradual erosion and larger landslide events. Along much of the frontage between 10 and 50m of erosion may be expected, however there is a risk that any one location a large landslip event could cause up to 50m of erosion. Defences along most of the frontage will become ineffective during this period

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	in the recent past. Up to 10m of recession could occur along this undefended stretch of coast by year 20, although there is a risk that a single event could cause between 10 and 50m erosion at a single location. At Watchet the seawall and harbour structures currently fix the shoreline position and therefore there will be no change along this frontage during much of this period. These defences will continue to minimise the risk of flooding and erosion, until they start to fail towards the end of this period. To the south, the defences between Watchet and Doniford will continue to help slow cliff erosion along this stretch for much of this period, but there will be issues of outflanking to either side of the defences. Similarly the rock revetment in front of the Doniford Holiday Camp will continue to afford both erosion and flood protection to the low cliffed areas. Any cliff erosion that does occur will provide sediment to feed the beaches downdrift, i.e. to the east.	result in more pronounced embayments forming along this coastline, with the resistant limestone areas and defended stretches forming headlands. At Watchet, the shoreline position has historically remained fixed by defences, including the harbour structures. Failure of the defences will result in the cliffs to landward becoming reactivated. These cliffs have historically eroded quite rapidly and similar rates may be expected. There is limited information on actual erosion rates, but it could be as high as 1m/year, which could result in up to 30m by the end of this period. To the east, a crenulated-form embayment is forming in the lee of the limestone outcrop at Helwell Bay. Failure of the defences here and at Doniford Holiday Camp are expect to result in erosion; this may initially be more rapid than experienced along undefended adjacent cliffs, as the cliffs have, in places, been held forward of their natural position. At Doniford the beach is narrower than that to the east, and the cliffs are much lower, therefore there would be an increased risk of both flooding, due to overtopping, and erosion during this period. Any cliff erosion that does occur will provide sediment to feed the beach downdrift, i.e. to the east. However, the individual embayments act as semi-closed systems and therefore transport around the headlands is likely to be limited and on a periodic basis. The Swill and its associated	and therefore natural erosion rates will resume. Ultimately the coastline will become defined by a series of crenulated bays, formed between the more resistant limestone outcrops, which will emerge as headlands. In the long term, these bays could reach a more stable form, resulting in lower rates of erosion; however this process may be prevented by the predicted acceleration in sea level rise. Sea level rise are predicted to reduce the defence role of the rocky intertidal platform, and thus the cliff erosion rates along the softer cliffs are likely to increase. Sediment transport rates may also be affected. Rates of cliff erosion will vary across this frontage, with little or no erosion being experienced in some places, but potentially up to 100m in other locations. At Watchet, it is assumed that the harbour structures will fail and become ineffective during this period. This will expose the low-lying coastline currently enclosed by the structures, to flooding and erosion.

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		pipeline does appear to disrupt along shoreline sediment transport, resulting in a build up of beach to the west of the outlet. Although the rock platforms are predicted to continue providing defence to the foreshore, sea level rise may reduce their defence role and therefore the cliff erosion rates could increase. Sediment transport rates may also be affected.	
St Audrie's Bay to Hinkley Point	Undefended shoreline except for rock armour backed by earth embankment at Lilstock. These defences are predicted to fail during the latter part of this epoch.	Undefended shoreline.	No defences.
	This mainly cliffed stretch of coastline is cut into Triassic shales and limestones which have historically eroded slowly due to their resistant nature. Future rates are predicted to be similar to these historical ones with less than 10m of erosion likely by year 20. There, however, is a risk of localised erosion events could result in up to 10m erosion at a single location. This will be a continuation of past trends, which has resulted in a series of small indents along this shoreline. Any sediment eroded from the cliffs will provide material to the foreshore and the extensive rock platforms will continue to afford some protection to the cliffs. There is potential for this sediment to be transported eastwards, towards Hinkley Point, but it is periodically interrupted by small headlands.	The cliffs will continue to erode quite slowly, with up to 5 to 25m by the end of this period. There is, however, a risk of isolated erosion events which may cause several metres of erosion over a very localised stretch. Even under a scenario of sea level rise, the extensive rock platform should continue to afford some protection to the backing cliffs. Any sediment eroded from the cliffs will provide material to the foreshore, which may be sufficient to enable a beach to be retained at the toe of the cliffs. Sediment will also be moved eastwards along the coast. The previously protected coastline at Lilstock is at risk from overtopping and flooding, although this risk will only be localised due to the	There will be continued, slow erosion of the cliffs, with up to 10 to 50m possible by year 100. Small erosion events will result in small bays being cut, reinforcing the naturally indented nature of this coastline. Under a scenario of sea level rise, the shore platforms may become partially submerged, but are likely to still play a role in affording some protection to the backing cliffs and beaches. The foreshore currently provides some protection to the cliffs in the form of the wide intertidal rock platforms, and these are predicted to continue doing so during this epoch. Narrow beaches are expected to be retained, particularly within the small bays formed as the cliffs erode. There is still likely to remain a sediment pathway eastwards towards Hinkley Point, but the

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	The short stretch of rock armour and earth embankment at Lilstock will continue to reduce the risk of flooding and erosion along this lower-lying section of coast for much of this period, but there will be a risk of outflanking due to continued cliff erosion either side.	hinterland topography. Similarly the small area of low-lying land at Kilve Pint is also at risk from flooding during this period as the natural gravel ridge will become more vulnerable to overtopping as a result of sea level rise. The potential for barrier roll back is limited as the coast is backed by rising topography.	interconnectivity of this coast may periodically reduce due to the emergence of headlands. The risk of very localised overtopping and flooding at Kilve Point and Lilstock will increase due to rising sea levels and the risk of the barrier becoming breached. Hinterland flooding will, however, be restricted due to the local topography. There is limited opportunity along this coastline for barrier roll back, therefore there is likely to be barrier narrowing.
Hinkley Point	Defences protecting Hinkley Point in form of recurve seawall backed by gabion baskets. These defences are assumed to remain throughout this epoch.	Defences around the power station site may start to fail during this period.	Remaining defences will fail.
	The low Jurassic lias cliffs around Hinkley Point have historically eroded slowly due to their resistant nature. The shoreline along the power stations frontage protrudes seawards by up to 100m, due to land reclamation during the construction of the power stations. The power stations are therefore believed to be underlain by made ground, composed of limestone and shales excavated from the foundations of the site. Its increased exposure means that shingle beaches are not present at the toe of the defence and waves are able to reach the defences at high water. The defences protecting the power stations are assumed to remain and will therefore fix the shoreline position and continue to	Whilst the defences remain the shoreline will remain fixed in position. Towards the end of this period defences may start to deteriorate and fail. As defences fail this shoreline will be at risk from both flooding and erosion. Erosion of the made ground, which underlies the sites, may be fairly rapid, as the shoreline was artificially extended up to 100m seaward of its original position, when the power stations were constructed. Once the made ground is eroded back to the original cliffs, then erosion rates as likely to return to those experienced historically. This would enable the shoreline to retreat to a less exposed alignment, as well as providing sediment for the gravel ridges to the east. Hinkley	Depending upon the exact timing of defence failure, the position of this shoreline may still lie seaward of its original position (prior to construction of the power stations). Erosion during this period may continue to be initially rapid, until the original cliff line is reached. A more steady rate of erosion would then continue, determined by the natural resistance of the lias limestone cliffs. Rates of recession are likely to be in the region of 0.1 to 0.5m/year. There is also an increased risk of backdoor flooding behind the power station sites, as defences fail to the east.

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	minimise the risk of flooding during this epoch. The defences also interrupt the transport of shingle westwards along this frontage and historically the gravel ridges downdrift have been eroding. This trend is predicted to continue during this epoch.	Point itself is, however, likely to continue to affect the longshore drift of sediment around to Stolford. There is also a risk of backdoor flooding behind the power station sites, as defences fail to the east.	
Hinkley Point to Parrett Estuary	There is a rock revetment fronting an earth embankment from Hinkley to Stolford with earth embankments and gabion walls east of Stolford to Wall Common. The majority of the defences along the western part of this section (Hinkley to Stolford) will remain during this period even without maintenance (as assumed under this scenario), although most of the defences along the Steart peninsula itself are expected to fail towards the end of this epoch.	The defences along the western part of this section would gradually deteriorate and fail during this period without further maintenance or upgrade (as assumed under this scenario). There will be no defences remaining along the Steart peninsula.	No defences.
	To the east of Hinkley Point the hinterland becomes low-lying, forming the start of the Steart Peninsular, which stretches westwards into the mouth of the Parrett. Between Hinkley and Stolford the gravel beaches have been greatly denuded and only a narrow strip of shingle is currently present. Currently the main defence is provided by a rock revetment, but this is also holding the coastline away from its natural alignment, which may be exacerbating the issue of beach loss. It is assumed that this defence will remain during this period.	Towards the eastern end of this frontage, the net long term trend of erosion of the beaches is expected to continue. Localised breaches may also occur as a result of sea level rise and the reduced protection afforded by the shingle ridge, causing flooding of the wide area of low-lying land that makes up the Steart Peninsula. Such breaches would be able to re-seal should cliff erosion provide sufficient sediment, however the continued defences at Hinkley Point may prevent this and breaches may become permanent. The evolution of the Steart Peninsula will also be	The low Jurassic lias cliffs around Hinkley Point have historically eroded slowly due to their resistant nature, and this is predicted to continue during this epoch. Erosion here could be in the region of up to 40m. Landward migration of the ridges is predicted due to sea level rise. Ridge erosion may lead to breaching between Hinkley Point and Steart resulting in hinterland flooding. Breaches may become permanent should there be insufficient sediment to naturally repair them. In this instance a tidal inlet could form which would reduce the

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	Between Stolford and Stert Point, protection from flooding is currently provided by the shingle barrier (and earth embankment/gabion defences) and attenuation of waves across the intertidal flats and salt marshes, which become prevalent towards Steart. The general trend has been long term erosion of both the salt marsh and the shingle beach and this net trend is expected to continue in the future along much of the frontage. Sediment transport rates east of Wall Common are negligible and therefore the beach in this region may remain more stable during this epoch. As the defences along the Steart Peninsula fail, there will be a significant increase in flood risk along this frontage.	dependent upon the Parrett Estuary and any changes in the estuary regime may affect this shoreline. It has been suggested that in the long term a new channel could be cut through the Steart Peninsula; this would significantly alter the hydrodynamic and sedimentary regime of the whole area. However, potential changes to the regime of the Parrett, and its interaction with the open coastline are not well understood; therefore the impacts of any changes within the estuary on this frontage are difficult to quantify, without further, more detailed, study.	stability of adjacent sections of ridge and thus may lead to subsequent enlargement of the breach. The evolution of the Steart Peninsula will also be dependent upon the Parrett Estuary; however, future changes in estuary regime, and the corresponding open coast response, are very difficult to predict. There is a potential risk that the main channel of the Parrett could migrate, with the potential for it to break through the Steart Peninsula. This would significantly alter the hydrodynamic and sedimentary regime of the whole area. Further studies are necessary to determine the likelihood of this occurring and the likely response of the system.
Parrett Estuary	The Parrett Estuary is constrained over much of its length by embankments with localised revetments, and, in the vicinity of Bridgwater, embankments, concrete or masonry walls, sheet piled walls and flood walls. The defences outside of Bridgwater are expected to fail towards the end of this epoch, whilst the urban defences are expected to maintain the standard of protection throughout.	Any of the defences constraining the channel outside of Bridgwater still remaining are expected to fail at the beginning of this epoch. The Bridgwater defences are predicted to fail by the end of this epoch.	There are no defences remaining and the channel is unconstrained. Therefore the potential for the channel to move position is increased in this epoch.
	The constrained nature of the Parrett channel, due to the presence of defences, means that there is little opportunity for change during this epoch. The key risk will be from the meandering nature of the low water channel which will put local pressure on the various defences within the	During this period the impact of accelerated sea level rise and failure of defences will become more significant. Apart from where the defences remain along the Bridgwater frontage, the channel of the Parrett	Future change is difficult to predict due to the uncertainty of estuary evolution resulting from both human change and sea level rise. Overall the estuary is expected to remain flood-dominant although ebb flows are likely to

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	estuary. Little net change within the estuary is therefore anticipated during much of this epoch, although as rural defences fail, there could be increased flood risk locally.	will become unconstrained for most of the estuary length during this period, following the failure of defences. Large areas are previously reclaimed land will become at risk of flooding, although the main town of Bridgwater will remain protected during this period. Flooding of low-lying land and the impact of rising sea levels could result in an increased tidal prism. This will affect not only the estuary but also the adjacent open coastlines. The estuary is likely to remain flood-dominant, with a greater capacity to import sediment, possibly at the expense of the adjacent shorelines. There could also be a tendency for the mouth of the estuary to widen, with resultant erosion along the Steart Peninsula and the frontage to the south of Burnham. Configurations of the low water channel will influence future patterns of erosion, sediment transport and deposition within the intertidal area. It is not, however, possible to predict how channel configuration may change in the future, without further studies. Changes in the low-water channel could also affect adjacent coasts such as at Burnham. Acceleration in the rate of sea level rise would increase water depths, tidal prism and current velocities, increasing the potential for sediment reworking both by waves and currents. Studies	increase. As areas flood the estuary will have greater capacity to import sediment, possibly at the expense of the adjacent shorelines. There could also be a tendency for the mouth of the estuary to widen, with resultant erosion along the Steart Peninsula and the frontage to the south of Burnham. Configurations of the low water channel will continue to influence future patterns of erosion, sediment transport and deposition within the intertidal area. It is not, however, possible to predict how channel configuration may change in the future. Changes in the low-water channel could also affect adjacent coasts such as at Burnham. Acceleration in the rate of sea level rise would increase water depths, tidal prism and current velocities, increasing the potential for sediment reworking both by waves and currents. Climate change may also change the proportions of fresh and saltwater with an increase in rainfall potentially causing an increase in river flows and inundation of low level land as sea levels rise. The Huntspill Channel regulates discharge from the lower parts of the River Brue catchment area, and as such provides a steady inflow of water into the lower Parrett. Increases in the discharge through this channel would be likely to cause further localised erosion of the banks either side of the confluence, and of the area of salt marsh

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		(EA, 2009) suggest, however, that overall sea level rise will have a marginal impact on the existing estuarine regime. Climate change may also change the proportions of fresh and saltwater with an increase in rainfall potentially causing an increase in river flows and inundation of low level land as sea levels rise. The Huntspill Channel regulates discharge from the lower parts of the River Brue catchment area, and as such provides a steady inflow of water into the lower Parrett. Increases in the discharge through this channel would be likely to cause further localised erosion of the banks either side of the confluence, and of the area of salt marsh downstream.	downstream.
Parrett Estuary to Brean Down	Along Burnham-on-Sea frontage there is a recurved seawall and stepped revetment constructed in 1983, which is assumed to remain during this epoch. There is also a flood gate at Maddocks Slade. Between Burnham and Brean the coastal dune system is the primary defence – records suggest that this dune ridge has restricted overtopping along this stretch. Between Brean and Brean Down there is a range of defences including a wave return wall, masonry walls, rock armour and gabion baskets. Some of these, such as the gabion baskets are at risk of	Along Burnham-on-Sea frontage the recurved seawall constructed in 1983 is assumed to remain, although this is dependent upon the future position of the Parrett low-water channel, any changes in which could have significant implications for flood risk management to the coastal defences to at Burnham-on-Sea. Between Burnham and Brean the coastal dune system is the primary defence and although the frontal dunes may erode the backing dune system should continue to minimise the risk of tidal flooding. Between Brean and Brean Down the range of defences are all at risk of failing as a result of	The defences at Burnham-on-Sea could deteriorate and fail during this period, although they are likely to remain an influence on coastal evolution throughout much of this epoch. Between Burnham and Brean the coastal dune system is likely to fail in places, allowing inundation by the sea to occur. However, this is likely to only affect he frontal dunes along Berrow Marsh and a new shoreline position at the toe of the back dunes is predicted to form. Between Brean and Brean Down, the defences are likely to have failed by this epoch, with erosion of the coastal dunes and flooding of the

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	failure during this period. The risk of back door flooding is also minimised by flood embankments along the left bank of the River Axe; these are assumed to remain.	undermining during this epoch. The flood embankments along the left bank of the River Axe could be at risk of failure during this period; which would increase the risk of back door flooding.	low-lying land behind occurring.
	This section can be split into two parts; the low-lying land from the Parrett Estuary to south of Brean Down and the resistant Carboniferous limestone headland of Brean Down itself, which will experience negligible change. At Burnham the defences will continue to fix the shoreline position and the coast along this stretch is likely to remain generally stable; although localised beach lowering may become an issue. Along the central section of undefended coastline, frontal dune erosion is likely to continue at rates between 0.4 and 2m/year. There is a risk that these frontal dunes could be breached during this period, which could impact on the Local Nature Reserve at Berrow; however, the high dunes behind will prevent further hinterland flooding. Between Brean and Brean Down the current defences will continue to fix the shoreline position and reduce the risk of hinterland flooding. It is also assumed that defences within the Axe will also remain during this period.	At Burnham, the defences are assumed to remain and will therefore continue to fix the shoreline position. The vulnerability of this coastline will, however, also depend upon changes within the Parrett estuary, and in particular the future route of the low water channel; it is possible that this could swing clockwise towards the coast as a result of tidal prism increases. If this occurs it could cause increased erosion of the foreshore fronting Burnham-on-Sea, and therefore increase the exposure of this coastline. Although the trend of dune erosion will continue along Berrow Dunes, the flood risk to the hinterland should remain low due to the higher dunes which lie behind. Between Brean and Brean Down, some defences could start to fail during this period, significantly increasing the risk of hinterland flooding. There would also be an increased risk of back-door flooding from the Axe. Limited change is predicted for the headland at Brean Down; less than 5m by the end of the epoch.	There will be limited change at Brean Down, due to the resistant nature of this headland; less than a total of 10m is anticipated by the end of the epoch. However, along the rest of the frontage the key risk will be from flooding, both from back door flooding from the Axe and open coast flooding as defences fail along the frontage. Assets situated above the flood plain within the coastal dunes will also be at risk of erosion and undermining, due to continued erosion of Berrow Dunes.

Location	Predicted Change for 'No Active Intervention'		
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		Should the wide intertidal mudflats erode as they have been recently, there would be predicted to be greater erosion at the shore as these mudflats provide protection of the coast through reducing incident wave energy. Eroding sediment will be transported south through longshore drift towards the Parrett Estuary or be deposited on Gore Sand.	
Brean Down to Anchor Head (Weston Bay)	The main defence along this frontage is a seawall protecting the town of Weston-Super-Mare from flooding and erosion. These defences are in the process of being upgraded. There is also a seawall to the south extending northwards from the River Axe to Uphill. This is predicted to begin to fail towards the end of this epoch under this scenario. There is a short stretch of undefended dunes to between Uphill and Weston-super-Mare. Embankments along the Axe Estuary and protecting low-lying hinterland from flooding, which are assumed to remain during this epoch.	The main defence along this frontage is along Weston-Super-Mare and consist of a seawall; it is assumed that this will have been upgraded in the short term. The seawall at Uphill is predicted to have failed completely during this period. The embankments along the Axe Estuary and protecting low-lying hinterland from flooding may start to degrade towards the end of this epoch (Black & Veatch, 2008).	The main defences along this frontage protect the town of Weston-Super-Mare from flooding and consist of a seawall. It is assumed that this will have been upgraded in the short term and will therefore remain during this period. Any remaining embankments along the Axe Estuary are assumed to fail during the first part of this epoch.
	This frontage is controlled by the two resistant Carboniferous headlands at either end, namely Brean Down and Anchor Head, which form a closed sediment system. A further influence is the presence of the River Axe, which discharges at the southern end of this bay. Brean Down is predicted to erode at rates similar	Cliff erosion at Brean Down is expected to continue occurring at a very slow rate with infrequent events and therefore by the end of this epoch total erosion is predicted to be less than 5m. Similar erosion is expected at Anchor Head. Shoreline retreat in undefended areas and foreshore lowering where defences prevent	Cliff erosion at Brean Down is expected to continue occurring at a very slow rate with infrequent events and therefore by the end of this epoch total erosion is predicted to be less than 10m. Similar erosion is expected at Anchor Head. Shoreline retreat in undefended areas and foreshore lowering where defences prevent

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	to historically, with negligible change expected during this period. Similarly erosion at Anchor head (the northern limit of the bay) is also predicted to be negligible. Along the main frontage of Weston-super-Mare the defences will continue to hold the shoreline position and minimise the risk of localised flooding and erosion. Defences to the south of Uphill are also assumed to remain and minimise flooding risk along this section during this period, although without maintenance they would begin to fail. The low rates of cliff erosion and littoral drift mean that there is little fresh sediment input to feed the beaches and dune system. Recently there has been a trend of slight erosion, particularly foreshore lowering and steepening associated with the defences in the north. This is predicted to continue during this epoch. The embankments constraining the River Axe will prevent any significant change in estuary morphology or processes.	natural retreat is predicted to continue during this epoch. The dune system north of Uphill is also likely to suffer erosion and this dune system will have been affected by failure of the seawall to the south. The risk of flooding of the low-lying hinterland (part of the Somerset Levels) is expected to increase throughout this epoch, particularly with rising sea levels. The failure, or at least reduction in standard of protection, of the Axe embankments would result in inundation of the low-lying hinterland occurring more frequently. The channel is predicted to realign to a more natural position once the embankments have failed. Its configuration will influence future patterns of erosion, sediment transport and deposition within the intertidal area. It is not, however, possible to predict how the channel configuration may change in the future. Acceleration in the rate of sea level rise would increase water depths, tidal prism and current velocities in the estuary, increasing the potential for sediment reworking both by waves and currents.	natural retreat is predicted to continue during this epoch. The dune system north of Uphill is also likely to suffer erosion. There is potential for the dune belt to be entirely lost in the centre of this frontage during this epoch. This would be predicted to result in the development of low cliffs due to erosion of the backing hinterland. The risk of flooding of the low-lying hinterland (part of the Somerset Levels) is predicted to increase throughout this epoch, particularly with rising sea levels. Potential for a breach of the dunes is high during this epoch which would cause significant flooding. The failure, or at least reduction in standard of protection, of the Axe embankments would result in inundation of the low-lying hinterland occurring more frequently. The channel is predicted to realign to a more natural position once the embankments have failed. Its configuration will influence future patterns of erosion, sediment transport and deposition within the intertidal area. It is not, however, possible to predict how the channel configuration may change in the future. Acceleration in the rate of sea level rise would increase water depths, tidal prism and current velocities in the estuary, increasing the potential for sediment reworking both by waves and currents. Sediment eroding from the Axe channel will be added to the system, but is likely to be deposited within the salt marsh area at the

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			estuary mouth.

C.4.4 NAI Data Interpretation

C.4.4.1 Introduction

A number of data sets were used in the predictions of future shoreline response and evolution under the scenario of no active intervention, (these data were also used and reported in the Assessment of Shoreline and Estuary Dynamics, Section C.1 above):

- The cliff assessment database from Futurecoast, which includes information regarding likely failure mechanism, recession protection and frequency;
- Ordnance Survey historical maps, which date back to the 1880s.
- Other historical change data sets: e.g. at some locations cliff position data sets are available ;
- Futurecoast predictions of future shoreline change under an 'unconstrained' scenario: this assumed that all defence structures were removed and other coastal defence management interventions ceased and therefore is not directly comparable to a 'no active intervention' scenario;
- Strategic Regional Coastal Monitoring programmes beach profile data: this data is only relevant for specific locations and restricted to specific time frames i.e. ten to fifteen years at most.
- Predictions of future shoreline response under a 'Do Nothing' scenario from the first SMP.
- Other predictions of future shoreline response under no active intervention (or 'do nothing') scenario, e.g. from strategy studies completed since the first SMP.
- Various studies and research papers.
- The National Coastal Erosion Risk Mapping research and development project (Halcrow, in progress) that used the Futurecoast data described above as a starting point, but which has been through a process of local validation with all coastal operating authorities to ensure the correct up-to-date information is being used as part of this project.
- The Futurecoast aerial CDs, Google Earth and other photographs were also used, together with any local knowledge of the area.

C.4.4.2 Consideration of Sea Level Rise

Section C.3.2 discusses sea level rise (SLR) and climate change in more detail. For this appraisal we have not considered the potential impact of changes in precipitation or storminess when estimating future change, because of the inherent uncertainties in these predictions (see UKCIP08 (2007)). We have, however, mentioned where any coastal systems could be sensitive to changes in these factors.

In advance of the latest sea level rise scenarios from UKCIP09, Defra (2006) produced new allowances for sea level rise (see Table C.3 in Section C.3), which have been considered in our predictions.

The response of the coast depends upon a number of factors, but at a basic level depends upon resistance of the coastal feature and the energy or forcing acting on it. In general terms, rising sea level results in higher water levels further up the beach profile and therefore increased wave energy. Response of the coast to changes in forcing factors is also often complex with a number of feedbacks, such as sediment inputs from cliff erosion, affecting the net change. There is a range of predictive methods available which incorporate sea level rise, but each is constrained by assumptions and limitations which affect their application to cliffs. The Bruun Model is probably one of the most used for cliffed coastlines and the modified version (as discussed in Bray and Hooke, 1997) has been used for this SMP. This is as follows:

$$R_2 = R_1 + (S_2 - S_1)\frac{L_*}{P(B + h_*)}$$

Where:

R_2 = future recession

R_1 = historical recession

S_1 = historical SLR

S_2 = future SLR

L_* = length of active profile

h_* = closure depth

B = height of cliff

P = proportion of sediment eroded that is coarse enough to remain on the beach

However, it is not appropriate to simply apply this equation across the board, as it assumes linear, year by year erosion, which is not the case for all cliffs. The manner in which cliff recession occurs depends upon the way in which the cliff tends to fail, which in turn depends upon its geological make-up, i.e. geology, rock structure, rock lithology and hydrogeology and the solubility of the rock.

In simple terms, cliffs may be divided into a number of generic categories (which were used by Futurecoast), and the general methodology for predicting cliff recession rates for each cliff type is discussed in the table below. However, there has also been consideration of local factors, such as: local geological characteristics, how it has behaved over the last century, human intervention and feedback mechanisms, for example inputs of sediment and beach build-up. Therefore a local-level appraisal, using these guidelines, has been undertaken.

Whichever method is used, a key input is the historical behaviour of the cliff, therefore the quality of this data affects the predictions made. The sources used in deriving this data are outlined above.

Cliff type	Key characteristics	General guidelines for predicting future recession
Simple cliff	This is usually a steep cliff face, with narrow foreshore zone and rapid removal of toe debris. Erosion typically occurs as rock falls, topples or slides from which material is deposited directly on the foreshore. There is often a rapid response to toe erosion.	As erosion rates are closely related to the rate of toe erosion and therefore sea level rise, the Bruun Model is an appropriate tool to use. Best and worst case scenarios have been derived by using historical rates, with no additional erosion assumed due to SLR as the lower estimate and historical rates + additional erosion due to SLR as the upper estimate. The exception to the above is where cliffs are composed of hard rock and are therefore resistant to erosion. In these situations historical recession rates would have been negligible or very low. These cliffs are unlikely to respond to sea level rise and the result will simply be that water levels lie higher up the cliff face. Historical rates of erosion should therefore be used as the best prediction.
Simple landslide	A marked degradation and storage zone is usually apparent, affording limited buffering against toe erosion. Toe erosion of cliff debris leads to oversteepening of the cliff face and a deep seated rotational slide develops.	Although there is a link between cliff erosion and the rate of toe erosion (or erosion of the debris), failure tends to be irregular and often medium or large scale, therefore in many cases, the use of the Bruun Model is not appropriate. The best estimate of erosion risk is therefore the recession potential identified by Futurecoast, unless other data is available on past landslide events.
Composite cliff	Partly coupled sequence of contrasting simple sub-systems. This typically involves inter-bedded hard and soft rocks. This can generally be as either soft	There is often a different response by different layers in the cliff face. The best approach therefore depends upon the exposures present and a site-by-site appraisal is required. It may be necessary to identify different rates for cliff face and cliff top

Cliff type	Key characteristics	General guidelines for predicting future recession
	rock caps resting on hard rock or as hard rock caps resting on softer rock. The latter case is more sensitive to recession.	recession.
Complex cliff	These have strongly coupled sequences of scarp and bench morphology, each with their own inputs, storage and outputs of sediment. The output from one system forms a cascading input to the next resulting in close adjustment of process and form with complex feedbacks.	There is often a different response by different layers in the cliff face. The best approach therefore depends upon the exposures present and a site-by-site appraisal is required. It may be necessary to identify different rates for cliff face and cliff top recession. In many cases the Bruun Model will not be appropriate as these types of cliffs often do not display a progressive recession, but are often subject to irregular events.
Relict cliff	Sequences of pre-existing landslides, which are currently not active, but which could be susceptible to reactivation and exhumation by either progressive marine erosion at the toe or raised groundwater levels.	The likelihood of reactivation over the next 100 years needs to be considered, because some systems are ancient. If reactivation is likely, the dominant driver of cliff top recession needs to be considered: if it is marine erosion driven, the Bruun Model is probably appropriate, if it is groundwater levels, then the recession potential estimates from Futurecoast may be most appropriate to estimate risk.
Additional Note: Where cliffs have been protected by defences which are then allowed to fail, the response to failure and removal of these defences will need to be considered. Soft cliff lines, which have been protected and prevented from retreating for a number of years may now lie seaward of their 'natural position'. In these situations, the possibility of a 'springback' effect needs to be considered, where rates of erosion in the first few years may exceed historical rates until the cliff toe lies at a position along the beach profile which is more commensurate with wave conditions.		

C.4.4.3 Data Assessments (NAI)

Location	Available data	Assumptions made in predictions of coastal change for NAI			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
Lundy	No data available from Futurecoast	Based on the cliff type, assumed that very slow erosion will continue, with infrequent rock falls. Therefore less than 10m predicted. Defences assumed to deteriorate, therefore potentially higher rates along the soft slate coast.			Limited data, but generally low rates expected. SLR not expected to have a major impact on rates.
Hartland Point to Westward Ho!	Futurecoast (Halcrow, 2002) stated that there was a mix of simple and complex cliffs. Cliffs predicted to erode at low rates (0.1-0.5m/year), but with a risk of 10 to 50m occurring along certain sections, should a landslip occur. This will be reduced towards Babbacombe where the cliffs are protected by a boulder and gravel ridge.	An erosion rate of 0.1 to 0.5m/year is assumed: linear extrapolation gives a maximum erosion of 2 to 10m by year 20. But risk that a single event could cause up to 10 to 50m at any one location, therefore maximum risk assumed to be 50m. At Clovelly it is assumed that defences would hold the shoreline position. At Buck Mills it is assumed that defences would continue to slow erosion locally.	An erosion rate of 0.1 to 0.5m/year is assumed: linear extrapolation gives a maximum erosion of 5 to 25m by year 20. But risk that a single event could cause up to 10 to 50m at any one location, therefore maximum risk assumed to be 50m. Defences at Buck Mills and Clovelly assumed to fail and therefore there could be a local increase in cliff erosion at these locations.	An erosion rate of 0.1 to 0.5m/year is assumed: linear extrapolation gives a maximum erosion of 10 to 50m by year 20. But risk that a single event could cause up to 10 to 50m at any one location. It is assumed that only one such event would occur over this period along a specific section of coast and that this would cause a total maximum of 50m at any one location.	Uncertainty over location and timing of landslips and also the likely retreat that could occur. The risk of landslips could increase due to changes in precipitation and SLR.
Westward Ho! to Taw/Torridge Estuary	Futurecoast (Halcrow, 2002) predicted a 'high' rate of change (50 to 100m by year 100). No data was available for cliff erosion to the west of	For the Pebble Ridge, assuming a maximum rate of 2 to 3m/year, then up to 40 to 60m predicted by year 20, reducing to the	For undefended cliffs, assume 0.1-0.5m/year giving 5 to 25m. For the Pebble Ridge, assuming a rate of	For undefended cliffs, assume 0.1-0.5m/year giving 10 to 50m. For the Pebble Ridge, assuming that retreat	No rates available for the cliffs and historical Ordnance Survey maps indicate little change. Various estimates available for Pebble Ridge, but further studies

Location	Available data	Assumptions made in predictions of coastal change for NAI			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
	Westward Ho! Historical maps do not show any significant change in cliff top position, therefore an average rate of 0.1 to 0.5m/year is assumed. Various rates of barrier retreat are available; with a maximum rate in the south , reducing to the north: Slade (unpublished) suggests that a common rate of retreat is 2-3m/year, but that in places it can be up to 50m. May (2003) suggested that from maps it was evident that the ridge moved 152m in the 100 years after 1961 equates to an average rate of 1.52m/year. Keene (1996) proposed that between 1959 and 1996 the ridge crest retreated 30 m (c. 0.8m/year). Orford suggested a rate of 2.6m/year. The Pebble Ridge is believed	north. For undefended cliffs, assume 0.1-0.5m/year giving 2 to 10m.	between 2 and 3m/year, then up to 100 to 150m predicted by year 20, reducing to the north. Key risk, however will be from tidal inundation. Flood risk is based on EA 2008 Flood Map.	rates increase to 4m/year, up to 330m total retreat could occur by year 100. If rates of 2m/ year were to continue then a total retreat of 200m could occur. Key risk, however will be from tidal inundation. Flood risk is based on EA 2008 Flood Map.	required to appraise varying rates along the length of the ridge. Uncertainty regarding the combined impact of both changes within the estuary and sea level rise on the mouth of the estuary and adjacent shorelines.

Location	Available data	Assumptions made in predictions of coastal change for NAI			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
	to be re-orientating counter-clockwise towards a swash alignment so that northerly drift and thus loss of cobbles is progressively reducing. Pethick (2007) suggests that retreat rates of >2m/year would be experience over the next 20 years, but that these could exponentially increase over the next century to 4m/year by 2100.				
Taw/Torridge Estuary: Outer Estuary	Pethick (2007) has been used as the main source of information.	Defences assumed to remain in similar condition. Little change expected within the outer estuary.	Defences assumed to start to fail. Erosion or breach of Crow Neck expected. Increased areas at risk from flooding as defences fail: based on EA 2008 Flood Map. General overall trend of slow infilling assumed to continue under sea level rise.	General overall trend of slow infilling assumed to continue under sea level rise. Increased areas at risk from flooding as defences fail: based on EA 2008 Flood Map.	High level of uncertainty regarding evolution under sea level rise. Uncertainty regarding whether the increased demand for sediment will be met through erosion of the open coast. Also uncertainty regarding future meander patterns within the estuary.
Taw/Torridge Estuary: Torridge Estuary	Pethick (2007) has been used as the main source of information.	Defences assumed to remain in similar condition.	Defences assumed to start to fail. Key risk from flooding:	General overall trend of slow infilling assumed to continue under sea level	High level of uncertainty regarding evolution under sea level rise. Uncertainty regarding whether the

Location	Available data	Assumptions made in predictions of coastal change for NAI			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
		Little change anticipated.	based on EA 2008 Flood Map. General overall trend of slow infilling assumed to continue under sea level rise. Local erosion/accretion dependent upon meanders – risk areas based on Pethick (2007). Geological controls will limit change along much of estuary.	rise. Local erosion/accretion dependent upon meanders – risk areas based on Pethick (2007). Geological controls will limit change along much of estuary.	increased demand for sediment will be met through erosion of the open coast. Also uncertainty regarding future meander patterns within the estuary.
Taw/Torridge Estuary: Taw Estuary	Pethick (2007) has been used as the main source of information.	Defences assumed to remain in similar condition. Little change anticipated.	Defences assumed to start to fail. Key risk from flooding: based on EA 2008 Flood Map. General overall trend of slow infilling assumed to continue under sea level rise. Local erosion/accretion dependent upon meanders – risk areas based on Pethick (2007). Geological controls will limit change along much of estuary.	General overall trend of slow infilling assumed to continue under sea level rise. Local erosion/accretion dependent upon meanders – risk areas based on Pethick (2007). Geological controls will limit change along much of estuary.	High level of uncertainty regarding evolution under sea level rise. Uncertainty regarding whether the increased demand for sediment will be met through erosion of the open coast. Also uncertainty regarding future meander patterns within the estuary.

Location	Available data	Assumptions made in predictions of coastal change for NAI			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
Taw/Torridge Estuary to Saunton Down	Pethick (2007) has been used as the main source of information. Futurecoast (Halcrow, 2002) suggested moderate (10-50m) change over next 100 years.	Groynes at Airy Point assumed to be largely ineffective. Limited change.	Dune system as a whole is expected to remain fairly resilient to change – local areas of erosion and accretion. Permanent breach considered unlikely.	Dune system as a whole is expected to remain fairly resilient to change – but increased risk of frontal dune erosion. Permanent breach considered unlikely.	Uncertainty regarding whether the increased demand for sediment will be met through erosion of the open coast. System is sensitive to changes in wind-wave climate and changes in storm frequency.
Saunton Down to Baggy Point (Croyde Bay)	SMP1 (Halcrow, 1998) suggested that this coastline was relatively stable. Futurecoast (Halcrow, 2002) suggested moderate (10-50m) change over next 100 years, with negligible change of the headlands (<10m). Cliff classification stated very low (<0.1m/year) recession rates for Baggy Point, but low (0.1 to 0.5m/year) for Saunton Down and within Croyde Bay, with potential landslide events causing up to 10 to 50m.	Baggy Point expected to erode at less than 0.1m/year – therefore less than 2m erosion. At Saunton Down between 10 and 50m could occur at a single location, due to a landslide event. Within Croyde Bay dunes are expected to remain stable.	Baggy Point expected to erode at less than 0.1m/year – therefore less than 5m erosion. At Saunton Down between 10 and 50m could occur at a single location, due to a landslide event. Within Croyde Bay dunes are expected to remain stable. The beach at Croyde is predicted to remain relatively stable due to the influence of the headlands although sea level rise may cause some retreat. However this material would be expected to be redeposited within the system. When defences	Baggy Point expected to erode at less than 0.1m/year – therefore less than 10m erosion. At Saunton Down between 10 and 50m could occur at a single location, due to a landslide event. Dune erosion is a risk during this period. At the northern end of the Bay, up to 8 to 40m possible (assuming no 'jump back' occurs and that defences fail at year 20).	Limited data available on historical changes to the dunes. The rate of dune erosion will depend upon the frequency and strength of future storm events.

Location	Available data	Assumptions made in predictions of coastal change for NAI			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
			fail at northern end of the Bay, cliff erosion could occur – expected to be around 0.1-0.5m/year, therefore up to 3 to 15m possible (assuming no 'jump back' occurs and that defences fail at year 20).		
Baggy Point to Morte Point (Morte Bay)	Futurecoast (Halcrow, 2002) suggested moderate (10-50m) change over next 100 years, with negligible change of the headlands (<10m). Cliff classification stated very low (<0.1m/year) recession rates for Baggy Point and Morte Point. SMP1 predicted less than 10m erosion over 50 years for the headlands. The SMP also Identified that the dunes were eroding, mainly during storms, but no estimates of future change provided.	Headlands expected to erode at less than 0.1m/year – therefore less than 2m erosion. At Putsborough there could be erosion of the sand-shale cliffs; probably mainly taking place during storm events, which could cause a metre or two of erosion. The dunes will continue to prevent any slope erosion along much of Morte Bay.	Headlands expected to erode at less than 0.1m/year – therefore less than 5m erosion. Continued erosion of the dunes, with maybe up to 25m of erosion (based on Futurecoast appraisal only). At Putsborough there could be erosion of the sand-shale cliffs; probably mainly taking place during storm events. Based on the cliff type, these could experience rates of c. 0.1-0.5m/year, based on their generic cliff type, therefore resulting in between 5 and 25m	Headlands expected to erode at less than 0.1m/year – therefore less than 10m erosion. Continued erosion of the dunes, with maybe up to 50m of erosion (based on Futurecoast appraisal only). Could be re-exposure of the cliffs behind in places, which typically would be expected to experience rates of 0.1-0.5m/year, based on their generic cliff type. At Putsborough there could be erosion of the sand-shale cliffs; probably mainly taking place during storm events. Based on	Limited data available on historical changes to the dunes. Very limited data on potential erosion rates of the cliffs forming Morte Bay, which are currently fronted by sand dunes. Limited data on the cliffs at Putsborough – a generic rate of 0.1 to 0.5m/year has been assumed and this band proposed is assumed to wide enough to take account of sea level rise. The rate of dune erosion will depend upon the frequency and strength of future storm events.

Location	Available data	Assumptions made in predictions of coastal change for NAI			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
			erosion during this period.	the cliff type, these could experience rates of c. 0.1-0.5m/year, based on their generic cliff type, therefore resulting in between 10 and 50m erosion during this period. This band is considered broad enough to take account of sea level rise.	
Morte Point to Widmouth Head	SMP1 stated less than 10m recession would occur over the next 50 years. Futurecoast predicted 'negligible/no change' over the next 100 years. The cliff classification did, however, identify a risk of localised landslips and slides, but identified that these would cause less than 10m erosion. The small pocket beaches are predicted to remain stable with any cliff erosion adding sediment.	The defences at Lee and Hele Bays assumed to fail towards the end of this epoch. Negligible change expected during this period (less than 10m erosion).	Localised defences at Ilfracombe assumed to fail during this epoch. The previously defended cliffs at Lee and Hele are predicted to erode at the same rates as the other cliffs. Negligible change expected during this period (less than 10m erosion).	Negligible change expected during this period (less than 10m erosion).	Timing of defence failure. Timing and location of landslide events – but low risk. Localised landslips may occur, be likely to be small (less than 10m recession) and localised. Sea level rise is unlikely to significantly increase erosion rates.
Widmouth Head to Hangman Point (Combe Martin	SMP1 stated less than 10m recession would occur over the next 50 years.	Local recurved seawall at Combe Martin assumed to remain during this epoch.	Local recurved seawall at Combe Martin assumed to fail towards the end of this	Negligible erosion of the resistant cliffs predicted. Risk of localised flooding	Timing of defence failure. Timing and location of landslide events – but low risk.

Location	Available data	Assumptions made in predictions of coastal change for NAI			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
Bay)	Futurecoast predicted 'negligible/no change' over the next 100 years. The cliff classification did, however, identify a risk of localised landslips and slides, but identified that these would cause less than 10m erosion.	Negligible erosion of the resistant cliffs predicted.	epoch. Negligible erosion of the resistant cliffs predicted. Risk of localised flooding at Combe Martin: based on EA 2008 Flood Map.	at Combe Martin: based on EA 2008 Flood Map.	
Hangman Point to Duty Head	SMP1 stated that while generally stable, some erosion of the cliffs does occur, but <10m over next 50 years. Futurecoast predicted 'negligible/no change' over the next 100 years. The cliff classification did, however, identify a risk of localised landslips and slides, but identified that these would cause less than 10m erosion	Negligible erosion expected, although at a very local scale there is a small risk of a landside events, which could cause up to 10m.	Negligible erosion expected, although at a very local scale there is a small risk of a landside events, which could cause up to 10m.	Negligible erosion expected, although at a very local scale there is a small risk of a landside events, which could cause up to 10m.	Timing and location of landslide events – but low risk.
Duty Head to Foreland Point (inc. Lynmouth Bay)	SMP1 stated that while generally stable, some erosion of the cliffs does occur, but <10m over next 50 years. The exception was Holdstone Down where rates may increase to 0.5-1m/year. Futurecoast predicted 'negligible/no change' over the	Negligible change to cliffs to west of Lynmouth. The Foreland is expected to erode more rapidly, but less than 10m expected (using Futurecoast upper limit and SMP1 lower limit). The boulder at Lynmouth	Assumed that defences at Lynmouth may start to fail. Therefore risk of flooding and erosion: based on EA 2008 Flood Map. Negligible change to cliffs to west of Lynmouth. The Foreland is expected to	Risk of flooding and erosion at Lynmouth: based on EA 2008 Flood Map. Negligible change to cliffs to west of Lynmouth. The Foreland is expected to erode more rapidly: 10 to 50m, assuming linear	Timing of defence failure at Lynmouth is an uncertainty. Erosion rates of The Foreland uncertain – Futurecoast band used, but it is assumed this is broad enough to include impacts of sea level rise. Risk of another flash flood event.

Location	Available data	Assumptions made in predictions of coastal change for NAI			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
	next 100 years. To west of Foreland Point, cliff classification suggested very low (<0.1m/year), but at Foreland Point suggested low (0.1-0.5m/year) recession rates.	is assumed to provide protection to Lynmouth frontage during this epoch.	erode more rapidly: 5 to 25m, assuming linear extrapolation of Futurecoast band.	extrapolation of Futurecoast band.	
Foreland Point to Gore Point	SMP1 stated less than 10m recession would occur over the next 50 years. Futurecoast predicted 'negligible/no change' over the next 100 years. The cliff classification suggested very low rates along much of the remainder of the frontage (<0.1m/year).	Negligible cliff erosion expected.	Negligible cliff erosion expected.	Negligible cliff erosion expected.	Timing and location of landslide events – but low risk.
Porlock Bay	Futurecoast predicted a 'high' (50-100m by year 100) rate of change. General information contained within Cope (2004) and Orford (2003). Bray & Duane (2001) determined rates of change along the barrier section: (1) barrier to west of breach = 0.42m/year (1888 – 1988),	Assumed that the seawall and harbour arm at Porlock Weir will remain during this period. Key risk along barrier section is overwashing and flooding of hinterland: based on EA Flood Map. Erosion of Porlockford predicted to be less than 10m (assuming a max. rate	Assumed that the seawall and harbour arm at Porlock Weir will fail during this period. Key risk along barrier section is overwashing and flooding of hinterland: based on EA Flood Map. Erosion of Porlockford predicted to be less than 25m (assuming a max. rate	Key risk along barrier section is overwashing and flooding of hinterland: based on EA Flood Map. Erosion of Porlockford predicted to be less than 25m (assuming a max. rate of 0.5m/year)	Uncertainty regarding risk of catastrophic breakdown of barrier and potential for permanency of any breaches. Timing of failure of Porlock Weir defences not certain and also the potential impact of this failure. Limited data on Porlockford cliff erosion.

Location	Available data	Assumptions made in predictions of coastal change for NAI			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
	= 0.83m/yr (since 1988) (2) New Works to war memorial = 0.25-0.5m/year (1888-1928). Then stability to 1988. Then a further 10m erosion near New Works. (3) East of war memorial = 0.25-0.5m/year (1888-1928). Then stable. Bray & Duane (2001) also suggested erosion of Porlockford cliffs at less than 0.5m/year.	of 0.5m/year)	of 0.5m/year)		
Hurlstone Point to Minehead	SMP1 concluded that the coastline would remain stable over the next 50 years, but with a possibility of foreshore steepening. Expected that the cliffs would continue to erode at the same rate as present. Futurecoast predicted 'negligible/no change' over the next 100 years. The cliff classification suggested very low rates along much of the remainder of the frontage (<0.1m/year). The cliff classification suggested that Minehead Bluff would recede	The vegetated nature of the cliffs suggests a low rate of activity, therefore negligible erosion is predicted for much of this coastline, but there is a risk that several metres (10 to 50m) of retreat could occur due to a single event.	Assumed groynes will fail (but already have a limited impact). The harbour breakwater at Minehead and associated concrete groyne assumed to remain. Assuming a linear extrapolation of the lower Futurecoast rates (0.1m/year): up to 5m erosion predicted. However there is a risk of a large scale event occurring along the Minehead Bluff, which	The harbour breakwater at Minehead and associated concrete groyne assumed to remain. Assuming a linear extrapolation of the lower Futurecoast rates (0.1m/year): up to 10m erosion predicted. However there is a risk of a large scale event occurring along the Minehead Bluff, which could cause several metres (10 to 50m) of	The timing of defence failure is uncertain. Timing and location of landslide events.

Location	Available data	Assumptions made in predictions of coastal change for NAI			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
	at low (0.1 – 0.5m/year) rates, but the cliffs at Culver were identified as complex, with a low risk of a large landslide event (causing more than 50m recession).		could cause several metres (10 to 50m) of retreat could occur due to a single event.	retreat could occur due to a single event.	
Minehead to Blue Anchor	SMP1 reports that beach levels dropped in the early part of the century. Key risk will be inundation of a large area of low-lying land. The SMP1 also states that at The Warren retreat is around 0.5m/year. At the eastern end of the frontage, SMP1 records that there has historically been 300m retreat of mean low water over the 'past century'. Futurecoast predicted a 'high' (50-100m by year 100) rate of change. Black & Veatch, 2006a; 2009) suggested at Minehead there has been 0.6m/year retreat in last 30 years. Erosion at the Warren has been 0.3m/year, with a breach possible within next 20 years. The	At Minehead defences assumed to remain therefore shoreline position fixed. Defences assumed to remain at Dunster and Blue Anchor Bay (apart from at eastern end of Blue Anchor), which will prevent roll-back of the beach. Defences at eastern end of Blue Anchor likely to fail in this period. May lead to a period of rapid cliff recession as cliff retreats to align with adjacent undefended cliff line. At the Warren there is a risk of overtopping and breaching; therefore flooding is a key risk: risk	At Minehead defences assumed to remain therefore shoreline position fixed. Defences at Dunster Beach and Blue Anchor assumed to fail at some point during this period. Net trend for landward retreat. Key risk is from flooding: risk based on EA Flood Map.	At Minehead defences assumed to remain therefore shoreline position fixed. Net trend for landward retreat. Key risk is from flooding: risk based on EA Flood Map.	The timing of defence failure is uncertain. Limited data on the retreat rates at the Warren.

Location	Available data	Assumptions made in predictions of coastal change for NAI			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
	undefended stretch at Dunster has been 0.6m/year.	based on EA Flood Map.			
Blue Anchor to St Audrie's Bay	SMP1 stated that erosion rates vary along the frontage with rates between Blue Anchor to Watchet of between 0.5 and 1m/year, although it is noted that these rates are often exceeded between Blue Anchor Hotel and Gray Rock. Rates are higher east of Watchet to Doniford, where they would exceed 1m/year. Within St Audrie's Bay, the cliffs are more stable, but up to 0.5m/year may still be experienced. Futurecoast predicted 'moderate' (10-50m) erosion over the next 100 years. The cliff classification suggested low rates along the cliffed frontages (0.1 – 0.5m/year), but with a risk of a landslide along the Watchet section, which could cause 10 to 50m recession. May (2003) reports that there	Concrete seawalls and rock groynes will prevent erosion of cliffs at Watchet, but risk of failure towards end of epoch. The shoreline position will be held by defences between Watchet and Doniford. The rock revetment at Doniford Holiday Camp will continue to minimise risk of flood and erosion, but is assumed to fail during this period. Based on linear extrapolation of Futurecoast rates for the undefended sections to the east of Blue Anchor Bay: 2 to 10m recession predicted, but risk of 10 – 50m due to a single event.	Assumed that harbour structures at Watchet will remain, but other defences may start to fail. Defences are also assumed to fail in Helwell Bay. Based on linear extrapolation of Futurecoast rates for the undefended sections to the east of Blue Anchor Bay: 2 to 10m recession predicted, but risk of 10 – 50m due to a single event. Elsewhere rates could vary from 0.1 to 1m/year, resulting in between 5 to over 50m erosion (assuming maximum rates of 1m/year and a initial rapid period of cliff retreat).	Assumed that harbour structures at Watchet will fail. Based on linear extrapolation of Futurecoast rates for the undefended sections to the east of Blue Anchor Bay: 2 to 10m recession predicted, but risk of 10 – 50m due to a single event. Elsewhere rates could vary from 0.1 to 1m/year, resulting in between 10 to over 100m erosion (assuming maximum rates of 1m/year and a initial rapid period of cliff retreat).	The timing of defence failure is uncertain. There is very limited information on actual rates of cliff retreat. The cliffs, in places, will also be affected by climate change, both due to sea level rise, the associated reduction in the effect of the shore platform and the any change in groundwater conditions.

Location	Available data	Assumptions made in predictions of coastal change for NAI			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
	have been few measurements of coastal change, but notes that retreat rates vary along the frontage. Mackintosh (1868; reported in May, 2003b) estimate the rate of cliff retreat as 1.2m/year.				
St Audrie's Bay to Hinkley Point	SMP1 reported that there were 'slow' rates of erosion along this frontage, but also (conversely) suggests that east of Lilstock a small bay has been created by 'relatively high erosion rate' at this point. May (2003) reports that the cliffs are more active to the west of Lilstock, where the cliffs are more exposed. Futurecoast predicted 'negligible/ no change' over the next 100 years. The cliff classification suggested 'low' rates along the cliffed frontages (0.1 – 0.5m/year).	The rock armour at Lilstock is assumed to remain for much of period. Based on linear extrapolation of Futurecoast rates: 2 to 10m recession predicted, but risk of up to 10m due to a single event.	The rock armour at Lilstock is assumed to become ineffective and fail at start of period/ end of short term. Based on linear extrapolation of Futurecoast rates: 5 to 25m recession predicted, but risk of up to 10m due to a single event. Gravel ridges at Kilve and Lilstock are predicted to roll-back at similar rates to the adjacent cliffs. Localised flooding at Lilstock and Kilve Point: risk based on EA Flood Maps.	Based on linear extrapolation of Futurecoast rates: 10 to 50m recession predicted, but risk of up to 10m due to a single event. Gravel ridges at Kilve and Lilstock are predicted to roll-back at similar rates to the adjacent cliffs. Localised flooding at Lilstock and Kilve Point: risk based on EA Flood Maps.	Limited information available on actual cliff erosion rates and barrier retreat rates.
Hinkley Point	Along the Power Station frontage rates of change were	The defences at Hinkley Point are assumed to	The defences at Hinkley Point are assumed to	The defences at Hinkley Point are assumed to fail	Timing of defence failure. Uncertainty regarding the resistance

Location	Available data	Assumptions made in predictions of coastal change for NAI			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
	concluded to be low in SMP1. Futurecoast cliff classification suggested 'low' rates along the Hinkley Point frontage (0.1 – 0.5m/year).	continue prevent shoreline retreat during this epoch.	continue prevent shoreline retreat during much of this epoch. As defences fail there could be rapid erosion of the made ground upon which the power station sit.	during this period. Initial rapid erosion of the made ground. Once original cliff line reach erosion here is expected to be around 0.1 – 0.5m/year, therefore 25 to 40m erosion may occur.	of the made ground and rates of cliff erosion once original shoreline is re-exposed.
Hinkley Point to Parrett Estuary	SMP1 stated that there have been 'considerable' changes along this frontage, particularly around Stert Point, where there have been movements of the order of 100s metres during the last two centuries. Futurecoast predicted a 'high' (50-100m by year 100) rate of change. The cliff classification suggested 'low' rates along the Hinkley Point frontage (0.1 – 0.5m/year). Futurecoast (Halcrow, 2002) suggested that the main channel may migrate, with the potential for it to break through the Steart Peninsula.	The rock revetment and earth embankment east of Hinkley will remain during this epoch. Defences along Steart Peninsula (east of Stolford) are assumed to fail during this epoch. A key issue will the risk of flooding: risk based on EA Flood Maps. East of Wall Common sediment transport rates are negligible and thus the beach is predicted to remain stable during this epoch.	The defences along the western part of this section assumed to gradually deteriorate and fail. To the east, a key issue will the risk of flooding: risk based on EA Flood Maps.	To the east, a key issue will the risk of flooding: risk based on EA Flood Maps.	No data on cliff erosion rates around Hinkley. Changes in the Parrett Estuary will affect the Steart Peninsula.
Parrett Estuary	EA (2009) and Black & Veatch	Estuary is constrained	The defences within the	The key issue will be flood	The timing of defence failure is

Location	Available data	Assumptions made in predictions of coastal change for NAI			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
	(2008) determined that estuary currently stable. EA (2009) undertook regime analysis to look at impact of sea level rise and MR at a number of sites. Atkins (2009) states that position of low-water channel is predicted to move clockwise (to the north of Gore Sands) by 2028 and this will have a significant impact on the foreshore levels at Burnham-on-Sea.	throughout: localised revetments in rural areas, and embankments with walls in the Bridgwater area. Here the flood risk will continue to be managed. The rural defences are predicted to fail during this epoch. The key issue will be flood risk: based on EA Flood Maps.	Bridgwater urban area are predicted to fail at the end of this epoch. The key issue will be flood risk: based on EA Flood Maps. Sea level rise is predicted to increase risk of flooding in the areas where there are no defences.	risk: based on EA Flood Maps. Sea level rise is predicted to increase risk of flooding in the areas where there are no defences.	uncertain. It is difficult to predict future changes in channel position. It is also difficult to predict how the estuary will respond to future changes in sea level.
Parrett Estuary to Brean Down	SMP1 did not define potential erosion rates but identified the issue of falling beach levels at Burnham. The SMP1 also predicted that over the next 50 years the dunes would continue to erode, but that the dune system would not breach during this period. Futurecoast predicted a 'high' (50-100m by year 100) rate of change, with 'negligible/no change' at Brean Down. The cliff classification suggested 'low' rates at Brean Down	It is assumed that the defences at Burnham-on-Sea will remain. These will continue to prevent any change in shoreline position and will manage the risk of flooding. Between Burnham and Brean, frontal dunes expected to erode, but flood risk low due to high dunes behind. At Brean, defences assumed to remain.	It is assumed that the defences at Burnham-on-Sea will remain. These will continue to prevent any change in shoreline position and will manage the risk of flooding. Between Burnham and Brean, frontal dunes expected to erode, but flood risk low due to high dunes behind. A key risk to the north of Brean will be inundation	A key risk to the north of Brean will be inundation: flood risk based on EA Flood Map. A key risk is inundation both due to defence failure and backdoor flooding from Axe: flood risk based on EA Flood Map. Assuming the lower limit of the Futurecoast band, less than 10m of erosion at Brean Down predicted	The timing of defence failure is uncertain.

Location	Available data	Assumptions made in predictions of coastal change for NAI			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
	(0.1 – 0.5m/year). Black & Veatch (2008) concluded that there had been little change over last century along Burnham and Brean stretches. Various changes along the Berrow frontage, but current erosion trend of up to 2m/year. Atkins (2009) states that position of low-water channel is predicted to move clockwise (to the north of Gore Sands) by 2028 and this will have a significant impact on the foreshore levels at Burnham-on-Sea.	Negligible change expected at Brean Down.	both due to defence failure and backdoor flooding from Axe: flood risk based on EA Flood Map. Assuming the lower limit of the Futurecoast band, less than 5m of erosion at Brean Down predicted by end of the period.	by end of the period.	
Brean Down to Anchor Head (Weston Bay)	Futurecoast predicted a 'high' (50-100m by year 100) rate of change, with negligible/no change' at Brean Down. The cliff classification suggested 'low' rates at Brean Down (0.1 – 0.5m/year).	Negligible change expected at Brean Down and Anchor Head. Defences at Weston Super Mare will continue to fix the shoreline position.	Assuming the lower limit of the Futurecoast band, less than 5m of erosion at Brean Down and Anchor Head predicted by end of the period. Defences at Weston Super Mare will continue to fix the shoreline position. The embankments	Assuming the lower limit of the Futurecoast band, less than 10m of erosion at Brean Down and Anchor Head predicted by end of the period. Defences at Weston Super Mare will continue to fix the shoreline position.	Limited data on shoreline change, as defences pre-date the earliest Ordnance Survey mapping. Defences assumed to be upgraded along Weston Super Mare.

Location	Available data	Assumptions made in predictions of coastal change for NAI			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
			constraining River Axe estuary and protecting low-lying hinterland from flooding may start to degrade towards the end of this epoch (from Black & Veatch, 2008).		

C.5 Baseline Case 2 – With Present Management (WPM)

C.5.1 Introduction

This section of the report provides analysis of shoreline response conducted for the scenario of 'With Present Management'. This has considered that all existing defence practices are continued; accepting that in some cases this will require considerable improvement to present defences to maintain their integrity and effectiveness and has taken account of the information about the defences contained in the Defence Assessment (see Section C.2).

The analysis has been developed using the understanding of coastal behaviour from both Futurecoast and the baseline understanding report produced (see Section C.1), existing coastal change data (see Section C.5.4) and information on the nature and condition of existing coastal defences.

C.5.2 Summary

The following text provides a summary of the analysis of shoreline response, with details specific to each location and epoch contained within the Scenario Assessment Table.

C.5.2.1 Short Term (to 2025)

In terms of defences, this coast is characterised by long stretches of undefended cliffed coastlines, small stretches of defences within pocket bays (which in places form part of the infrastructure rather than performing a defence role), and longer stretches of seawalls and revetments (and in places groynes) along the key towns and villages. The coastline in general is poorly connected, meaning that often the impact of defences is only very localised, particularly along the western parts of the SMP frontage; the main exceptions are the stretch of coast from Minehead to Blue Anchor, and in the areas around the outer parts of the Taw/Torridge and Parrett Estuaries.

Along the large stretches of undefended shoreline there would be a continuation of current trends. In places, this would mean that beaches would continue to narrow due to the lack of new sediment inputs and there would be continued cliff erosion at a range of rates, dependent upon the local geology, although along much of this coastline, the cliff erosion rates are low. In areas where undefended cliffs are located adjacent to coastal defences, particularly where the cliffs are comprised of areas of softer, more readily erodible sediment such as between Blue Anchor and Watchet, there would be a risk of outflanking of defended areas towards the end of this period.

During this period, defences such as seawalls, revetments and groynes would continue to reduce the risk of coastal flooding and erosion. As the coastal system continues to transgress as a result of rising sea levels, this would squeeze the intertidal zone as nearshore areas deepen and defences prevent natural landward movement of the shoreline. In places, where defences front resistant cliff lines, this situation would not differ from the natural situation. A number of the defences along the SMP area such as those to the east of Minehead would require updating during this period as they are presently in a poor condition and would fail to provide adequate protection against flooding by 2025.

Continued beach management activity in areas where this is presently undertaken would be required throughout this period as any cessation could lead to the loss of beaches in these areas and increase the risk of flooding of low-lying land. It is therefore assumed under this scenario, that beach management would retain beaches in their current state and plan-form position. Where no beach management occurs, such as in Porlock Bay and along the Pebble Ridge at Westward Ho!, beaches will transgress landwards and where insufficient sediment inputs to these beaches occurs, they are likely to narrow and flatten and become more susceptible to overwashing and even breaching. This would result in an increased risk of flooding to low lying coastal flood plains, should a large storm event occur during this period.

Within both the Taw/Torridge and Parrett Estuaries, continued defence provision will constrain the ability of the estuary to evolve naturally, although in this epoch it is unlikely that this would significantly impact upon currently observed trends in the estuaries during this epoch. At the mouth of the Parrett Estuary, the main risk in this epoch is the meandering of the low water channel, which has the potential to put local pressure on various defences both within and adjacent to the estuary mouth, including those at Burnham-on-Sea.

C.5.2.2 Medium Term (to 2055)

During this period, the effect of rising sea levels will become more significant. The increased exposure would impact both defended and undefended coastlines, although the nature of this coastline means that in general the impact of defences would tend to felt relatively locally due to the limited littoral drift.

Where defences exist, the natural retreat of the shoreline will be inhibited and beaches would therefore become increasingly narrow and steeper. Unless there is beach management, there would need to be significant improvements made to prevent undermining and increased overtopping of defences.

This beach narrowing and lowering, will be exacerbated by accelerated sea level rise; without the ability of the shoreline to respond by moving landward, there will be deeper water and greater wave exposure at the seawalls and revetments. These conditions will not be conducive to beach retention and any sediment arriving on these frontages is likely to be rapidly transported offshore again. This will also increase the vulnerability of these defence structures to both undermining and overtopping and more frequent work to maintain their integrity will be required, to prevent erosion and maintain the shoreline in its present position. Such work may also require the construction of new defences, including the control structures along the shoreline combined with beach recharge. Where beach management is part of the management strategy, there could need to be increased frequency of works to maintain the beaches in their current state. Without beach recharge and management, although defence against flooding and erosion would be provided, many areas could experience beach loss to the detriment of the amenity and recreation value of the area.

This beach narrowing and lowering will also occur along much of the undefended cliffed coastline. In these areas the slow erosion rates of the predominantly resistant cliffs means there will be limited input of new sediment to the shoreline to keep pace with rising sea levels.

Where beaches are not managed and are backed by low-lying hinterland such as at Porlock Weir and the Pebble Ridge at Westward Ho!, then the tendency will be for these beaches to roll landwards as sea level rise, becoming more swash aligned and vulnerable to overtopping, overwashing and breaching due to a lack of new sediment inputs to the beaches as this roll back occurs. There would therefore be increased flooding of low-lying areas behind these beaches, with any breaches becoming less likely to re-seal naturally due to reducing amounts of available sediment during this epoch.

The majority of the defences throughout the SMP area are likely to require replacing or upgrading during this period as existing structures reach the end of their effective life, and the effects of sea level rise and increased storminess caused by climate change increase the risk of flooding and erosion. In some areas it will become increasingly technically difficult to provide adequate defences in present positions. In all areas, replacement defences will need to be much larger than present structures in order to continue to provide adequate levels of protection to areas they protect in the future.

At a number of locations including Blue Anchor and Westward Ho!, where defended stretches are adjacent to retreating non-defended stretches, defended areas may become more prominent. These promontories could further inhibit sediment transfer between areas (more so than presently occurs) and become more exposed to wave action, which in turn will require additional defence measures to be taken to ensure the integrity of the defences against more waves and to prevent against outflanking of the defences by erosion of adjacent cliffs and/or dunes.

The Taw/Torridge and Parrett Estuaries would be affected by sea level rise and climate change, although without much greater study it is not possible to quantify the potential impacts due to the significant uncertainty that remains. The mouth of the Taw-Torridge estuary will attempt to widen during this epoch in response to rising sea levels, but will be constrained by continued defence provision around the outer part of the estuary. This will cause increased erosion pressure on the defences within the estuary, particularly in the areas around the mouth in this epoch. The form of the inner estuary is unlikely to alter significantly due to the continued presence of defences.

Similarly, the Parrett Estuary will also remain constrained in its ability to adapt to sea level rise and climate change and as such the form of much of the estuary will be unlikely to alter significantly in this epoch. The main issue at the mouth of the Parrett Estuary in this epoch will remain the meandering of the low water channel, which has the potential to put local pressure on various defences both within and adjacent to the estuary mouth.

C.5.2.3 Long Term (to 2105)

Along much of this coastline there would be little difference from the future under a scenario of no active intervention due to the fact that long stretches of coast are undefended and the poor connectivity in terms of littoral drift.

Where defences are predominantly short stretches at the back of pocket beaches, they would only have a localised impact although by this period there would be little or no beach fronting the defences.

At other locations, such as Blue Anchor and Burnham-on-Sea, the defended stretches of coast could now stand several metres proud of the adjacent undefended shorelines and there would be an increasing risk of outflanking. The increased exposure of these defences would also require substantial and longer extents of defences to be constructed. Without beach management there would be no beach present at the toe and even where beach management activities take place it would technically become very difficult. There would be an impact on adjacent beaches, through interruption of sediment drift. The deeper water at these artificial headlands could also result in any sediment reaching these points being deflected offshore rather than moving down the coast.

Along undefended sections of coastline, erosion of the softer areas of cliff would accelerate in response to sea level rise, with periodic cliff failures and landslides occurring to provide occasional inputs of sediment to local beaches. Harder, more resistant rock cliffs would be unaffected by sea level rise and continue to retreat at historical rates, failing only as a result of infrequent, geologically controlled event. Where beaches front cliffs that contain sufficient coarse sediment they will be maintained as narrow beaches despite sea level rise. Where there is insufficient coarse sediment supply to beaches from local cliff erosion, then beaches will become increasingly narrow as sea levels rise and an increasing number would disappear in places along with shore platforms by 2105.

Breaches and tidal inundation of defended flood risk areas would continue to be averted under this scenario, although much more substantial defences would be required, as beaches will be increasingly narrowed and lost from in front of these structures. The technical viability of providing defences in present positions would become increasingly difficult in a number of areas during this period.

Barrier beaches and spits that are undefended and not subject to management activities would continue to adapt and retreat in response to sea level rise. There would be an increasing risk of breaching occurring during the rollback of these features onto low-lying land throughout this period, particularly where the features will narrow as sediment is re-distributed along their lengths and there is insufficient input of new sediment to replenish stocks. Where these features are managed, then they are very likely to require intervention to repair the breaches. These breaches are especially likely to occur where discontinuities in beach plan form develop as a result of the partial defence of a beach whilst the remaining beach is able to retreat.

The Taw/Torridge and Parrett Estuaries would be affected by sea level rise and climate change, although without much greater study it is not possible to quantify the potential impacts due to the significant uncertainty that remains. The mouth of the Taw-Torridge estuary will continue to attempt to widen during this epoch in response to rising sea levels, but will be constrained by continued defence provision throughout the estuary. This will cause increased erosion pressure on the defences within the estuary. The form of the inner estuary is unlikely to alter significantly due to the continued presence of defences, however, there is potential for increased erosion of adjacent open coast areas as sediment is moved into the estuary as a result of sea level rise.

Similarly, the Parrett Estuary will also remain constrained in its ability to adapt to sea level rise and climate change and as such the form of much of the estuary will be unlikely to alter significantly in this epoch. The main issue at the mouth of the Parrett Estuary in this epoch will remain the meandering of the low water channel, which has the potential to put local pressure on various defences both within and adjacent to the estuary mouth. The planned construction of a surge barrier within the estuary to reduce the risk of flooding upstream by this epoch could also impact on the future evolution of the estuary.

C.5.3 WPM Scenario Assessment Table

Location	Predicted Change for 'With Present Management'		
	Short Term (to 2025)	Medium Term (to 2055)	Long Term (to 2105)
Lundy	Undefended cliffs apart from at Landing Bay, where defences include a concrete seawall with masonry splash wall, concrete breakwater and stone gabion revetments. These structures will need maintenance towards the end of this period to maintain the standard of defence.	Undefended cliffs apart from at Landing Bay, where defences include concrete seawall with masonry splash wall, concrete breakwater and stone gabion revetments. These structures will require on-going maintenance during this epoch.	Undefended cliffs apart from at Landing Bay, where defences include concrete seawall with masonry splash wall, concrete breakwater and stone gabion revetments. Further maintenance/improvements would be required during this epoch.
	The resistant granite cliffs have historically been eroding very slowly. In the future it is predicted that recession will continue to occur at similar historic rates such that this frontage would change negligibly during this epoch. Along the south-east of the island, soft slates are exposed and these are more prone to erosion, with up to 10m of recession possible due to infrequent rock falls. Erosion of these softer cliffs will provide material to the small pocket beaches, which are predicted to remain relatively stable. The only defended section of coast lies at the back of the pocket beach at Landing Bay. If maintained, the defences will continue to prevent toe erosion of the soft shale cliffs and reduce the risk of cliff recession.	Erosion of the granite cliffs will continue to occur at very low rates, with negligible change expected around the majority of the island; in isolated areas up to 10m of recession is possible as a result of small scale, infrequent rock falls. Although sea level rise will increase exposure of the cliffs, their resistant nature means that the erosion rate is unlikely to be affected. Where small pocket beaches lie at the toe of these cliffs these could become submerged and lost as sea levels rise. Where the softer slates outcrop, sea level rise could potentially increase erosion rates slightly, although sediment would be supplied to the fronting beaches, which could provide some toe protection. The pocket beach at Landing Bay is reliant on incoming sediment from the cliffs. The continued maintenance of defences along this section will reduce cliff erosion along this stretch and therefore reduce the local input of sediment to the fronting beach. Therefore the beach could	The resistant granite cliffs have historically been eroding very slowly. In the future it is predicted that recession will continue to occur at similar historic rates such that this frontage would change very little during this epoch, with up to 10m of recession possible in isolated areas as a result of small scale, infrequent rock falls. The self-contained pocket beaches are also expected to remain stable, with any erosion of cliffs potentially providing additional sediment. Sea level rise may cause erosion rates along the softer slate cliffs, where undefended, to increase as the cliffs become increasingly exposed to wave action. Material supplied from this erosion may be retained locally as small beaches. Some beach steepening and narrowing at Landing Bay is expected as a result of sea level rise and the reduced input of new sediment from cliff erosion as a result of ongoing maintenance of the defences.

Location	Predicted Change for 'With Present Management'		
	Short Term (to 2025)	Medium Term (to 2055)	Long Term (to 2105)
		become increasingly vulnerable to erosion or submergence with sea level rise.	
Hartland Point to Westward Ho!	Resistant, undefended inter-bedded sandstone and shale cliffs apart from localised defences at Clovelly (harbour structures and a seawall) and Bucks Mill (gabions and seawall).	Undefended cliffs apart from localised defences at Clovelly (harbour structures and a seawall) and Buck's Mill (gabions and seawall). All structures are likely to require improving/ upgrading during this epoch.	Continued improvements and maintenance required to local defences at Clovelly (harbour structures and a seawall) and Buck's Mill (gabions and seawall) during this epoch.
	The cliffs along this coastline are generally cut into interbedded sandstones and shales, which have been subject to faulting and folding in the geological past. As a result, the cliffs are subject to different rates of erosion, with some stretches being fairly resilient to erosion and other stretches prone to large landslips. The shales tend to be more easily eroded than the sandstones but rates of erosion also depend upon the bedding and the degree of faulting and folding. Overall, this coastline has generally experienced low rates of erosion and this trend is expected to continue in the future, such that overall this frontage will maintain a similar form during this epoch. Along much of this coastline erosion is likely to be less than 10m over the next 20 years. However, certain stretches may be prone to landslip events, which could cause between 10 and 50m through a single event. Narrow cobble and gravel beaches are present at the toe of the cliffs. To the west of Chapman Rock these tend to be confined to small pocket	Much of this coast will continue to erode, with less than a total of 20m expected by year 50. However, there is a risk of localised landslide events, which could result in up to 10 to 50m of erosion during a single event. Areas where shales outcrop and previous landslips are evident are most at risk. Sea level rise is predicted to increase erosion rates along these softer cliffs as the cliffs come under increasing attack due to higher water levels. The frequency of landslips may also be affected by any increase in rainfall resulting from future climate change; however, due to uncertainty in the possible future changes in precipitation, no direct account has been taken of this in the predictions. Erosion of the cliffs will supply some sediment to the beaches, although much of the material that makes up these cobble and gravel beaches is essentially relict. Finer material will be transported westwards and either deposited on the intermittent beaches or transported west beyond Hartland Point to be recirculated within	Continual slow erosion of the cliffs is expected along much of this frontage; although there is a risk of isolated landslips where softer rocks outcrop. Here the risk of landslips will increase due to sea level rise and any change in precipitation patterns. Where the coast is backed by resistant cliffs, sea level rise is unlikely to affect the rates of erosion. Between 10 and 40m may be expected along much of the frontage, with actual recession dependent upon the local geology, which varies due to the complex pattern of faulting and folding along this stretch of coast. In a single landslip event up to 10 to 50m of erosion could occur. Although the beaches are mainly relict and composed of gravel and cobble, any erosion of the cliffs may contribute to their stability. As sea levels rise, some of the smaller pocket beaches along the western end of this frontage may become submerged. Along the rest of the frontage beaches are likely to be retained, but due to the predicted increase in water levels may be

Location	Predicted Change for 'With Present Management'		
	Short Term (to 2025)	**Medium Term (to 2055)**	**Long Term (to 2105)**
	beaches, but to the east they become more continuous, forming a barrier beach. Much of this material is likely to be relict, but cliffs may also input some material to the beaches. The coarser material will tend to remain locally and be moved very slowly along in a net eastwards direction, with the finer sediments transported further eastwards to be recirculated within the Bideford Bay circulatory system. During this period both the barrier beaches and the pocket beaches are likely to remain relatively stable. At Clovelly there is currently a small harbour enclosed by breakwaters and backed by a seawall. These structures will continue to afford protection to the enclosed beach and backing infrastructure. The harbour structures will also continue to affect the net eastwards drift, but are only likely to have a very local effect as Clovelly sits within a natural embayment. At Buck Mills there is a short stretch of seawall and gabions associated with access to the beach; these will continue to provide toe protection and reduce the risk of cliff recession at this location.	the Bideford Bay circulatory system. The pocket beaches along the frontage to the west of Chapman Rock are self-contained; therefore they are predicted to remain stable during this epoch. At Clovelly, the harbour structures are expected to require maintenance during this epoch. The harbour arm will continue to trap sediment and protect the enclosed beach, although a reduction in incoming sediment due to sea level rise may result in some cutback at the northern end. However, due to the slight natural embayment, and the shelter afforded from westerly conditions, sufficient beach is expected to be retained along this frontage to provide coastal defence. The backshore defences may require upgrading as the risk of overtopping will increase with sea level rise. At Buck Mills, ongoing maintenance of the defences will continue to prevent cliff erosion locally. The section of defence is short therefore it is unlikely to be affecting large scale processes in terms of sediment inputs or alongshore transport; however continuing to defend here may become technically more difficult, particularly if the undefended cliffs immediately to the west erode further.	narrow and become more volatile as larger waves will be able to reach the upper beach on a more frequent basis. The structures at Clovelly will continue to affect alongshore transport along this stretch, with sediment being held to the west of the harbour arm. The harbour arm will also protect the enclosed beach area. However, some beach narrowing may occur as a result of higher sea levels. The frontage may also become more exposed to wave attack due to sea level rise, but the cliffs backing this frontage are very resistant and therefore unlikely to change. Further upgrade of the backing defences may be required, if not undertaken in the previous epoch, to reduce the risk of overtopping and resultant flooding. At Buck Mills, ongoing maintenance of the defences would provide continued protection of the cliff toe and reduce the risk of landsliding; however, outflanking will increasingly become an issue as a result of erosion of the undefended cliffs to the west. Therefore it is likely to become technically more difficult to maintain the current defences.
Westward Ho! to Taw/Torridge	Westward Ho! is protected by a seawall with additional rock armour toe protection at the	The seawall at Westward Ho!, and associated rock armour, is expected to require ongoing	The seawall at Westward Ho!, and associated rock armour, is predicted to require ongoing

Location	Predicted Change for 'With Present Management'		
	Short Term (to 2025)	Medium Term (to 2055)	Long Term (to 2105)
Estuary	northern end of the wall. Repair and maintenance is likely to be required towards the end of this epoch. Under this scenario it is assumed that the current management strategy of repairing any breaches through recycling of shingle will continue. The rest of the frontage is undefended.	repair and maintenance during this epoch. It is assumed that the current practice of repairing any breaches will continue. The rest of the frontage is undefended.	repair and maintenance during this epoch. It is assumed that any breaches that form will be repaired.
	The southern end of this frontage is characterised by low cliffs, which turn inland and are replaced by the extensive spit and dune system of Northam Burrows, which has formed at the mouth of the Taw/Torridge estuary. This spit and dune complex is set back about a kilometre from the cliffed coastline to the west. It is fronted by a pebble and cobble beach ridge, known as the Pebble Ridge, which extends from Westward Ho! into the mouth of the Taw/Torridge Estuary. Seaward of the ridge is a wide intertidal beach consisting of a thin veneer of sand overlying clays, which merges, to the north, into the tidal flats of the Taw/Torridge Estuary. At the southern end of this frontage the low cliffs are cut into raised beach deposits, which consist of sand and rounded pebbles. These are currently eroding and therefore release pebbles back into the beach system. These low cliffs, where undefended, are expected to continue to erode at a similar rate to present, which is estimated to be between 0.1 and 0.5m/year. Further east there is a seawall and revetment which will continue to prevent cliff erosion, although a trend of beach	At the southern end of this frontage, erosion of the undefended low cliffs would continue, which would release some sand and cobble sized sediments into the system. Pethick (2007) suggested that only sediments eroding from east of the Nose would be available to feed the ridge due to the topography providing barriers to drift. However, such inputs are not significant enough to affect the net recession trend of the Pebble Ridge. Maintenance of the defences at Westward Ho! would continue protecting against localised flooding and erosion; although beach narrowing would be expected and this, together with outflanking, along the adjacent undefended cliffs, could make continued defences technically more difficult. Historically the Pebble Ridge has been realigning towards a swash-aligned position. This has meant that the southern end of the feature has retreated more rapidly than the northern end. This landward roll back of the ridge has been accompanied by a net reduction in volume. This process is expected to continue in the future as it is not thought that the feature has yet attained a	Erosion of the low undefended cliffs at the southern end of this frontage would continue, with rates potentially increasing due to sea level rise. Maintenance of the defences at Westward Ho! would continue protecting against localised flooding and erosion; however, along these sections there will be increased issues of outflanking and undermining resulting from beach narrowing, as the shoreline is unable to retreat naturally. Retreat, realignment and subsequent break-down of the Pebble Ridge will continue. The ridge could have retreated over 300m in total by the end of this period. This stretch of low-lying coast will therefore be at high risk from flooding due to breaching and increased overtopping. It is unlikely that breaches, particularly at the southern end, will seal naturally, and there may not be sufficient sediment available to allow artificial repair. The current recycling of sediment may also be detrimental to the long term integrity of the Pebble Ridge, as it has been postulated (Pethick, 2007) that there is a net loss of coarse sediment from the distal end of the barrier and that the

Location	Predicted Change for 'With Present Management'		
	Short Term (to 2025)	**Medium Term (to 2055)**	**Long Term (to 2105)**
	narrowing along this stretch is expected to continue. These defences prevent sediment inputs to the system; however it is thought unlikely that inputs from this short section of cliffs would be sufficient to change the overall evolution of the Pebble Ridge. The Pebble Ridge currently receives only limited, if any, inputs of new sediment and historically it has been eroding; this erosion is predicted to continue during this epoch, associated with a gradual movement towards swash-alignment from the previous drift-aligned shoreline. The source of sediment is uncertain, but it has been postulated (Orford, 2004) that material probably originated from a large pulse of sediment from Gore Point to the south, following a series of landslips. It is therefore unlikely that local cliff erosion is a significant source. The ridge crest is narrowing and lowering, with a net loss of coarse sediment at the northern end, and, as such, the risk of overtopping and possibly even breaching is predicted to increase during this epoch. Any breaches during this period would be expected to be re-sealed by littoral processes as there is sufficient material being moved alongshore to achieve this. Otherwise it is assumed, under this scenario, that artificial repair of breaches would be undertaken. Sediment eroded from the cliffs to the south will be moved along this frontage, but finer sediments	swash-aligned position. It has been postulated that the rate of retreat could increase exponentially in the future, with between 100 and 150m retreat possible by year 50. As coarse material is moved from south to north, and is not being replaced in sufficient quantities from further south, the risk of the Pebble Ridge becoming breached will increase during this period and it is likely that over time these breaches will not become sealed naturally. Under this scenario, it is assumed that the current management practices of repairing breaches with shingle recycled from elsewhere will continue, although this may increase the vulnerability of other areas. Sea level rise will also increase the likelihood of hinterland flooding and breaching of the defences. It is thought unlikely the Taw/Torridge Estuary would cut an alternative route through the low-lying area behind the barrier.	practice of recycling coarse sediment to the seaward side of the ridge may enhance this mechanism. The location of any breach may be significant; for example, a breach into Sandymere Lagoon may result in the development of a tidal inlet. Any tidal inlets that develop may accelerate the rate of barrier breakdown. These inlets may, however, allow sediment incursion into these back-barrier areas allowing accumulation of finer sediments in the long term; however, this is likely to be a slow process (Orford, 2004: Pethick, 2007). There is, however, a small possibility that a pulse of sediment could be supplied to this shoreline, should a large landslip event occur to the west. However, it has been questioned whether sediment would actually reach this frontage, even if such an event occurred, due to the landward retreat of the ridge (Orford, 2004). It is thought unlikely the Taw/Torridge Estuary would cut an alternative route through the low-lying area behind the barrier.

<table>
<tr><th rowspan="2">Location</th><th colspan="3">Predicted Change for 'With Present Management'</th></tr>
<tr><th>Short Term (to 2025)</th><th>Medium Term (to 2055)</th><th>Long Term (to 2105)</th></tr>
<tr><td></td><td>are likely to continue northwards into the mouth of the estuary and from there either be moved into the outer estuary or into the sediment circulation system and eventually back onto these beaches. The transport of coarser sediments is more limited and there is a very limited supply of new sediments; therefore the trend of net volume loss along the Pebble Ridge is expected to continue during this epoch.

The evolution of this area will be affected by the future management and evolution of the Taw/Torridge estuary and its associated tidal delta, which play an important role in the sediment circulation within the Bay.</td><td></td><td></td></tr>
<tr><td rowspan="2">Taw/Torridge Estuary: Outer Estuary</td><td>The northern seaward side of Northam Burrows is protected by rock armour where it re-curves into the estuary mouth; this is assumed to remain. Along the northern side of the estuary mouth there is a series of groynes at Airy Point, although their current impact on drift is minimal, and a rock revetment along Crow Neck that protects against erosion: this is assumed to remain, although there is a risk it could be breached, which may require additional works.</td><td>The rock armour revetments at Northam Burrows are assumed to remain, but along Crow Neck new defences may be required if a breach is to be prevented.

It is also assumed that embankments will remain and be improved, as necessary, in the Taw and Torridge Estuaries.</td><td>Further works may be required to the rock armour revetments at Northam Burrows and along Crow Neck.

It is also assumed that embankments will remain and be improved, as necessary, in the Taw and Torridge Estuaries.</td></tr>
<tr><td>The channel in the outer estuary is characterised by a number of rock outcrops which ultimately constrain channel movement. The mouth of the estuary is also constrained by the high rates of longshore transport, which have resulted in the formation of the two spits. Despite the trend for</td><td>During this period the impact of accelerated sea level rise and changes in the alignment of the Pebble Ridge, along the open coast to the south, may start to have an impact on the estuary and in particular the outer estuary.</td><td>There is a high level of uncertainty with regard to how the estuary will evolve as sea levels rise. In general the trend of slow infilling is expected to continue, with sediments from alongshore and the nearshore being moved into the estuary. The mouth of the estuary will also attempt to widen in</td></tr>
</table>

Location	Predicted Change for 'With Present Management'		
	Short Term (to 2025)	**Medium Term (to 2055)**	**Long Term (to 2105)**
	swash alignment along Braunton Burrows shoreline, during this period little change is anticipated in the rate of longshore drift; therefore this will remain a constraint on the mouth. The defences will remain the same as today; therefore the current trend of very slow accretion within the estuary is likely to continue. The trend of dune erosion at Crow Neck is expected to continue, but should be controlled by the defences here. The defences within the inner estuaries of the Taw and Torridge are assumed to remain and therefore changes within the inner estuaries will be small.	A net trend of continued, slow infilling is expected under a scenario of sea level rise and the estuary will also attempt to widen at its mouth (Pethick, 2007). The channel bed is over-deepened by more than 15m below its present level, and therefore sea level rise is not predicted to cause an increase in channel size, rather a reduction of infilling rates (Pethick, 2007). There are geological constraints, but also the strong longshore movement of sand has also been a constraint on the mouth width. The rate of sediment transport from the Northam Burrows frontage may be temporarily affected by any breaches occurring during this period, although sand may still be transported in the nearshore zone, and it is also assumed that any breaches would be artificially repaired. The cobble ridge along the northern shore will provide some protection; therefore it is possible that the Airy Point shoreline will suffer greater erosion (Pethick, 2007). The evolution of the Taw and Torridge estuaries will remain constrained by defences; therefore the form of the inner estuaries is unlikely to significantly change. These areas are therefore expected to remain sinks for sediment and continue to slowly infill.	response to an increased tidal prism. The cobble ridge along the northern shore will provide some protection; therefore it is possible that the Airy Point shoreline will suffer greater erosion (Pethick, 2007). The evolution of the Taw and Torridge estuaries will remain constrained by defences; therefore the form of the inner estuaries is unlikely to significantly change. These areas will therefore remain sinks for sediment and continue to slowly infill. The estuary will therefore remain a net sink for sediment and as demand for sediment increase; this could result in increased erosion of the open coast shorelines as more sediment is moved into the estuaries. It is, however, very difficult to quantify such impacts, without further study.
Taw/Torridge Estuary: Torridge	There is a range of flood walls and embankments protecting settlements and reclaimed farmland including Bideford, Hallspill and Appledore,	Existing embankments may require maintenance and upgrading during this period.	Existing embankments may require further maintenance and upgrading during this period.

Location	Predicted Change for 'With Present Management'		
	Short Term (to 2025)	Medium Term (to 2055)	Long Term (to 2105)
Estuary	Yelland and Instow.		
	During this period, the defences are generally expected to remain in their current condition and therefore little net change is expected within the Torridge Estuary, with current trends expected to continue. This may place increased stress on the defences at Appledore and Bideford due to the current position of the meanders.	The defences will continue to fix the shoreline position in places and minimise the risk of hinterland flooding. Under a scenario of sea level rise, the net trend of infilling is likely to continue, albeit at a slow rate due to the lack of availability of muddy sediments in the coastal system. Configurations of the low water channel will influence future localised patterns of erosion, sediment transport and deposition within the intertidal area. North of Torridge Bridge, increases in meander amplitude, as a result of sea level rise, are predicted to impact channel banks on both sides of the estuary (Pethick, 2007) and in particular, the settlements of Appledore and Instow. Channel widening and meander development will therefore increase pressure on the defences during this epoch, resulting in increased need for maintenance (Pethick, 2007). It is not thought likely that the channel would be able to cut a new path through Northam Burrow back barrier area, as it occupies an incised channel and has remained in its current configuration for the duration of the Holocene period (Pethick, 2007).	Future change is difficult to predict due to the uncertainty of estuary development following sea level rise and climate change. The Torridge is extremely confined by its geology, with limited opportunity for salt marsh development, even if sufficient sediments were available. Defences will also continue to fix the shoreline position in places and minimise the risk of hinterland flooding. As sea level rise accelerates, the estuary is expected to continue to slowly infill, although the rate of accretion may reduce (Pethick, 2007). North of Torridge Bridge, increases in meander amplitude that may result from sea level rise are predicted to impact channel banks on both sides of the estuary, e.g. along the settlements of Appledore and Instow. Channel widening and meander development will increase pressure on the defences during this epoch, resulting in increased need for maintenance (Pethick, 2007). Acceleration in the rate of sea level rise would increase water depths, tidal prism and current velocities in the estuary, increasing the potential for sediment reworking both by waves and currents.
Taw/Torridge Estuary: Taw	There is a range of flood walls and protecting settlements including Barnstaple, Sticklepath and Bishop's Tawton. There are also defences	Existing embankments may require maintenance and upgrading during this period.	Existing embankments may require further maintenance and upgrading during this period.

Location	Predicted Change for 'With Present Management'		
	Short Term (to 2025)	Medium Term (to 2055)	Long Term (to 2105)
Estuary	associated with the railway and reclaimed farmland upstream of Barnstaple.		
	During this period little change is expected within the Taw Estuary, with current trends expected to continue. Key areas at risk will be at the apex of meanders, such as at Barnstaple, but defences will continue to minimise the risk of flooding. Upstream of Barnstaple, the edge of the floodplain is bordered by a railway embankment on the right bank and by rapidly rising ground on the left bank. Here little or no change is anticipated.	During this period the impact of accelerated sea level rise will become more significant. Overall net, slow infilling of the estuary is expected to continue. The defences will continue to minimise the risk of flooding of lower-lying intertidal areas. With sea level rise there would, however, be increased pressure on defences at Barnstaple and Sticklepath as the estuary tries to widen in response to a greater tidal prism. A key control on patterns of erosion and accretion will remain the configurations of the low water channel. There is potential for increased stress of existing defences West Ashford, Home Marsh Farm and Bickington (Pethick, 2007).	Future change is difficult to predict due to the uncertainty of estuary development following sea level rise and climate change. the net trend of sediment infilling is expected to continue, although the supply of muddy sediment is low. The defences will continue to minimise the risk of flooding of lower-lying intertidal areas, although increased pressure may be placed on these defences as the estuary responds to an increased tidal prism resulting form sea level rise. In particular defences at Barnstaple and Sticklepath are likely to be put under increased pressure. A key control on patterns of erosion and accretion will remain the configurations of the low water channel. There is potential for increased stress of existing defences West Ashford, Home Marsh Farm and Bickington (Pethick, 2007).
Taw/Torridge Estuary to Saunton Down	This frontage is largely undefended apart from a series of groynes at Airy Point and a blockwork wall and gabions at Saunton to the north (at the eastern end of Saunton Down).	This frontage is largely undefended apart from a series of ineffective groynes at Airy Point and a blockwork wall with gabions at Saunton, which may require maintenance during this epoch.	This frontage is largely undefended, but the localised defences at Airy Point and at Saunton may require further maintenance during this epoch.
	This frontage comprises the extensive dune system of Braunton Burrows, which is one of the largest dune systems in western Britain. This system sits within the Taw/Torridge embayment, which lies between the headlands of Saunton	This dune system is expected to remain fairly resilient to change. There are likely to be localised areas of accretion and erosion, with the possible development of	During this period a key influence on this beach-dune system will be any change in sediment input due to either the change in shoreline orientation along the Pebble Ridge and Northam Burrows to the south or changes in the estuary tidal delta

Location	Predicted Change for 'With Present Management'		
	Short Term (to 2025)	Medium Term (to 2055)	Long Term (to 2105)
	Down to the north and Westward Ho! to the south. This section discusses the dune system from the start of the cliffs at Saunton Down to Airy Point. Historically this system has remained resilient to change and has exhibited a trend of dune vertical growth. This trend is expected to continue during this period, with little change in dune or beach predicted. The groynes at Airy Point are largely ineffective at present and therefore not predicted to have a significant impact on coastal processes.	blow-outs at some locations. Overall the dune system is expected to maintain a net positive budget. If a blow-out were to occur along the central section there is a risk that the backing slack areas could become flooded on every spring tide. The impacts of sea level rise may start to felt during this period; however, the primary driver of dune erosion is likely to be the frequency of storm events and the coincidence of surges with high wave activity, which is when the majority of the dune erosion will take place. Actual erosion and accretion rates along the frontage will be dependent upon the future frequency and strength of such events; there is, however, currently large uncertainty over whether frequency of storms will increase, or storm tracks change, as a result of climate change. Any sediment eroded from the dunes is expected to remain within the system; therefore the dune system as a whole is likely to remain relatively robust. The future evolution of this frontage is also linked to changes within the Taw/Torridge Estuary system and in particular the tidal delta, which plays an important role in terms of sediment circulation within the Bay. This delta allows sand to bypass the estuary mouth, while maintaining an open channel to the sea (Pethick, 2007).	resulting from changes in the estuary regime. Although the dune system as a whole is expected to remain fairly resilient to change, this period could be one of shoreline retreat and erosion of the fronting dunes. A primary driver of dune erosion will also be the frequency of storm events and the coincidence of surges with high wave activity. There is, however, currently large uncertainty over whether frequency of storms will increase, or storm tracks change, as a result of climate change. Any sediment eroded from the dunes is expected to be moved into the sediment circulatory system, but the return of sediment to this shoreline may be reduced. A breach is considered unlikely due to the width of the dunes, but erosion of the frontal dunes may lead to slacks become flooded on every high tide.

Location	Predicted Change for 'With Present Management'		
	Short Term (to 2025)	**Medium Term (to 2055)**	**Long Term (to 2105)**
Saunton Down to Baggy Point (Croyde Bay)	This section is largely undefended apart from a seawall protecting the northern end of Croyde Bay.	The seawall at Croyde Bay could require maintenance during this epoch.	Ongoing maintenance and possible upgrade works required to the seawall at Croyde Bay, otherwise this frontage is undefended.
	Croyde Bay is enclosed by the resistant headlands at Saunton Down and Baggy Point. It is thought to be a 'closed system' in terms of sediment transport, with sediment tending to be internally redistributed. The bay itself is characterised by a wide sandy beach backed by dunes. The headlands of Saunton Down and Baggy Point are characterised by a rock platform and lower cliff composed of resistant shales, overlain by raised beach deposits consisting mainly of sands with pebble layers and some shingle. The headlands are predicted to continue to evolve as historically. The resistant shale deposits will change very little, but where the softer raised beach deposits outcrop there is a risk of erosion though either toe erosion or sub-serial weathering, which could result in a few metres of erosion during a single event. The beach in the centre of Croyde Bay has historically been relatively stable due to protection afforded by the headlands, and this trend is predicted to continue during this period. Any sediment eroded from the beach or dune face is likely to be retained and redistributed within the bay.	Erosion of the headlands is predicted to continue as historically. During this period, the resistant rock platform will continue to afford some control on the backing cliffs, but there is a risk of erosion, through sub-aerial processes of the sandy cliffs above. Baggy Point is expected to erode very slowly (i.e. less than 5m erosion by year 50), but at Saunton Down there is a risk that a landslide events could cause up to 50m erosion. Defences will continue to prevent cliff erosion at the northern end of Croyde Bay. The beach in the centre of Croyde Bay has historically been relatively stable and it is predicted to continue to remain so during this period, despite sea level rise. There may be localised areas of dune erosion, mainly driven by human activity, but any slight erosion is not predicted to affect the integrity of the beach or the wide dune system backing it, with any sediment eroded from the beach or dune face likely to be re-deposited within the bay.	Erosion of the cliffs either side of Croyde Bay, will continue as historically, although there is a risk that sub-aerial weathering of the softer cliffs could increase should precipitation increase in the future due to climate change. Baggy Point is expected to erode very slowly (i.e. less than 5m erosion by year 50), but at Saunton Down there is a risk that a landslide events could cause up to 50m erosion at any one location, although along the remainder of the coast change could be less than 10m. At the northern end of the bay, continued maintenance of defences will prevent erosion of the cliffs. The beach in the centre of Croyde Bay has historically been relatively stable due to the protective influence of headlands. During this period, however, raised water levels, due to sea level rise, may mean that the foot of the dunes is reached more frequently, resulting in erosion. During quiescent times some of this material will be returned to the dunes, but it is possible that a net trend of retreat could be initiated, particularly considering the limited input of new sediment to this system. Actual rates of erosion will be dependent upon the future frequency and strength of storm events, which is when the majority of the dune erosion will take place.

Location	Predicted Change for 'With Present Management'		
	Short Term (to 2025)	Medium Term (to 2055)	Long Term (to 2105)
			There is, however, large uncertainty over whether frequency of storms will increase, or storm tracks change, as a result of climate change.
Baggy Point to Morte Point (Morte Bay)	Most of this frontage is undefended. There are local defences at Putsborough, in the form of masonry walls and a rock revetment which protect the car park to the south and dunes along the northern end of Putsborough. Some of the defences are likely to require maintenance towards the end of this epoch. Dune management is currently undertaken and under this scenario this is assumed to continue.	This frontage is generally undefended, apart from local defences at Putsborough, in the form of masonry walls and a rock revetment, which could require maintenance during this epoch. Dune management will continue.	This frontage is generally undefended, apart from the localised defences at Putsborough, which could require further improvements/maintenance during this epoch, depending on works undertaken in the medium term.
	Morte Bay is controlled by the erosion-resistant headlands of Baggy Point to the south and Morte Point to the north. The bay itself comprises Woolacombe Sand; a wide sandy beach backed by dunes and Woolacombe Down, and Barricane Beach and Grunta Beach; small pocket beaches separated from Woolacombe Sand by smaller headlands. The frontage as a whole is predicted to remain largely stable during this epoch due to the controlling nature of the headlands. The headlands are resistant and are predicted to continue to erode at the very low rates experienced historically; erosion is likely to be in the form of small, infrequent rock falls; therefore negligible erosion is predicted during this period, but the occurrence of very localised events, which	The resistant headlands will change very little during this period, although there is a risk of localised erosion events occurring, which could cause several metres of cliff recession. The primary drivers of dune erosion will be the frequency of storm events, the coincidence of surges with high wave activity, and the impact of human use of the dunes. Actual erosion and accretion rates along the frontage will be dependent upon the future frequency and strength of storm events, which is when the majority of the dune erosion will take place, and under a scenario of sea level rise, waves will reach the dune toe more frequently. There is, however, uncertainty over whether frequency of storms will increase, or storm tracks change, as a result of climate change.	There will be very little change along the resistant headlands, although local cliff fall events may occur. Sea level rise is unlikely to significantly accelerate this process, therefore negligible change is anticipated along the majority of the frontage, although there is a low risk of an isolated cliff fall event, which could result in several metres of recession. Erosion of the dunes will be driven by storm events; however there is significant uncertainty over whether frequency of storms will increase, or storm tracks change, as a result of climate change. Retreat is not possible due to the backing topography of Woolacombe Down; therefore it is likely that the dune belt will narrow in the future. Where the dunes narrow sufficiently, the relict cliffs could become exposed to the waves and

Location	Predicted Change for 'With Present Management'		
	Short Term (to 2025)	**Medium Term (to 2055)**	**Long Term (to 2105)**
	are likely to result in less than 10m erosion, is possible. The frequency of storm events will be the key control on the rate of future dune erosion. Any sediment eroded from the dunes will become deposited on the beach, and therefore may return to the dunes during quiescent periods, as cross-shore transport is dominant in Morte Bay. It is also possible that some sediment may be lost offshore. Overall the dune system should change little during this period, but it will be vulnerable to human pressures. The pocket beaches of Barricane Beach and Grunta Beach, to the north of Woolacombe, are predicted to remain stable. The defences at Putsborough are predicted to continue locally protecting against flood and coastal erosion throughout this epoch, although the rock revetment along the dunes may need to be improved and there is also a risk of erosion along the car park.	This is essentially a closed sediment system, therefore sediment eroded from the dunes should become deposited on the beach, but there may also be a loss of sediment offshore. The pocket beaches of Barricane Beach and Grunta Beach, to the north of Woolacombe, are predicted to remain stable, although sea level rise could begin to cause narrowing and steepening as a result of coastal squeeze against the backing, erosion resistant cliffs. The defences at Putsborough will continue to protect the local area from shoreline retreat, but there could be an increased risk of overtopping therefore these private defences may require upgrading.	therefore some erosion may occur. This would add sediment to the system, but it is not predicted that a significant quantity would be released during this period. Barricane Bay, to the north of Woolacombe, is predicted to experience narrowing and steepening as a result of coastal squeeze against the backing, erosion resistant cliffs, as sea levels rise. The defences at Putsborough will continue to protect the local area from shoreline retreat, however with rising sea levels these defences will become increasingly exposed; therefore additional works could be required to address this.
Morte Point to Widmouth Head	Largely undefended cliffs apart from localised defences, including a seawall at Lee Bay, sea defences at Ilfracombe and a seawall at Hele Bay. There are also harbour structures at Ilfracombe which may provide some defence. Some maintenance works may be required during this period.	Largely undefended cliffs, but the localised defences at Lee Bay, Ilfracombe and Hele Bay may require further maintenance during this epoch.	Largely undefended cliffs, apart from localised defences. Ongoing maintenance and improvements of the defences will be required during this epoch.
	This frontage is comprised of hard rock, namely	As the cliffs are resistant, erosion is likely to be in	Much of this coastline will remain resistant to

Location	Predicted Change for 'With Present Management'		
	Short Term (to 2025)	Medium Term (to 2055)	Long Term (to 2105)
	slates, shales and sandstones with heavily indented embayments formed due to differential erosion. These embayments are effectively closed systems which are unconnected in terms of sediment transport. Historically this frontage has only experienced slow rates of recession, in the region of a few hundred metres since sea levels stabilised approximately 4,000 years ago. Therefore, in general, this coast is expected to experience negligible change over the next 20 years. Any erosion will be in the form of infrequent and small scale events. Similarly little change is expected to occur within the many embayments, which effectively form a series of closed sediment systems. Storm events may affect beach levels; however it is likely that these will be in the nature of cyclical changes with the sediment returning during calmer conditions. At Lee Bay and Hele Bay the existing defences will continue to provide defence but the risk of overtopping may increase; therefore work may be required to address this. The existing defences and structures at Ilfracombe are expected to remain, which will continue to minimise the risk of overtopping and associated flooding. These defences are only thought to have a very localised impact on coastal processes.	the form of infrequent and small scale events; therefore, in general, this coast is expected to experience negligible change over the next 50 years. Due to exposure of different rock types, there will, however, be slight variations in erosion rates along the coast, with the risk that a rock fall event could cause several metres of erosion; however this will only have implications very locally and for much of the coast the frequency of such of an event is considered to be 'low', i.e. every 10 to 100 years. Morte Point prevents any sediment input to this frontage from further west and also the indented nature of this shoreline means that there is limited connectivity between the bays. New sediment input to the beaches is therefore dependent upon local cliff erosion, which is generally negligible. Sea level rise may therefore result in some of the smaller pocket beaches becoming permanently submerged, as retreat of the beaches is not possible due to the resistant cliffs to landward, and there is little fresh sediment available. Elsewhere beach narrowing is likely to occur and small beaches may remain at the toe of the cliffs, where fed by rock fall events. At Lee Bay the risk of overtopping and flooding of the properties will increase due to sea level rise, possibly requiring improvement of the defences, although they will still prevent erosion of the resistant cliffs behind. At Hele Bay any beach	change, due to the nature of the geology, with negligible change predicted for this period. Rates of change are also unlikely to be significantly affected by sea level rise. Localised cliff falls will be the main mechanism of retreat, but these will be restricted to very localised areas. The embayments are predicted to continue to narrow due to sea level rise and it is possible that some of the smaller pocket beaches could disappear. Shoreline narrowing is also anticipated at Hele Bay and Lee Bay, which would increase the risk of overtopping; improvements to the defences may therefore be required. At Ilfracombe, there will be an increased risk of overtopping and localised flooding, therefore defences may require upgrading to continue protecting the hinterland. A small beach may be retained to the east of Capstone Point, but this is likely to be much narrower during this period, due to sea level rise resulting in higher water levels.

Location	Predicted Change for 'With Present Management'		
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		narrowing will increase the pressure on the defences, potentially meaning further improvements are necessary. The extent of flooding will ultimately be restricted by the rising topography. At Ilfracombe maintenance of the defences will continue to prevent against erosion and flooding, although improvements may be required as sea level rises. A small beach will be retained to the east of Capstone Point, due to the indented nature of this frontage.	
Widmouth Head to Hangman Point (Combe Martin Bay)	Largely undefended cliffs, with a localised section of recurved seawall at Combe Martin and harbour structures at Watermouth.	Largely undefended with a recurved seawall at Combe Martin; this may require maintenance during this epoch. The harbour structures at Watermouth are assumed to remain.	Largely undefended with a recurved seawall at Combe Martin, which will require ongoing maintenance during this epoch. The harbour structures at Watermouth are assumed to remain.
	This frontage is comprised of hard rock, namely shale and sandstone, with heavily indented embayments. These embayments are effectively closed systems which are unconnected in terms of sediment transport. Historically this frontage has only experienced very slow rates of recession; therefore future erosion is expected to be negligible and in the form of infrequent and small scale events. The embayments are predicted to remain generally stable during this period; storm events may affect beach levels, however it is likely that these will be cyclical changes with the sediment	Along most of this coast there will be negligible change in shoreline position during this period, due to the resistant nature of the cliffs. As a result of sea level rise the small pocket beaches that characterise this shoreline are likely to narrow due to the combination of high water levels, resistant cliffs and lack of new sediment inputs. At Combe Martin, the defences will continue to protect the hinterland, although increasing pressure on the shoreline as a result of high water levels may cause narrowing and result in	Negligible change is expected along this shoreline due to the resistant nature of the cliffs; however, many of the smaller pocket beaches may become permanently submerged due to high water levels as sea levels rise and the lack of fresh sediment inputs. The rate of cliff erosion is unlikely to be affected by sea level rise therefore the input of sediment to the system is expected to remain minimal. Elsewhere the beaches are likely to become narrower, including at Combe Martin. At Combe Martin the defences will continue to reduce the risk of flooding and erosion locally, but are not expected to affect coastal processes

Location	Predicted Change for 'With Present Management'		
	Short Term (to 2025)	**Medium Term (to 2055)**	**Long Term (to 2105)**
	returning during calmer conditions. Watermouth has historically been eroding and this trend is likely to continue due to the minimal inputs of sediment from cliff erosion.	the defences becoming more vulnerable. This location is also potentially vulnerable to flash flood events which may provide occasional large inputs of sediment as the slate and sandstone bedrock is likely to be eroded during such events.	along adjacent stretches. This location is also potentially vulnerable to flash flood events which may provide occasional large inputs of sediment as the slate and sandstone bedrock is likely to be eroded during such events.
Hangman Point to Duty Head	Undefended frontage.	No defences.	No defences.
	The cliffs in this frontage are more uniform than further west and composed of sandstones with alternating slate and shale bands. The cliffs are resistant and any recession is likely to be in the form of very localised and infrequent events. Therefore along the majority of the coast negligible erosion is expected, although locally up to 10m of erosion could potentially result from an isolated cliff fall. Along much of this frontage there is only a small amount of talus at the toe of the cliffs, but pocket beaches are present in the small embayments which are present. There is not thought to be much input to these beaches from alongshore transport, but during this period, the beaches are expected to remain relatively stable.	Negligible erosion is expected during this period, although there is a risk of a small, localised rock fall occurring, which could result in several metres of erosion. However, the frequency of such events is very low and the effects would only be felt at a very local scale. As a result of minimal sediment inputs, resistant backing cliffs and sea level rise, the small pocket beaches may narrow during this period.	The shoreline is not expected to change significantly as the cliffs are resistant to change. There is a risk of a cliff fall event, but the frequency of such events is very low (every 100 to 250 years). It is unlikely that sea level rise will significantly affect this very slow rate of change. Some pocket beaches may become permanently submerged during this period as a result of rising sea levels and the lack of new sediments into the system.
Duty Head to Foreland Point (inc. Lynmouth Bay)	Undefended apart from the seawall and harbour structures at Lynmouth (which may provide some defence function). The seawall on the western side of the harbour is fronted by a rock and masonry revetment. Some cliff stabilisation has been undertaken at	Undefended apart from the seawall and harbour structures at Lynmouth (which may provide some defence function). The seawall may require maintenance and repair during this epoch. Some cliff stabilisation has been undertaken at western end of Lynmouth which may require upgrading or	Undefended apart from the seawall and harbour structures at Lynmouth (which may provide some defence function). The seawall will require ongoing maintenance throughout this epoch. Some cliff stabilisation has been undertaken at western end of Lynmouth which may require

Location	Predicted Change for 'With Present Management'		
	Short Term (to 2025)	Medium Term (to 2055)	Long Term (to 2105)
	western end of Lynmouth to reduce the risk of rock falls. It is thought unlikely that fluvial flash flood events will supply sediment to the shoreline during this period due to continued fluvial defences along the River Lyn.	maintenance during this epoch. It is thought unlikely that fluvial flash flood events will supply sediment to the shoreline during this period due to continued fluvial defences along the River Lyn.	upgrading or maintenance during this epoch. It is thought unlikely that fluvial flash flood events will supply sediment to the shoreline during this period due to continued fluvial defences along the River Lyn.
	The cliffs in this frontage are composed of sandstones with alternating slate and shale bands. Along much of the coast the cliffs are very resistant, with negligible change expected over the period. Where softer sandstones are exposed, such as along Foreland Point, slightly greater recession rates are expected, but even here less than 10m would be likely. To the west of Lynmouth, the cliffs tend to be fronted by only narrow talus deposits. To the east of Lynmouth there are narrow linear beaches, feed by local cliff erosion; these are expected to remain quite stable during this period. At Lynmouth, the cliff stabilisation works to the west, and the seawall, which runs for over 350m from the harbour westwards along the toe of the cliffs, are expected to remain and will therefore continue to prevent any shoreline retreat. The harbour structures will also afford some protection to the town. The boulder delta at Lynmouth, a legacy of a flash flood event that occurred in 1952, is predicted to remain stable during this epoch. As such, it will continue to provide some protection to the low-lying land	The cliffs in this frontage are composed of sandstones with alternating slate and shale bands. Along much of the coast the cliffs are very resistant, with negligible change expected over the period. Where softer sandstones are exposed, such as along Foreland Point, here between 5 and 25m of erosion may occur by the end of this period. To the west of Lynmouth, the cliffs tend to be fronted by only narrow talus deposits. To the east of Lynmouth there are narrow linear beaches, feed by local cliff erosion; these are expected to remain quite stable during this period. Maintenance of the defences and river training arm will continue to afford some protection to the town. The training arm may have a localised impact in trapping sediment on the western side, but due to the sediment size it is not expected to be significant. Risk of overtopping and flooding to properties along the Lynmouth frontage is predicted to increase during this epoch as sea levels rise, potentially requiring upgrading of the defences.	To the west of Lynmouth, the presently undefended cliffs will continue to behave as at present, with only very low rates of retreat anticipated. Further east, along The Foreland, erosion rates will be slightly higher and may be increased further due to sea level rise. Between 10 and 50m of erosion may occur by year 100. This input of sediment should help to retain narrow beaches along this stretch. Maintenance of the defences and the river training arm will continue to prevent any shoreline retreat. The training arm may have a localised impact in trapping sediment on the western side, but due to sediment size it is not expected to be significant. The problem of overtopping and flooding along the Lynmouth frontage is predicted to continue during this epoch, and the defences may need improvement to mitigate against this. Although the maintenance of defences will prevent further sediment input into the system, the boulder delta at Lynmouth, is predicted to remain stable during this epoch and, as such, it will continue to provide some protection to the

<table>
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<tr><td></td><td>behind.

The defences along the Lyn River greatly reduce the likelihood of a flash flood event occurring in the short to medium term; these structures are assumed to remain.</td><td>Although the maintenance of defences will prevent further sediment input into the system, the beach at Lynmouth is likely to be protected by the boulder delta which is a legacy of a flash flood event that occurred in 1952. It is predicted to remain stable during this epoch and, as such, it will continue to provide some protection to the low-lying land behind. The defences along the Lyn River greatly reduce the likelihood of a flash flood event occurring and these structures are assumed to remain.</td><td>low-lying land behind.

The defences along the Lyn River greatly reduce the likelihood of a flash flood event occurring and these structures are assumed to remain.</td></tr>
<tr><td rowspan="2">Foreland Point to Gore Point</td><td>There are no defences present along this section.</td><td>No defences.</td><td>No defences.</td></tr>
<tr><td>This undefended frontage of sandstone and mudstone cliffs has historically been retreating very slowly and in the future erosion is predicted to occur at similar rates, but with a risk of localised erosion due to wave undercutting at the cliff toe. This may result in the erosion of relict landslip deposits in the upper cliffs, which would erode, but then protect the cliff toe.

Sediment transport within this region is limited both due to the resistant nature of the cliffs, and Foreland Point acting as a barrier to drift entering the region from further west.</td><td>Negligible change is expected during this period along most of this frontage. Local scale events may cause a few metres of erosion due to long term wave undercutting at the cliff toe and localised rock slides.

Sediment transport within this region is limited both due to the resistant nature of the cliffs, and Foreland Point acting as a barrier to drift entering the region from further west. Any sediment movement will be eastwards towards Gore Point, supplying the gravel beaches fronting the cliff and potentially continuing on around into Porlock Bay.</td><td>The current trend of very slow retreat is expected to continue and, in general, the form of this frontage is predicted to remain similar throughout all three epochs. There is a risk that the continued undercutting at the toe of the cliffs could result in the erosion of relict landslip deposits in the upper cliffs, which would erode, but then protect the cliff toe.

Sediment transport within this region is limited both due to the resistant nature of the cliffs, and Foreland Point acting as a barrier to drift entering the region from further west. Any sediment movement will be eastwards towards Gore Point, supplying the gravel beaches fronting the cliff and potentially continuing on around into Porlock Bay.</td></tr>
<tr><td>Porlock Bay</td><td>Defences along the Porlock Bay frontage include a seawall and harbour arm associated with Porlock</td><td>Defences along this section include groynes, seawall and the harbour arm associated with the</td><td>Defences along this section include groynes, seawall and the harbour arm associated with the</td></tr>
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Location	Predicted Change for 'With Present Management'		
	Short Term (to 2025)	Medium Term (to 2055)	Long Term (to 2105)
	Weir, and groynes associated with New Works. There is also an earth embankment protecting the car park. These defences are likely to require works to repair them towards the end of this epoch. It is assumed that the current management strategy will continue; this means that the artificial reprofiling of the barrier ridge would cease.	Weir, will all require ongoing maintenance. It is assumed that artificial reprofiling of the barrier ridge does not take place.	Weir, will require ongoing maintenance and likely upgrade during this epoch. It is assumed that artificial reprofiling of the barrier ridge does not take place.
	Overall the current trends experienced along the barrier are expected to continue in the future, with the barrier remaining in a state of net retreat. Without any management, the barrier is able to respond naturally and become more dissipative by widening and flattening; however, a continuation of overwashing is predicted during this epoch. Between Gore Point and Porlockford cliffs, Porlock Weir will continue to have an impact on the local sediment drift, which sediment being held on the western side. The defences here also appear to have interrupted the occasional westwards drift of sediment, which has resulted in as lobe of shingle at this location. This area is therefore expected to remain in a similar state to present. Along Porlockford cliffs, cliff recession is likely to continue, albeit at the slow rates experienced recently, i.e. less than 0.5m/year. Overall this stretch will remain quite stable due to the influence of the Porlock Weir and the ebb-tidal at	The defences at the Weir will continue to restrict sediment transport eastwards which has resulted in localised accumulation on the updrift western side. Continued maintenance of these defences will help maintain a situation similar to today. There will, however, be increased pressure on the defences at Porlockford, as beach levels along here are expected to drop due to the interruption of sediment from the north-west and continued transport eastwards. In the past, it appears that the Weir has also interrupted to occasional westward movement of shingle, resulting in the lobe of shingle that is present; therefore beach levels here could fluctuate. There will be continued erosion of Porlockford Cliffs, which could be at an increased rate, both due to the limited input of sediment and sea level rise. The 1996 breach is expected to remain open, with continued stability of the western spit and growth of the ebb tidal delta. Growth of this delta could be at the expense of the coast to the	The defences at the Weir will continue to restrict sediment to the beaches further east. This will maintain beaches updrift, but could cause issues downdrift (although historical evidence suggests that westward transport may occasional occur). The defences and cliffs at Porlockford will be at increased risk as beaches here become denuded. Erosion of Porlockford cliffs will release some sediment, but much of this is likely to be moved further eastwards. These soft cliffs will also be sensitive to accelerated sea level rise. It is thought likely that the 1996 breach will remain open, due insufficient rates of longshore drift (exacerbated by the Weir); however, the rate of salt marsh growth behind the breach could decrease the tidal prism sufficiently to allow the breach to reseal, should sufficient sediment be available. Conversely, an increase in sea level rise would tend to increase the tidal prism; therefore it would depend upon the balance between these two processes. There is therefore a degree of uncertainty associated with this stretch coast and

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<tr><td></td><td>the 1996 breach.

The breach is expected to remain open with continued growth of the associated ebb tidal delta. Both spits at the mouth of the breach are likely to remain relatively stable over this period. The area of salt marsh behind the ridge in the vicinity of the 1996 breach is predicted to continue to vertically accrete.

The groynes to the east of New Works will continue to have an impact on alongshore drift and should help maintain some beach stability along the barrier along this section; however these groynes do not prevent cross-shore processes and therefore the barrier will still be prone to roll-over as gravel is pushed over the crest. The groynes may therefore start to intercept more sediment during this period, although it is assumed that they will not be maintained and could therefore fail at some point during this period.

Further eastwards the barrier is expected to remain generally stable and largely static, as it will continue to be feed with sediment from the west and is sufficiently robust. Certain sections, are however, likely to become increasingly vulnerable to overwashing and crest narrowing.</td><td>immediate west of the breach and here there is a high risk that the barrier integrity could be threatened. Alternatively, it is possible that the delta could afford some protection to the shoreline. The salt marsh behind the breach is expected to continue to vertically accrete, although its lateral extent could start to become squeezed as a result of barrier roll-back, as its landward boundary is currently fixed by field boundaries.

There is also a risk of breaching along the eastern spit as the breach position moves progressively eastwards. The vulnerability of the barrier along this stretch will also be increased as the remaining groynes to the east of New Works deteriorate and fail or become less effective as the barrier retreats landwards. This would result in increased longshore drift locally and therefore the barrier along this stretch could become reduced in volume and vulnerable to crest recession and narrowing. Here the risk of hinterland flooding would therefore increase.

The stretch of coast between New Works and the War Memorial will also be vulnerable to breaching during this period, although up to this point it has remained in a largely static, but oversteepened state. Any sediment released as groynes fail to the east of New Works is likely to continue to moved further eastwards and also the growth of the ebb-tidal delta could result in a</td><td>that to the west.

It is possible that breaches may occur along other sections of the barrier, particularly to the east of New Works, up to the War Memorial. The ebb-tidal delta at the breach could continue to act as a sink for this sediment. There is also a limited supply of sediment in the system as a whole and any sediment moved into this frontage, will continue eastwards towards Hurlstone Point. The frequency of wave overwashing events would also increase with accelerated sea level rise and this coastline would be vulnerable to any increase in storminess or change in wind-wave climate.

Any breaches formed, due to catastrophic failure of the barrier, could remain open, but this would be governed by inlet efficiency, which may depend upon the number of breaches forming. It is not thought likely that sediment released by defences updrift failing would be a significant enough to close breaches otherwise.

Further east, between Horner Water and Hurlstone Point, the beach will continue to be fed from sediment being moved alongshore; therefore much of this is likely to remain stable and static. Accelerated sea level rise may, however, have an increased impact during this period and it is likely that the boulder foreshore could become less effective in terms of wave dissipation. Therefore during this period, the trend may start to change to net crest recession</td></tr>
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Location	Predicted Change for 'With Present Management'		
	Short Term (to 2025)	Medium Term (to 2055)	Long Term (to 2105)
		diminished input from further west (despite the potential increase in feed due to failure of Porlock Weir). Therefore this stretch could be denuded of volume and in its oversteepened state it is at greater risk of catastrophic breakdown. It is possible that any breaches that form could become permanent, but it has been suggested (Orford, 2003) that inlet efficiency could be reduced, should a number of breaches form, which would then limit the permanence of breaches. Further east, between Horner Water and Hurlstone Point, the beach is expected to remain stable and relatively static.	as the barrier starts to roll landward. The barrier, along most of its length, is likely, however, to remain robust and provide continued protection to the low-lying hinterland behind.
Hurlstone Point to Minehead	Largely undefended cliffs with some buried groynes immediately west of Minehead, and a terminal groyne associated with the harbour breakwater.	Largely undefended cliffs with some buried groynes immediately west of Minehead, and a terminal groyne associated with the harbour breakwater; this is not expected to require maintenance during this epoch.	Largely undefended cliffs with some buried groynes immediately west of Minehead, and a terminal groyne associated with the harbour breakwater; this is not expected to require maintenance during this epoch.
	The heavily faulted and folded sandstones along this stretch of the coastline are predicted to experience low rates of recession as has occurred historically; therefore negligible erosion is predicted by year 20 for most of this coast. However, there is a risk of small frequent rock falls at Minehead Bluff, which locally could cause up to 10 to 50m retreat over a short section of cliff. The cliffs are fronted by a narrow gravel beach	Low rates of erosion are expected to continue, with generally less than 5m erosion predicted by year 50. However, there is a risk of a large landslide at Minehead Bluff, which locally could cause up to 10 to 50m retreat over a short section of cliff. The cliffs are fronted by a narrow gravel beach and beach lowering towards the east may continue. There is little, if any, incoming sediment from updrift and therefore should sediment be	The cliffs along this stretch are expected to continue to slowly erode, with less than 10m expected by the end of this period. However, there is a risk of a large landslide at Minehead Bluff, which locally could cause up to 10 to 50m retreat over a short section of cliff. The cliffs are fronted by a narrow gravel beach which is predicted to narrow and continue lowering during this epoch. There is little, if any, incoming sediment from updrift and therefore

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	which is predicted to generally remain stable during this epoch, although trends of beach lowering towards the east may continue. There is little, if any, incoming sediment from updrift areas and therefore beaches rely on local sediment inputs, which are negligible due to the slow rates of cliff erosion. The harbour breakwater at Minehead and associated concrete groyne will continue to trap sediment and prevent it travelling further east around into Minehead Bay, resulting in a localised accumulation of sediment updrift.	lost it would not be expected to be replaced. This trend is predicted to be exacerbated by rising sea levels and increased storminess associated with climate change which will deplete beach sediments further without any significant sources of sediment from updrift areas to replace it. The resistant cliffs mean that the beach will be unable to retreat and therefore narrowing is expected. The barrier to drift provided by the harbour structures is predicted to continue during this epoch, with any sediment travelling from the west being trapped updrift. This would help provide some protection to the cliffs immediately north-west of Minehead.	should sediment be lost it would not be expected to be replaced. This trend is predicted to be exacerbated by rising sea levels and increased storminess associated with climate change which will deplete beach sediments further without any significant sources of sediment from updrift areas to replace it. The barrier to drift provided by the harbour structures is predicted to continue during this epoch, with any sediment travelling from the west being trapped updrift. The wider beach that would be retained updrift of the structure would afford some protection to the cliff behind.
Minehead to Blue Anchor	The Minehead urban area is protected by a scheme constructed in 1997-8 consisting of a new recurve seawall, rock revetments and groynes coupled with a large beach recharge. These structures will remain during this period without requiring maintenance or upgrading. Further groynes are found along Dunster Beach protecting the gravel storm ridge. These comprise timber groynes that would be expected to require upgrading during this epoch. Within Blue Anchor Bay there is a scheme involving a concrete seawall and timber groynes, with the wall reinforced by a rock revetment and T-head rock groynes in the east. These defences are assumed to remain as they were constructed	The Minehead urban area is protected by a scheme constructed in 1997-8 consisting of new recurve seawall, rock revetments and groynes; these are expected to remain during this epoch. Further groynes are found along Dunster Beach protecting the gravel storm ridge, which are likely to require maintenance during this epoch. Within Blue Anchor Bay there is a scheme involving a concrete seawall and timber groynes, with the wall reinforced by a rock revetment and T-head rock groynes in the east; ongoing maintenance may be required during this epoch.	The Minehead urban area is protected by a scheme constructed in 1997-8 consisting of new recurve seawall, rock revetments and groynes; these may need some improvements during this period. Ongoing maintenance and improvement of the Dunster groynes may be required during this epoch. Within Blue Anchor Bay there is a scheme involving a concrete seawall and timber groynes, with the wall reinforced by a rock revetment and T-head rock groynes in the east; these structures are likely to require ongoing maintenance during this period.

Location	Predicted Change for 'With Present Management'		
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	in the last few years, although defences at the very eastern end of Blue Anchor are likely to require some works during this period.		
	This is a low-lying section of the shoreline fronted by a gravel and cobble ridge and sandy lower beach. Along some of this stretch the shingle beach forms the main defence, whilst the rest of the coast is protected by seawalls and groynes. At Minehead there have been extensive defence works including a beach recharge. The predominately sandy beach is held in place by large rock groynes. There will be no change in shoreline position due to the defences, and during this period the groynes should maintain beach stability. However, the terminal groyne at the eastern end of the bay will continue to prevent sediment leaving the scheme. This may exacerbate problems at the Warren where an overall trend of shoreline retreat is predicted due to its exposure to storm wave energy. This area is therefore vulnerable to overtopping and flooding. It is possible that a breach in the ridge could occur, but the sand dunes that back this area should prevent a total breakdown. To the west, whilst Blue Anchor Bay as a whole has remained quite stable historically, the gravel storm ridge has been eroded, particularly along Dunster Beach, due to the net eastward	To the west of the Harbour Arm breakwater, there could be a risk of flooding, but this would be very minor. There is not a backdoor flood route to Minehead (Black & Veatch, 2006a). Defences are Minehead will remain, fixing the shoreline position at this location. The groynes, whilst reducing longshore losses will not prevent offshore sediment movement and therefore during this period, under rising sea levels, there may start to be intertidal narrowing, unless further beach recharge is undertaken. There is expected to be continued retreat at the Warren with increasing risk of overtopping along this stretch, with associated flooding behind. As the ridge thins the dunes will also become more exposed to wave attack. The groynes at Dunster may help to stabilise the beach locally by retaining longshore drift, but offshore losses may continue, resulting in beach retreat here, as a result of sea level rise. Along the undefended stretches erosion will continue, with roll back and narrowing of the ridge. There will therefore be an increased risk of breaching and flooding of the hinterland. There is also an associated risk of backdoor flooding to	The defences will remain along the Minehead frontage but will be increasingly exposed to wave action, unless further beach recharge has been undertaken. There could therefore be an increased risk of overtopping. To the west of the Harbour Arm breakwater, there could be a risk of flooding, but this would be very minor and there is not a backdoor flood route to Minehead (Black & Veatch, 2006a). Continued shoreline retreat is predicted across the remainder of the undefended frontage. At the Warren, as the ridge becomes increasingly denuded of material the dune behind will become increasingly exposed to erosion and overtopping. Flooding of the hinterland area is therefore a key risk here. Between Dunster Beach and Blue Anchor, the groynes may become redundant in their current position, as the shoreline behind retreats. Along this stretch there will be an increased risk of overtopping, breaching and resultant large scale flooding. At Blue Anchor defences will continue to fix the shoreline position, which could stand several metres seaward of the adjacent shorelines by this period. These defences will continue to reduce

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	Short Term (to 2025)	**Medium Term (to 2055)**	**Long Term (to 2105)**
	movement of shingle, but little input from further west. Where groynes have been constructed the beach has remained fairly stable and this trend is expected to continue during this period. Along the undefended stretch net retreat is likely to continue at rate of around 0.6m/year (Black & Veatch, 2006a), with roll back and narrowing of the ridge. The defences at Blue Anchor will prevent roll back of the beach, and thus beach narrowing is expected.	Minehead (Black & Veatch, 2009). The defences at Blue Anchor Bay will continue to fix the shoreline position and prevent roll back of the beach, and thus beach lowering may be expected. This section of shoreline will become increasingly exposed as adjacent undefended stretches continue to erode at rates of around 0.6m/year or more.	the risk of flooding, but would require upgrading, due to increased exposure. There would also be a high risk of outflanking, unless works are undertaken to address this.
Blue Anchor to St Audrie's Bay	Undefended cliffs from Blue Anchor to Watchet and the eastern extent of Doniford Bay to St Audrie's Bay. Watchet is protected by concrete seawalls, and rock groynes and revetments in the harbour area and these may require upgrading towards the end of this epoch. Between Watchet and Doniford Bay there are localised stretches of defences and small groynes protecting the low-lying land. Doniford Bay is protected by a rock revetment which may require repair during this epoch.	The defences at Watchet, Doniford and along the coast between Watchet and Doniford will require ongoing maintenance during this epoch.	Further maintenance of the localised defences at Watchet, Doniford and along the coast between Watchet and Doniford may be required.
	This frontage mostly comprises Triassic shale and limestone and Jurassic mudstone cliffs fronted by intertidal rock platforms, intersected by small embayments. To the east of Blue Anchor Bay, sandstone cliffs are replaced by mudstone cliffs, which erode via cliff falls, landslips and rotational slides. Such	The mudstone cliffs along this frontage erode via cliff falls, landslips and rotational slides, which have resulted in significant amounts of erosion at certain locations in the recent past. Along much of the undefended frontage, between 5 and 25m of recession may occur, but a landslide event at any one location could cause up to 10 to 50m of	Differential erosion of this cliffed frontage will continue, although rates may increase due to sea level rise. Failure will be through both gradual erosion and larger landslide events. Along much of the frontage between 10 and 50m of erosion may be expected, however there is a risk that at any one location a larger event could cause up to

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	events have resulted in several metres of erosion in the recent past. Up to 10m of recession could occur along this undefended stretch of coast by year 20 although there is a risk that a single event could cause between 10 and 50m erosion at a single location. At Watchet the seawall and harbour structures will continue to fix the shoreline position and to minimise the risk of flooding and erosion, although this is only a localised effect. To the east, the defences between Watchet and Doniford will continue to help slow cliff erosion along this stretch, but there may be issues of outflanking to either side of the defences. Similarly the rock revetment in front of the Doniford Holiday Camp will continue to afford both erosion and flood protection to the low cliffed areas. Any cliff erosion that does occur will provide sediment to feed the beaches downdrift, i.e. to the east.	erosion. At Watchet, the shoreline position will remained fixed by defences, including the harbour structures. To the east, a crenulated-form embayment is forming in the lee of the limestone outcrop at Helwell Bay. Defences, in the form of groynes and rock revetment, have been put in place to prevent cliff erosion here, and at Doniford Bay. Here the beach is narrower than to the east and the cliffs are much lower. Differential cliff erosion to the varying geology and continued impact of defences will result in more pronounced embayments forming along this coastline, with the resistant limestone areas and defended stretches forming headlands. Any cliff erosion that does occur will provide sediment to feed the beach downdrift, i.e. to the east, although due to the defences there are not predicted to be significant impacts. The Swill and its associated pipeline appears to disrupt along shoreline sediment transport, resulting in a localised build up of beach to the west of the outlet. Although the rock platforms are predicted to continue providing defence to the foreshore, sea level rise may reduce their defence role and therefore the cliff erosion rates could increase.	50m of erosion. Ultimately the coastline will become defined by a series of crenulated bays, formed between the more resistant limestone outcrops, which will emerge as headlands. In the long term, these bays could reach a more stable form, resulting in lower rates of erosion; however this process may be prevented by the predicted acceleration in sea level rise. Any cliff erosion that does occur will provide sediment to feed the beach downdrift, i.e. to the east. However, as the crenulated bays develop, sediment transport may reduce. The Swill and its associated pipeline acts to disrupt along shoreline sediment transport, resulting in a localised build up of beach to the west of the outlet. At Watchet, the shoreline position will remained fixed by defences, which will prevent any cliff erosion.

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		Sediment transport rates may also be affected.	
St Audrie's Bay to Hinkley Point	Undefended shoreline except for rock armour backed by earth embankment at Lilstock. These defences are predicted to require upgrading towards the end of this epoch.	Undefended shoreline except for the rock armour and earth embankment at Lilstock which will need ongoing maintenance during this epoch.	Undefended shoreline except for rock armour and earth embankment at Lilstock. Ongoing maintenance and improvement will be required during this epoch.
	This mainly cliffed stretch of coastline is cut into Triassic shales and limestones which have historically eroded slowly due to their resistant nature. Future rates are predicted to be similar to these historical ones with less than 10m of erosion likely by year 20. There, however, is a risk of localised erosion events that could result in up to 10m erosion at a single location. This will be a continuation of past trends, which has resulted in a series of small indents along this shoreline. Any sediment eroded from the cliffs will provide material to the foreshore and the extensive rock platforms will continue to afford some protection to the cliffs. There is potential for this sediment to be transported eastwards, towards Hinkley Point, but it is periodically interrupted by small headlands. The short stretch of rock armour and earth embankment at Lilstock will continue to reduce the risk of flooding and erosion along this lower-lying section of coast, but there will be a risk of outflanking due to continued cliff erosion either side; therefore works may be required to address	The cliffs will continue to erode quite slowly, with up to 5 to 25m by the end of this period. There is, however, a risk of isolated erosion events which may cause several metres of erosion over a very localised stretch. Even under a scenario of sea level rise, the extensive rock platform should continue to afford some protection to the backing cliffs. Any sediment eroded from the cliffs will provide material to the foreshore, which may be sufficient to enable a beach to be retained at the toe of the cliffs. Sediment will also be moved eastwards along the coast. The defences at Lilstock will continue to reduce flooding and erosion risks locally, but risks of outflanking may increase due to cliff erosion to either side, unless works have been undertaken to address this risk. Similarly the small area of low-lying land art Kilve Point is also at risk from flooding during this period as the natural gravel ridge will become more vulnerable to overtopping as a result of sea level rise. The potential for barrier roll back is very limited as	There will be continued, slow erosion of the cliffs, with up to 10 to 50m possible by year 100. Small erosion events will result in small bays being cut, reinforcing the naturally indented nature of this coastline. Under a scenario of sea level rise, the shore platforms may become partially submerged, but are likely to still play a role in affording some protection to the backing cliffs and beaches. The foreshore currently provides protection to the cliffs in the form of the wide intertidal rock platforms, and these are predicted to continue doing so during this epoch. Narrow beaches are expected to be retained, particularly within the small bays formed as the cliffs erode. There is still likely to remain a sediment pathway eastwards towards Hinkley Point, but the interconnectivity of this coast may periodically reduce due to the emergence of headlands. The risk of very localised overtopping and flooding at Kilve Point will increase due to rising sea levels and the risk of the barrier becoming breached. Hinterland flooding will, however, be restricted due to the local topography. There is

Location	Predicted Change for 'With Present Management'		
	Short Term (to 2025)	**Medium Term (to 2055)**	**Long Term (to 2105)**
	this towards the end of the period.	the coast is backed by rising topography.	limited opportunity along this coastline for barrier roll-back, therefore there is likely to be barrier narrowing. At Lilstock the defences will continue to reduce flooding and erosion risks locally.
Hinkley Point	Defences protecting Hinkley Point power stations in form of recurve seawall backed by gabion baskets.	Defences at Hinkley Point will need maintenance towards the end of this epoch.	Defences may require maintenance and upgrading.
	The defences will continue to protect the power station site from flooding and erosion (due to overtopping). The shoreline position will therefore remain fixed during this epoch. The shoreline along the power stations frontage protrudes seawards by about 100m, due to land reclamation during the construction of the power stations. The power stations are therefore believed to be underlain by made ground, composed of limestone and shales excavated from the foundations of the site. The increased exposure of this shoreline means that shingle beaches are not present at the toe of the defence and therefore waves are able to reach the defences at high water. The defences protecting the power stations are assumed to remain and will therefore fix the shoreline position and continue to minimise the risk of flooding during this epoch. The defences also interrupt the transport of	The defences will continue to fix the shoreline position and minimise the risk of erosion. As the undefended cliffs to the west erode, there could be an increasing risk of outflanking to the west of the site; therefore works could be required to address this. The site will also become increasingly exposed; therefore the risk of overtopping could increase, unless defences are improved to address this. As well as preventing the input of sediment from the erosion of these cliffs, as the promontory increases, any sediment travelling east will become trapped and unable to continue eastwards towards Stolford.	The defences will continue to fix the shoreline position, but there would be an increasing risk of outflanking due to continued erosion of the undefended cliffs to the west. As sea levels rise the fronting platforms could become increasingly submerged and eroded; thereby increasing the wave energy at the toe of the defences. The promontory will interrupt any sediment transport taking place, it may also promote the loss of fine sediment offshore.

Location	Predicted Change for 'With Present Management'		
	Short Term (to 2025)	Medium Term (to 2055)	Long Term (to 2105)
	shingle westwards along this frontage and historically the gravel ridges downdrift have been eroding. This trend is predicted to continue during this epoch.		
Hinkley Point to Parrett Estuary	There is a rock revetment fronting an earth embankment from Hinkley to Stolford with earth embankments and gabion walls east of Stolford to Wall Common. The defences along Steart Peninsula may require upgrading towards the end of this epoch, whilst defences towards Hinkley will undergo maintenance.	The defences east of Hinkley Point will require repair and upgrade during this epoch to maintain an adequate standard of protection.	All defences may require ongoing maintenance and possible further upgrade during this epoch to maintain an adequate standard of protection.
	To the east of Hinkley Point the hinterland becomes low-lying, forming the start of the Steart Peninsular, which stretches westwards into the mouth of the Parrett. Between Hinkley and Stolford the gravel beaches have been greatly denuded and only a narrow strip of shingle is currently present. Currently the main defence is provided by a rock revetment, but this is also holding the coastline away from its natural alignment, which may be exacerbating the issue of beach loss. Between Stolford and Steart Point, protection from flooding is currently provided by the shingle barrier (and earth embankment/gabion defences) and attenuation of waves across the intertidal flats and salt marshes, which become prevalent towards Steart. The general trend has been long term erosion of both the salt marsh and the shingle beach and this net trend is expected to	The gravel ridge is predicted to continue eroding during this epoch, with the ridges rolling back to a more natural and less exposed alignment. The low-lying hinterland is likely to become increasingly at risk from flooding via overtopping, therefore defences would need to be increased in height to minimise this risk. Localised breaches may also occur as a result of sea level rise and the reduced protection afforded by the shingle ridge, causing flooding of the wide area of low-lying land that makes up the Steart Peninsula. Such breaches would be able to re-seal should there be sufficient sediment, however the continued defence of Hinkley Point may prevent this and breaches may become permanent. Steart Point interacts with the Parrett Estuary; therefore any changes in the estuary regime may affect this shoreline. It has been suggested that in the long term a new channel could be cut through	Due to the impact on sediment drift of both the defences along the Hinkley Point power stations frontage and the natural headland of Hinkley Point, the gravel ridges are predicted to have little incoming sediment to maintain them and they may narrow as well has migrating landwards, in response to sea level rise. Ridge erosion may lead to increased risk of breaching between Hinkley Point and Steart resulting in hinterland flooding, although continued defence provision here would minimise this risk. Breaches may become permanent should there be insufficient sediment to naturally repair them. In this instance a tidal inlet would form which would reduce the stability of adjacent sections of ridge and thus may lead to subsequent enlargement of the breach. The evolution of the Steart Peninsula will also be

Location	Predicted Change for 'With Present Management'		
	Short Term (to 2025)	Medium Term (to 2055)	Long Term (to 2105)
	continue in the future along much of the frontage. Sediment transport rates east of Wall Common are negligible and therefore the beach in this region may remain more stable during this epoch.	the Steart Peninsula; this would significantly alter the hydrodynamic and sedimentary regime of the whole area. However, potential changes to the regime of the Parrett, and its interaction with the open coastline are not well understood; therefore the impacts of any changes within the estuary on this frontage are difficult to quantify, without further, more detailed, study.	dependent upon the Parrett Estuary; however, future changes in estuary regime, and the corresponding open coast response, are very difficult to predict. There is a potential risk that the main channel of the Parrett could migrate, with the potential for it to break through the Steart Peninsula. Further studies are necessary to determine the likelihood of this occurring and the likely response of the system.
Parrett Estuary	The Parrett Estuary is constrained over much of its length by embankments with localised revetments, and, in the vicinity of Bridgwater, embankments, concrete or masonry walls, sheet piled walls and flood walls. The defences outside of Bridgwater will require repair during this epoch, whilst the urban defences are expected to maintain the standard of protection throughout.	The Bridgwater defences are likely to require repair and maintenance as they begin to degrade during this epoch. The other defences will require continued maintenance. A surge barrier may also be constructed during the latter part of this epoch in support of the defences (Environment Agency, 2009).	All defences require continued maintenance during this epoch.
	The constrained nature of the Parrett channel, due to the presence of defences, means that there is little opportunity for change during this epoch. The key risk will be from the meandering nature of the low water channel which will put local pressure on the various defences within the estuary. Little net change within the estuary is therefore anticipated during much of this epoch and the risk of flooding will be minimised.	Maintenance of the defences means that much of the estuary remains constrained. Currently the estuary is in a stable state and this is likely to continue for much of this period, however, as sea level rise this will start to impact on the estuary as a whole. Sea level rise is expected to result in an increased tidal prism and therefore an increase in tidal flow. Sediment deposition in the lower reaches may increase. Studies (EA, 2009) suggest, however, that overall sea level rise will have a marginal impact on the existing estuarine regime.	During this period the effect of sea level rise could become more significant. Sea level rise is expected to increase the tidal prism, resulting in increased tidal flows, although the estuary is expected to remain flood dominant. Maintenance of the defences means that the channel will remain constrained along much of the estuary. Increased water levels could increase pressure on the defences and therefore works are likely to be required to address this. Defences would also be affected by any changes in the position of the low water channel; however, this

Location	Predicted Change for 'With Present Management'		
	Short Term (to 2025)	Medium Term (to 2055)	Long Term (to 2105)
		Climate change may also change the proportions of fresh and saltwater with an increase in rainfall potentially causing an increase in river flows and inundation of low level land as sea levels rise. The Huntspill Channel regulates discharge from the lower parts of the River Brue catchment area, and as such provides a steady inflow of water into the lower Parrett. Increases in the discharge through this channel would be likely to cause further localised erosion of the banks either side of the confluence, and of the area of salt marsh downstream. The defences will minimise the risk of flooding, but localised pressure on defences may result from changes in the position of the low water channel – which are difficult to predict without further studies.	is difficult to predict, without further studies. Changes in the estuary may affect the adjacent coastline through affecting the position of the outer low water channel. It has been postulated (Pethick, 2002) that the increase in tidal prism would caused the outer low water channel to swing clockwise, which would affect the coastline of Burnham. Climate change may also change the proportions of fresh and saltwater with an increase in rainfall potentially causing an increase in river flows and inundation of low level land as sea levels rise. The Huntspill Channel regulates discharge from the lower parts of the River Brue catchment area, and as such provides a steady inflow of water into the lower Parrett. Increases in the discharge through this channel would be likely to cause further localised erosion of the banks either side of the confluence, and of the area of salt marsh downstream.
Parrett Estuary to Brean Down	Along the Burnham-on-Sea frontage there is a recurved seawall and stepped revetment constructed in 1983, which is assumed to remain during this epoch. There is also a flood gate at Maddocks Slade. Between Burnham and Brean the coastal dune system is the primary defence – records suggest that this dune ridge has restricted overtopping along this stretch.	Along Burnham-on-Sea frontage the recurved seawall constructed in 1983 is assumed to remain, although the need for further works will depend upon the future position of the Parrett low water channel, which could affect exposure conditions along this shoreline. Between Burnham and Brean the coastal dune system is the primary defence and although the frontal dunes may erode, the backing dune system	The defences at Burnham-on-Sea are likely to require upgrading during this epoch in order to continue to provide current levels of protection. Between Burnham and Brean the coastal dune system is likely to fail in places, allowing inundation by the sea to occur. However, this is likely to only affect he frontal dunes along Berrow Marsh and a new shoreline position at the toe of the back dunes is predicted to form.

Location	Predicted Change for 'With Present Management'		
	Short Term (to 2025)	**Medium Term (to 2055)**	**Long Term (to 2105)**
	Between Brean and Brean Down there is a range of defences including a wave return wall, masonry walls, rock armour and gabion baskets. Some of these, such as the gabion baskets are at risk of failure during this period and so will require repair and possibly rebuilding in this epoch. The risk of back door flooding is also minimised by flood embankments along the left bank of the River Axe; these are assumed to remain.	should continue to provide a high standard of protection from flooding. Between Brean and Brean Down the range of defences including a wave return wall, masonry walls, rock armour and gabion baskets are all at risk of failing as a result of undermining during this period and so these will need to be upgraded during this epoch to ensure required levels of protection are maintained. The risk of back door flooding is minimised by flood embankments along the left bank of the River Axe; these could be at risk of failure during this period and could therefore need to be upgraded during this period.	Between Brean and Brean Down, the defences will continue to be maintained.
	This section can be split into two parts; the low-lying land from the Parrett Estuary to south of Brean Down and the resistant Carboniferous limestone headland of Brean Down itself, which will experience negligible change. At Burnham the defences will continue to fix the shoreline position and the coast along this stretch is likely to remain generally stable; although localised beach lowering may become an issue. Along the central section of undefended coastline, frontal dune erosion is likely to continue at rates between 0.4 and 2m/year. There is a risk that these frontal dunes could be breached during this period, which could impact on the Local Nature Reserve at Berrow; however, the high dunes	At Burnham, the defences will continue to fix the shoreline position. The vulnerability of this coastline will, however, also depend upon changes within the Parrett estuary, and in particular the future route of the low water channel; it is possible that this could swing clockwise towards the coast as a result of tidal prism increases. If this occurs it could cause increased erosion of the foreshore fronting Burnham-on-Sea, and therefore increase the exposure of this coastline. Although the trend of dune erosion will continue along Berrow Dunes, the flood risk to the hinterland should remain low due to the higher dunes which lie behind. Between Brean and Brean Down, some defences	At Burnham, the defences will continue to fix the shoreline position and provide flood and erosion protection, but more substantial defences may be required in response to both sea level rise and any change in the outer low water channel of the Parrett. There could also be a risk of outflanking due to erosion of the adjacent undefended dunes. The erosional trend will continue along the dune frontage. Assets situated above the flood plain within the coastal dunes will also be at risk of erosion and undermining, due to continued erosion of Berrow Dunes. Between Brean and Brean Down the flood risk will be minimised by the defences, which will also fix the shoreline position; defence of this low-

Location	Predicted Change for 'With Present Management'		
	Short Term (to 2025)	Medium Term (to 2055)	Long Term (to 2105)
	behind will prevent further hinterland flooding. Between Brean and Brean Down the current defences will continue to fix the shoreline position and reduce the risk of hinterland flooding. It is also assumed that defences within the Axe will also remain during this period.	could start to fail during this period, significantly increasing the risk of hinterland flooding. There would also be an increased risk of back-door flooding from the Axe. Limited change is predicted for the headland at Brean Down; less than 5m by the end of the epoch. Should the wide intertidal mudflats erode as they have been recently, there would be predicted to be greater erosion at the shore as these mudflats provide protection of the coast through reducing incident wave energy. Eroding sediment will be transported south through longshore drift towards the Parrett Estuary or be deposited on Gore Sand.	lying hinterland also depends, however, on continued maintenance of defences along the left bank of the Axe. There will be limited change at Brean Down, due to the resistant nature of this headland; less than a total of 10m is anticipated by the end of the epoch.
Brean Down to Anchor Head (Weston Bay)	The main defence along this frontage is a seawall protecting the town of Weston-Super-Mare from flooding and erosion. These defences are in the process of being upgraded. There is also a seawall to the south extending northwards from the River Axe to Uphill; this is expected to require upgrading during this epoch. There is a short stretch of undefended dunes along the Uphill to Weston-super-Mare frontage. Embankments along the Axe Estuary and protecting low-lying hinterland from flooding are assumed to remain during this epoch.	The main defence along this frontage is along Weston-Super-Mare and consist of a seawall; it is assumed that this will have been upgraded in the short term. The seawall at Uphill may need to be upgraded in order to continue to provide adequate levels of protection. Embankments along the Axe Estuary and protecting low-lying hinterland from flooding are likely to require maintenance and possibly further works towards the end of this epoch.	The seawall at Weston-Super-Mare is likely to require ongoing maintenance, as will the seawall at Uphill. Embankments along the Axe Estuary and protecting low-lying hinterland from flooding, will also require maintenance, assuming works have been undertaken in the medium term to ensure adequate crest heights.
	This frontage is controlled by the two resistant	Cliff erosion at Brean Down is expected to	Cliff erosion at Brean Down and Anchor Head is

Location	Predicted Change for 'With Present Management'		
	Short Term (to 2025)	Medium Term (to 2055)	Long Term (to 2105)
	Carboniferous headlands at either end, namely Brean Down and Anchor Head, which form a closed sediment system. A further influence is the presence of the River Axe, which discharges at the southern end of this bay. Brean Down is predicted to erode at rates similar to historically, with negligible change expected during this period. Similarly erosion at Anchor head (the northern limit of the bay) is also predicted to be negligible. Along the main frontage of Weston-super-Mare the defences will continue to hold the shoreline position and minimise the risk of localised flooding and erosion. Defences to the south of Uphill are also assumed to remain and minimise flooding risk along this section during this period. The low rates of cliff erosion and littoral drift mean that there is little fresh sediment input to feed the beaches and dune system. Recently there has been a trend of slight erosion, particularly foreshore lowering and steepening associated with the defences in the north. This is predicted to continue during this epoch. The embankments constraining the River Axe will prevent any significant change in estuary morphology or processes.	continue occurring at a very slow rate with infrequent events and therefore by the end of this epoch total erosion is predicted to be less than 5m. Similar erosion is expected at Anchor Head. Shoreline retreat in undefended areas and foreshore lowering where defences prevent natural retreat is predicted to continue during this epoch. The dune system north of Uphill is also likely to suffer erosion. The risk of flooding of the low-lying hinterland (part of the Somerset Levels) is predicted to increase throughout this epoch, due to rising sea levels, particularly if erosion of the undefended dunes increases. The defences along the northern part of the frontage will maintain the shoreline position and minimise flood risk; however, they may become increasingly exposed as the foreshore lowers. The embankments constraining the River Axe will prevent any significant change in shoreline morphology or processes. However acceleration in the rate of sea level rise could increase water depths, tidal prism and current velocities in the Axe, increasing the potential for sediment reworking both by water and currents.	predicted to continue occurring at a very slow rate with infrequent events and therefore by the end of this epoch total erosion is predicted to be less than 10m. Shoreline retreat in undefended areas and foreshore lowering where defences prevent natural retreat is predicted to continue during this epoch. The dune system north of Uphill is also likely to suffer erosion. The risk of flooding of the low-lying hinterland (part of the Somerset Levels) is predicted to increase throughout this epoch due to rising sea levels. The potential for a breach of the dunes is also an increased risk during this epoch which would cause significant flooding. There is potential for the dune belt to be entirely lost in the centre of this frontage during this epoch. This would be predicted to result in the development of low cliffs due to erosion of the backing hinterland. The defences in the northern part of the frontage will maintain the shoreline. These defences are, however, predicted to become under increasingly under pressure due to foreshore lowering and potentially outflanking. The presence of the defences will also limit the sediment available to feed the dunes to the south and therefore this may add to the erosion here. Additionally the extra pressure on the dunes will make maintenance of the defences at Uphill increasingly

Location	Predicted Change for 'With Present Management'		
	Short Term (to 2025)	Medium Term (to 2055)	Long Term (to 2105)
			difficult. The embankments constraining the River Axe will prevent any significant change in shoreline morphology or processes. However acceleration in the rate of sea level rise would increase water depths, tidal prism and current velocities in the Axe, increasing the potential for sediment reworking both by water and currents.

C.5.4 WPM Data Interpretation

C.5.4.1 Introduction

The approach to data interpretation for the 'with present management' scenario is broadly the same as the approach described for the 'no activation intervention' scenario described in Section C.4.4). This included the use of a number of data sets in the predictions of future shoreline response and evolution under the scenario of 'with present management', as follows (these data were also used and reported in the Assessment of Shoreline and Estuary Dynamics, Section C.1 above):

- The cliff assessment database from Futurecoast, which includes information regarding likely failure mechanism, recession protection and frequency;
- Ordnance Survey historical maps, which date back to the 1880s.
- Other historical change data sets: e.g. at some locations cliff position data sets are available ;
- Futurecoast predictions of future shoreline change under an 'with present management practices' scenario: this assumed that all present management practices were to continue regardless of cost;
- Strategic Regional Coastal Monitoring programmes beach profile data: this data is only relevant for specific locations and restricted to specific time frames i.e. ten to fifteen years at most.
- Various studies and research papers.
- The National Coastal Erosion Risk Mapping research and development project (Halcrow, in progress) that used the Futurecoast data described above as a starting point, but which has been through a process of local validation with all coastal operating authorities to ensure the correct up-to-date information is being used as part of this project.
- The Futurecoast aerial CDs, Google Earth and other photographs were also used, together with any local knowledge of the area.

C.5.4.2 Consideration of Sea Level Rise

Section C.4.4.2 provides full details as to the how sea level rise has been considered throughout the SMP area depending upon the characteristics of the range of cliff types found along this coast.

C.5.4.3 Data Assessments (WPM)

Location	Available data	Assumptions made in predictions of coastal change for WPM			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
Lundy	No data available from Futurecoast	Based on the cliff type, assumed that very slow erosion will continue, with infrequent rock falls. Therefore less than 10m predicted. Landing Bay and its access is defended by a seawall, breakwater and gabion revetments, which will continue to prevent shoreline retreat.			Limited data, but generally low rates expected. SLR not expected to have a major impact on rates.
Hartland Point to Westward Ho!	Futurecoast (Halcrow, 2002) stated that there was a mix of simple and complex cliffs. Cliffs predicted to erode at low rates (0.1-0.5m/year), but with a risk of 10 to 50m occurring along certain sections, should a landslip occur. This will be reduced towards Babbacombe where the cliffs are protected by a boulder and gravel ridge.	An erosion rate of 0.1 to 0.5m/year is assumed: linear extrapolation gives a maximum erosion of 2 to 10m by year 20. But risk that a single event could cause up to 10 to 50m at any one location, therefore maximum risk assumed to be 50m. At Clovelly it is assumed that defences would hold the shoreline position. At Buck Mills it is assumed that defences would continue to slow erosion locally.	An erosion rate of 0.1 to 0.5m/year is assumed: linear extrapolation gives a maximum erosion of 5 to 25m by year 20. But risk that a single event could cause up to 10 to 50m at any one location, therefore maximum risk assumed to be 50m. At Clovelly it is assumed that defences would hold the shoreline position. At Buck Mills it is assumed that defences would continue to slow erosion locally.	An erosion rate of 0.1 to 0.5m/year is assumed: linear extrapolation gives a maximum erosion of 10 to 50m by year 20. But risk that a single event could cause up to 10 to 50m at any one location. It is assumed that only one such event would occur over this period along a specific section of coast and that this would cause a total maximum of 50m at any one location. At Clovelly it is assumed that defences would hold the shoreline position. At Buck Mills it is assumed that defences would continue to slow erosion locally.	Uncertainty over location and timing of landslips and also the likely retreat that could occur. The risk of landslips could increase due to changes in precipitation and SLR.
Westward Ho! to	Futurecoast (Halcrow, 2002)	Westward Ho! is	Westward Ho! is	Westward Ho! is	No rates available for the cliffs and

Location	Available data	Assumptions made in predictions of coastal change for WPM			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
Taw/Torridge Estuary	predicted a 'high' rate of change (50 to 100m by year 100). No data was available for cliff erosion to the west of Westward Ho! Historical maps do not show any significant change in cliff top position, therefore an average rate of 0.1 to 0.5m/year is assumed. Various rates of barrier retreat are available; with a maximum rate in the south , reducing to the north: Slade (unpublished) suggests that a common rate of retreat is 2-3m/year, but that in places it can be up to 50m. May (2003) suggested that from maps it was evident that the ridge moved 152m in the 100 years after 1961 equates to an average rate of 1.52m/year. Keene (1996) proposed that between 1959 and 1996 the ridge crest retreated 30 m (c. 0.8m/year).	protected by a seawall with rock armour toe preventing localised flooding and erosion. For the Pebble Ridge, assuming a maximum rate of 2 to 3m/year, then up to 40 to 60m predicted by year 20, reducing to the north. For undefended cliffs, assume 0.1-0.5m/year giving 2 to 10m.	protected by a seawall with rock armour toe preventing localised flooding and erosion, but foreshore lowering as the beach is unable to retreat naturally. For undefended cliffs, assume 0.1-0.5m/year giving 5 to 25m. For the Pebble Ridge, assuming a rate of between 2 and 3m/year, then up to 100 to 150m predicted by year 20, reducing to the north. Key risk, however will be from tidal inundation. Flood risk is based on EA 2008 Flood Map.	protected by a seawall with rock armour toe preventing localised flooding and erosion, but foreshore lowering as the beach is unable to retreat naturally. For undefended cliffs, assume 0.1-0.5m/year giving 10 to 50m. For the Pebble Ridge, assuming that retreat rates increase to 4m/year, up to 330m total retreat could occur by year 100. If rates of 2m/year were to continue then a total retreat of 200m could occur. Key risk, however will be from tidal inundation. Flood risk is based on EA 2008 Flood Map.	historical OS maps indicate little change. Various estimates available for Pebble Ridge, but further studies required to appraise varying rates along the length of the ridge. Uncertainty regarding the combined impact of both changes within the estuary and sea level rise on the mouth of the estuary and adjacent shorelines.

Location	Available data	Assumptions made in predictions of coastal change for WPM			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
	Orford suggested a rate of 2.6m/year. The Pebble Ridge is believed to be re-orientating counter-clockwise towards a swash alignment so that northerly drift and thus loss of cobbles is progressively reducing. Pethick (2007) suggests that retreat rates of >2m/year would be experience over the next 20 years, but that these could exponentially increase over the next century to 4m/year by 2100.				
Taw/Torridge Estuary: Outer Estuary	Pethick (2007) has been used as the main source of information.	Defences remain. Little change expected within the outer estuary.	Defences remain and minimise flood risk. General overall trend of slow infilling assumed to continue under sea level rise.	Defences remain and minimise flood risk. General overall trend of slow infilling assumed to continue under sea level rise.	High level of uncertainty regarding evolution under sea level rise. Also uncertainty regarding future meander patterns within the estuary.
Taw/Torridge Estuary: Torridge Estuary	Pethick (2007) has been used as the main source of information.	Defences remain and minimise flood risk. Little change anticipated.	Defences remain and minimise flood risk. General overall trend of slow infilling assumed to continue under sea level rise.	Defences remain and minimise flood risk. General overall trend of slow infilling assumed to continue under sea level rise.	High level of uncertainty regarding evolution under sea level rise. Also uncertainty regarding future meander patterns within the estuary.

Location	Available data	Assumptions made in predictions of coastal change for WPM			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
			Local erosion/accretion dependent upon meanders – risk areas based on Pethick (2007). Geological controls will limit change along much of estuary.	Local erosion/accretion dependent upon meanders – risk areas based on Pethick (2007). Geological controls will limit change along much of estuary.	
Taw/Torridge Estuary: Taw Estuary	Pethick (2007) has been used as the main source of information.	Defences remain and minimise flood risk. Little change anticipated.	Defences remain and minimise flood risk. General overall trend of slow infilling assumed to continue under sea level rise. Local erosion/accretion dependent upon meanders – risk areas based on Pethick (2007).	Defences remain and minimise flood risk. General overall trend of slow infilling assumed to continue under sea level rise. Local erosion/accretion dependent upon meanders – risk areas based on Pethick (2007).	High level of uncertainty regarding evolution under sea level rise. Uncertainty regarding whether the increased demand for sediment will be met through erosion of the open coast. Also uncertainty regarding future meander patterns within the estuary.
Taw/Torridge Estuary to Saunton Down	Pethick (2007) has been used as the main source of information. Futurecoast (Halcrow, 2002) suggested moderate (10-50m) change over next 100 years.	Groynes at Airy Point assumed to be largely ineffective. Limited change.	Dune system as a whole is expected to remain fairly resilient to change – local areas of erosion and accretion. Permanent breach considered unlikely.	Dune system as a whole is expected to remain fairly resilient to change – but increased risk of frontal dune erosion. Permanent breach considered unlikely.	Uncertainty regarding whether the increased demand for sediment will be met through erosion of the open coast. System is sensitive to changes in wind-wave climate and changes in storm frequency.
Saunton Down to Baggy Point (Croyde Bay)	SMP1 (Halcrow, 1998) suggested that this coastline was relatively stable. Futurecoast (Halcrow, 2002)	Baggy Point expected to erode at less than 0.1m/year – therefore less than 2m erosion.	Baggy Point expected to erode at less than 0.1m/year – therefore less than 5m erosion.	Baggy Point expected to erode at less than 0.1m/year – therefore less than 10m erosion.	Limited data available on historical changes to the dunes. The rate of dune erosion will depend upon the frequency and strength of

Location	Available data	Assumptions made in predictions of coastal change for WPM			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
	suggested moderate (10-50m) change over next 100 years, with negligible change of the headlands (<10m). Cliff classification stated very low (<0.1m/year) recession rates for Baggy Point, but low (0.1 to 0.5m/year) for Saunton Down and within Croyde Bay, with potential landslide events causing up to 10 to 50m.	At Saunton Down between 10 and 50m could occur at a single location, due to a landslide event. Within Croyde Bay dunes are expected to remain stable.	At Saunton Down between 10 and 50m could occur at a single location, due to a landslide event. Within Croyde Bay dunes are expected to remain stable. The beach at Croyde is predicted to remain relatively stable due to the influence of the headlands although sea level rise may cause some retreat. However this material would be expected to be redeposited within the system. Defences at northern end of the bay assumed to remain.	At Saunton Down between 10 and 50m could occur at a single location, due to a landslide event. Dune erosion is a risk during this period. Defences at northern end of the bay assumed to remain.	future storm events.
Baggy Point to Morte Point (Morte Bay)	Futurecoast (Halcrow, 2002) suggested moderate (10-50m) change over next 100 years, with negligible change of the headlands (<10m). Cliff classification stated very low (<0.1m/year) recession rates for Baggy Point and Morte	Headlands expected to erode at less than 0.1m/year – therefore less than 2m erosion. Localised rock revetments at Putsborough which protect against shoreline retreat and hinterland	Headlands expected to erode at less than 0.1m/year – therefore less than 5m erosion. Continued erosion of the dunes, with maybe up to 25m of erosion (based on Futurecoast appraisal	Headlands expected to erode at less than 0.1m/year – therefore less than 10m erosion. Continued erosion of the dunes, with maybe up to 50m of erosion (based on Futurecoast appraisal	Limited data available on historical changes to the dunes. Very limited data on potential erosion rates of the cliffs forming Morte Bay, which are currently fronted by sand dunes. The rate of dune erosion will depend

Location	Available data	Assumptions made in predictions of coastal change for WPM			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
	Point. SMP1 predicted less than 10m erosion over 50 years for the headlands. The SMP also Identified that the dunes were eroding, mainly during storms, but no estimates of future change provided.	flooding. The dunes will continue to prevent any slope erosion along much of Morte Bay.	only). Localised rock revetments at Putsborough which protect against shoreline retreat and hinterland flooding.	only). Could be re-exposure of the cliffs behind in places, which typically would be expected to experience rates of 0.1-0.5m/year, based on their generic cliff type. Localised rock revetments at Putsborough which protect against shoreline retreat and hinterland flooding.	upon the frequency and strength of future storm events.
Morte Point to Widmouth Head	SMP1 stated less than 10m recession would occur over the next 50 years. Futurecoast predicted 'negligible/no change' over the next 100 years. The cliff classification did, however, identify a risk of localised landslips and slides, but identified that these would cause less than 10m erosion. The small pocket beaches are predicted to remain stable with any cliff erosion adding sediment.	Seawalls at Lee Bay, Ilfracombe and Hele Bay. Harbour structures also assumed to remain. Negligible change expected during this period (less than 10m erosion).	Seawalls at Lee Bay, Ilfracombe and Hele Bay. Harbour structures also assumed to remain. Negligible change expected during this period (less than 10m erosion).	Seawalls at Lee Bay, Ilfracombe and Hele Bay. Harbour structures also assumed to remain. Negligible change expected during this period (less than 10m erosion).	Timing and location of landslide events – but low risk. Localised landslips may occur, be likely to be small (less than 10m recession) and localised. Sea level rise is unlikely to significantly increase erosion rates.

Location	Available data	Assumptions made in predictions of coastal change for WPM			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
Widmouth Head to Hangman Point (Combe Martin Bay)	SMP1 stated less than 10m recession would occur over the next 50 years. Futurecoast predicted 'negligible/no change' over the next 100 years. The cliff classification did, however, identify a risk of localised landslips and slides, but identified that these would cause less than 10m erosion.	Recurved seawall at Combe Martin assumed to remain and minimise flood risk. Negligible erosion of the resistant cliffs predicted.	Negligible erosion of the resistant cliffs predicted. Recurved seawall at Combe Martin assumed to remain and minimise flood risk.	Negligible erosion of the resistant cliffs predicted. Recurved seawall at Combe Martin assumed to remain and minimise flood risk.	Timing and location of landslide events – but low risk.
Hangman Point to Duty Head	SMP1 stated that while generally stable, some erosion of the cliffs does occur, but <10m over next 50 years. Futurecoast predicted 'negligible/no change' over the next 100 years. The cliff classification did, however, identify a risk of localised landslips and slides, but identified that these would cause less than 10m erosion	Negligible erosion expected, although at a very local scale there is a small risk of a landside events, which could cause up to 10m.	Negligible erosion expected, although at a very local scale there is a small risk of a landside events, which could cause up to 10m.	Negligible erosion expected, although at a very local scale there is a small risk of a landside events, which could cause up to 10m.	Timing and location of landslide events – but low risk.
Duty Head to Foreland Point (inc. Lynmouth Bay)	SMP1 stated that while generally stable, some erosion of the cliffs does occur, but <10m over next 50 years. The exception was Holdstone Down where rates may	Negligible change to cliffs to west of Lynmouth. The Foreland is expected to erode more rapidly, but less than 10m expected (using Futurecoast upper	Seawall at Lynmouth assumed to remain as well as flash flood alleviation scheme. The boulder delta at Lynmouth is expected to remain stable during	Seawall at Lynmouth assumed to remain as well as flash flood alleviation scheme. The boulder delta at Lynmouth is expected to remain stable during	Erosion rates of The Foreland uncertain – Futurecoast band used, but it is assumed this is broad enough to include impacts of sea level rise.

Location	Available data	Assumptions made in predictions of coastal change for WPM			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
	increase to 0.5 - 1m/year. Futurecoast predicted 'negligible/no change' over the next 100 years. To west of Foreland Point, cliff classification suggested very low (<0.1m/year), but at Foreland Point suggested low (0.1-0.5m/year) recession rates.	limit and SMP1 lower limit). Seawall at Lynmouth assumed to remain as well as flash flood alleviation scheme. The boulder delta at Lynmouth is expected to remain stable during this epoch.	this epoch. Negligible change to cliffs to west of Lynmouth. The Foreland is expected to erode more rapidly: 5 – 25m, assuming linear extrapolation of Futurecoast band.	this epoch. Negligible change to cliffs to west of Lynmouth. The Foreland is expected to erode more rapidly: 10 – 50m, assuming linear extrapolation of Futurecoast band.	Risk of another flash flood event.
Foreland Point to Gore Point	SMP1 stated less than 10m recession would occur over the next 50 years. Futurecoast predicted 'negligible/no change' over the next 100 years. The cliff classification suggested very low rates along much of the remainder of the frontage (<0.1m/year).	Negligible cliff erosion expected.	Negligible cliff erosion expected.	Negligible cliff erosion expected.	Timing and location of landslide events – but low risk.
Porlock Bay	Futurecoast predicted a 'high' (50-100m by year 100) rate of change. General information contained within Cope (2004) and Orford(2003). Bray & Duane (2001) determined rates of change	Assumed that the seawall and harbour arm at Porlock Weir and seawall at Porlockford will remain. All other defences assumed not to be maintained and no beach management.	Assumed that the seawall and harbour arm at Porlock Weir and seawall at Porlockford will remain. All other defences assumed not to be maintained and no beach management.	Assumed that the seawall and harbour arm at Porlock Weir and seawall at Porlockford will remain. All other defences assumed not to be maintained and no beach management.	Uncertainty regarding risk of catastrophic breakdown of barrier and potential for permanency of any breaches. Limited data on Porlockford cliff erosion.

Location	Available data	Assumptions made in predictions of coastal change for WPM			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
	along the barrier section: (1) barrier to west of breach = 0.42m/year (1888 – 1988), = 0.83m/yr (since 1988) (2) New Works to war memorial = 0.25-0.5m/year (1888-1928). Then stability to 1988. Then a further 10m erosion near New Works. (3) East of war memorial = 0.25-0.5m/year (1888-1928). Then stable. Bray & Duane (2001) also suggested erosion of Porlockford cliffs at less than 0.5m/year.	Key risk along barrier section is overwashing and flooding of hinterland: based on EA Flood Map. Erosion of Porlockford predicted to be less than 10m (assuming a max. rate of 0.5m/year)	Key risk along barrier section is overwashing and flooding of hinterland: based on EA Flood Map. Erosion of Porlockford predicted to be less than 25m (assuming a max. rate of 0.5m/year)	Key risk along barrier section is overwashing and flooding of hinterland: based on EA Flood Map. Erosion of Porlockford predicted to be less than 25m (assuming a max. rate of 0.5m/year)	
Hurlstone Point to Minehead	SMP1 concluded that the coastline would remain stable over the next 50 years, but with a possibility of foreshore steepening. Expected that the cliffs would continue to erode at the same rate as present. Futurecoast predicted 'negligible/no change' over the next 100 years. The cliff classification suggested very low rates along much of the remainder of the frontage	The harbour breakwater at Minehead and associated concrete groyne assumed to remain. The vegetated nature of the cliffs suggests a low rate of activity, therefore negligible erosion is predicted for much of this coastline, but there is a risk that several metres (10 to 50m) of retreat	The harbour breakwater at Minehead and associated concrete groyne assumed to remain. Assuming a linear extrapolation of the lower Futurecoast rates (0.1m/year): up to 5m erosion predicted. However there is a risk of a large scale event occurring along the	The harbour breakwater at Minehead and associated concrete groyne assumed to remain. Assuming a linear extrapolation of the lower Futurecoast rates (0.1m/year): up to 10m erosion predicted. However there is a risk of a large scale event occurring along the	Timing and location of landslide events.

Location	Available data	Assumptions made in predictions of coastal change for WPM			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
	(<0.1m/year). The cliff classification suggested that Minehead Bluff would recede at low (0.1 – 0.5m/year) rates, but the cliffs at Culver were identified as complex, with a low risk of a large landslide event (causing more than 50m recession).	could occur due to a single event.	Minehead Bluff, which could cause several metres (10 to 50m) of retreat could occur due to a single event.	Minehead Bluff, which could cause several metres (10 to 50m) of retreat could occur due to a single event.	
Minehead to Blue Anchor	SMP1 reports that beach levels dropped in the early part of the century. Key risk will be inundation of a large area of low-lying land. The SMP1 also states that at The Warren retreat is around 0.5m/year. At the eastern end of the frontage, SMP1 records that there has historically been 300m retreat of mean low water over the 'past century'. Futurecoast predicted a 'high' (50-100m by year 100) rate of change. Black & Veatch, 2006a; 2009) suggested at Minehead there has been 0.6m/year retreat in last 30 years. Erosion at the	At Minehead defences assumed to remain therefore shoreline position fixed. Also the harbour breakwater at Minehead and associated concrete groyne (discussed in previous section) assumed to remain. Defences assumed to remain at Dunster and Blue Anchor Bay, which will prevent roll-back of the beach. At the Warren there is a risk of overtopping and breaching; therefore flooding is a key risk: risk based on EA Flood Map.	At Minehead defences assumed to remain therefore shoreline position fixed. Also the harbour breakwater at Minehead and associated concrete groyne (discussed in previous section) assumed to remain. Defences assumed to remain at Dunster and Blue Anchor Bay, which will prevent roll-back of the beach. Net trend for landward retreat. Key risk is from flooding: risk based on EA Flood Map.	At Minehead defences assumed to remain therefore shoreline position fixed. Also the harbour breakwater at Minehead and associated concrete groyne (discussed in previous section) assumed to remain. Defences assumed to remain at Dunster and Blue Anchor Bay, which will prevent roll-back of the beach. Net trend for landward retreat. Key risk is from flooding: risk based on EA Flood Map.	Limited data on the retreat rates at the Warren.

Location	Available data	Assumptions made in predictions of coastal change for WPM			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
	Warren has been 0.3m/year, with a breach possible within next 20 years. The undefended stretch at Dunster has been 0.6m/year.				
Blue Anchor to St Audrie's Bay	SMP1 stated that erosion rates vary along the frontage with rates between Blue Anchor to Watchet of between 0.5 and 1m/year, although it is noted that these rates are often exceeded between Blue Anchor Hotel and Gray Rock. Rates are higher east of Watchet to Doniford, where they would exceed 1m/year. Within St Audrie's Bay, the cliffs are more stable, but up to 0.5m/year may still be experienced. Futurecoast predicted 'moderate' (10-50m) erosion over the next 100 years. The cliff classification suggested low rates along the cliffed frontages (0.1 – 0.5m/year), but with a risk of a landslide along the Watchet section, which could cause 10 to 50m	Concrete seawalls and rock groynes assumed to remain and prevent erosion of cliffs at Watchet. The shoreline position will be held by defences between Watchet and Doniford. The rock revetment at Doniford Holiday Camp assumed to continue to minimise risk of flood and erosion. Based on linear extrapolation of Futurecoast rates for the undefended sections to the east of Blue Anchor Bay: 2 to 10m recession predicted, but risk of 10 – 50m due to a single event.	Concrete seawalls and rock groynes assumed to remain and prevent erosion of cliffs at Watchet. The shoreline position will be held by defences between Watchet and Doniford. The rock revetment at Doniford Holiday Camp assumed to continue to minimise risk of flood and erosion. Based on linear extrapolation of Futurecoast rates for the undefended sections to the east of Blue Anchor Bay: 2 to 10m recession predicted, but risk of 10 – 50m due to a single event.	Concrete seawalls and rock groynes assumed to remain and prevent erosion of cliffs at Watchet. The shoreline position will be held by defences between Watchet and Doniford. The rock revetment at Doniford Holiday Camp assumed to continue to minimise risk of flood and erosion. Based on linear extrapolation of Futurecoast rates for the undefended sections to the east of Blue Anchor Bay: 2 to 10m recession predicted, but risk of 10 – 50m due to a single event.	There is very limited information on actual rates of cliff retreat. The cliffs, in places, will also be affected by climate change, both due to sea level rise, the associated reduction in the effect of the shore platform and the any change in groundwater conditions.

Location	Available data	Assumptions made in predictions of coastal change for WPM			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
	recession. May (2003) reports that there have been few measurements of coastal change, but notes that retreat rates vary along the frontage. Mackintosh (1868; reported in May, 2003b) estimated the rate of cliff retreat as 1.2m/year.				
St Audrie's Bay to Hinkley Point	SMP1 reported that there were 'slow' rates of erosion along this frontage, but also (conversely) suggests that east of Lilstock a small bay has been created by 'relatively high erosion rate' at this point. May (2003) reports that the cliffs are more active to the west of Lilstock, where the cliffs are more exposed. Futurecoast predicted 'negligible/ no change' over the next 100 years. The cliff classification suggested 'low' rates along the cliffed frontages (0.1 – 0.5m/year).	The rock armour at Lilstock is assumed to remain. Based on linear extrapolation of Futurecoast rates: 2 to 10m recession predicted, but risk of up to 10m due to a single event.	The rock armour at Lilstock is assumed to remain. Based on linear extrapolation of Futurecoast rates: 5 to 25m recession predicted, but risk of up to 10m due to a single event. Gravel ridges at Kilve and Lilstock are predicted to roll-back at similar rates to the adjacent cliffs. Localised flooding at Kilve Point: risk based on EA Flood Maps.	The rock armour at Lilstock is assumed to remain. Based on linear extrapolation of Futurecoast rates: 10 to 50m recession predicted, but risk of up to 10m due to a single event. Gravel ridges at Kilve and Lilstock are predicted to roll-back at similar rates to the adjacent cliffs. Localised flooding at Kilve Point: risk based on EA Flood Maps.	Limited information available on actual cliff erosion rates and barrier retreat rates.
Hinkley Point	Along the Power Station	The defences at Hinkley	The defences at Hinkley	The defences at Hinkley	

Location	Available data	Assumptions made in predictions of coastal change for WPM			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
	frontage rates of change were concluded to be low in SMP1. Futurecoast cliff classification suggested 'low' rates along the Hinkley Point frontage (0.1 – 0.5m/year).	Point are assumed to remain and to fix shoreline position.	Point are assumed to remain and to fix shoreline position.	Point are assumed to remain and to fix shoreline position.	
Hinkley Point to Parrett Estuary	SMP1 stated that there have been 'considerable' changes along this frontage, particularly around Steart Point, where there have been movements of the order of 100s metres during the last two centuries. Futurecoast predicted a 'high' (50-100m by year 100) rate of change. The cliff classification suggested 'low' rates along the Hinkley Point frontage (0.1 – 0.5m/year).	The rock revetment and earth embankment east of Hinkley assumed to remain, as well as defences along the Steart Peninsula (east of Stolford). East of Wall Common sediment transport rates are negligible and thus the beach is predicted to remain stable during this epoch.	The rock revetment and earth embankment east of Hinkley assumed to remain, as well as defences along the Steart Peninsula (east of Stolford).	The rock revetment and earth embankment east of Hinkley assumed to remain, as well as defences along the Steart Peninsula (east of Stolford).	Changes in the Parrett Estuary will affect the Steart Peninsula.
Parrett Estuary	EA (2009) and Black & Veatch (2008) – determined that estuary currently stable. EA (2009) undertook regime analysis to look at impact of sea level rise and MR at a number of sites. Atkins (2009) states that	Flood risk continued to be managed by defences along much of estuary. Little change in estuary form. Key control on local erosion/accretion will be meandering low water channel.	Flood risk continued to be managed by defences along much of estuary. Key control on local erosion/accretion will be meandering low water channel. Sea level rise is predicted	Flood risk continued to be managed by defences along much of estuary. Key control on local erosion/accretion will be meandering low water channel. Sea level rise is predicted	It is difficult to predict future changes in channel position. It is also difficult to predict how the estuary will respond to future changes in sea level.

Location	Available data	Assumptions made in predictions of coastal change for WPM			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
	position of low-water channel is predicted to move clockwise (to the north of Gore Sands) by 2028 and this will have a significant impact on the foreshore levels at Burnham-on-Sea.		to increase risk of flooding in the areas where there are no defences.	to increase risk of flooding in the areas where there are no defences.	
Parrett Estuary to Brean Down	SMP1 did not define potential erosion rates but identified the issue of falling beach levels at Burnham. The SMP1 also predicted that over the next 50 years the dunes would continue to erode, but that the dune system would not breach during this period. Futurecoast predicted a 'high' (50-100m by year 100) rate of change, with 'negligible/no change' at Brean Down. The cliff classification suggested 'low' rates at Brean Down (0.1 – 0.5m/year). Black & Veatch (2008) concluded that there had been little change over last century along Burnham and Brean stretches. Various changes along the Berrow	It is assumed that the defences at Burnham-on-Sea will remain and will fix shoreline position. Between Burnham and Brean, frontal dunes expected to erode, but flood risk low due to high dunes behind. Assumed risk of back door flooding will be minimised as defences along Axe assumed to remain. At Brean, defences assumed to remain. Negligible change expected at Brean Down.	It is assumed that the defences at Burnham-on-Sea will remain and will fix shoreline position. Between Burnham and Brean, frontal dunes expected to erode, but flood risk low due to high dunes behind. Assumed risk of back door flooding will be minimised as defences along Axe assumed to remain. At Brean, defences assumed to remain. Negligible change expected at Brean Down.	It is assumed that the defences at Burnham-on-Sea will remain and will fix shoreline position. Between Burnham and Brean, frontal dunes expected to erode, but flood risk low due to high dunes behind. Assumed risk of back door flooding will be minimised as defences along Axe assumed to remain. At Brean, defences assumed to remain. Negligible change expected at Brean Down.	Possible impact on this frontage due to changes in Parrett Estuary and associated outer low water channel/

Location	Available data	Assumptions made in predictions of coastal change for WPM			Uncertainty
		0 to 20 years	20 to 50 years	50 to 100 years	
	frontage, but current erosion trend of up to 2m/year. Atkins (2009) states that position of low-water channel is predicted to move clockwise (to the north of Gore Sands) by 2028 and this will have a significant impact on the foreshore levels at Burnham-on-Sea.				
Brean Down to Anchor Head (Weston Bay)	Futurecoast predicted a 'high' (50-100m by year 100) rate of change, with negligible/no change' at Brean Down. The cliff classification suggested 'low' rates at Brean Down (0.1 – 0.5m/year).	Negligible change expected at Brean Down and Anchor Head. Defences at Weston-super-Mare will continue to fix the shoreline position.	Defences at Weston-super-Mare will continue to fix the shoreline position. Assuming the lower limit of the Futurecoast band, less than 5m of erosion at Brean Down and Anchor Head predicted by end of the period.	Defences at Weston-super-Mare will continue to fix the shoreline position. Assuming the lower limit of the Futurecoast band, less than 5m of erosion at Brean Down and Anchor Head predicted by end of the period.	Limited data on shoreline change, as defences pre-date the earliest Ordnance Survey mapping. Defences assumed to be upgraded along Weston Super Mare.

C.6 References

C.6.1 Relating to Sections C.1, C.4 and C.5

- Atkins (2009). **Severn Estuary Flood Risk Management Strategy: Flood Risk Management at Steart Peninsula, River Parrett and Burnham-on-Sea (Draft Report)**. Environment Agency, April 2009.
- Babtie Brown & Root (2002). **Stolford to Combwich Strategy Study – Volume 1 Strategy Summary Plan (consultation draft)**. Environment Agency South-West Region, September 2002.
- Black & Veatch (2004). **Weston Seafront Strategy Study**. North Somerset Council, May 2004.
- Black & Veatch (2006a). **Minehead to Blue Anchor Coastal Defences: Technical Report**. Environment Agency South-West Region, July 2006.
- Black & Veatch (2006b). **Bridgwater to Burnham-on-Sea Flood Management Strategic Report (Draft)**. Environment Agency South-West Region, August 2006.
- Black & Veatch (2006c). **Parrett Tidal Flood Defence: Sluice/Embankments Technical Review**. Environment Agency South-West Region, December 2006.
- Black & Veatch (2008). **Burnham to Brean Coastal Study: Final Report**. Environment Agency South-West Region, April 2008.
- Black & Veatch (2009). **Warren Point to Dunster Beach Coastal Defence Study: Draft Report** Environment Agency South-West Region, February 2009.
- Bray M. (2000). **Porlock Bay Research and Preliminary Results**. Letter from Dr Malcolm Bray (University of Portsmouth) to Sue Ford and Nick Stevens (Environment Agency North Wessex Area), 20th April 2000.
- Bray M.J and Duane W.J. (2001) Porlock Bay: **Geomorphological investigation and monitoring**. Report to the Environment Agency by RACER.
- Bray M. and Duane W. (2005). **Porlock Bay Geomorphological Investigation and Monitoring: Gravel Barrier Breaching and Tidal Lagoon Development**. Defra/Environment Agency R&D research project STCG 024, March 2005.
- Cope S.N. (2004). **Breaching of UK Coarse-Clastic Barrier Beach Systems: methods developed for predicting breach occurrence, stability and flooded hinterland evolution**. PhD, University of Portsmouth.
- Corns R.G. (2006). **Blue Anchor to Lilstock Coast SSSI – Sea Defences at the Blue Anchor Hotel**. Letter from R. G. Corns (Conservation Officer, Natural England) to Mr S. Strom (Owner, Blue Anchor Hotel), 6th December 2006.
- Environment Agency (2006). **Bridgwater to Burnham-on-Sea Flood Management**. Draft Strategic Planning Report. August 2006.
- Environment Agency (2008). **North Devon Catchment Flood Management Plan**. Consultation Draft (April, 2008).
- Environment Agency (2009). **Preferred Parrett Estuary Flood Risk Management Strategy Report**. Consultation Draft (January, 2009).
- Everything Exmoor website. **Woolacombe**. *http://www.everythingexmoor.org.uk/_W/Woolacombe.php*. Date accessed: 11/12/2008.
- Garrard P (2006). **Dunster Beach Chalets Flood Risk Plan**. Dunster Beach Holidays Ltd, October 2006. Work undertaken for Three Counties Flood Risk Assessment.
- GeoSea Consulting (1997). Quoted in SMP Halcrow (1998) op cit.
- Halcrow (1998). **Bridgwater Bay to Bideford Bay Shoreline Management Plan**. North Devon and Somerset Coastal Group, June 1998.
- Halcrow (2002). **Futurecoast**. *See also the Defra website:* *http://www.defra.gov.uk/environ/fcd/policy/smp.htm*

- Halcrow (2009). **Steart Peninsula Managed Realignment: Preliminary Geomorphological Assessment (Draft)**. Environment Agency, April 2009.
- HR Wallingford (2002). **Culver Sand, Bristol Channel: Study of Coastal Impacts of Proposed Dredging – Stage 2: Final Report (Report EX4600)**. Hanson Aggregates Marine Limited, December 2002.
- Jacobs Babtie (2005). **Lilstock Sea Defence and Outfall Pre-Feasibility Study (Final Report)**. Environment Agency South-West Region, October 2005.
- Jacobs Babtie (2006). **Brue Pill Tidal Banks Stabilisation Pre-Feasibility Study (Final Report)**. Environment Agency South-West Region, February 2006.
- Jacobs (2008). **Taw Banks Study Report (Rev A03)**. Environment Agency South-West Region, February 2008.
- Jennings S., Orford J.D., Canti M., Devoy R.J.N. and Straker V. (1998). **The role of relative sea-level rise and changing sediment supply on Holocene gravel barrier development: the example of Porlock, Somerset, UK**. *The Holocene* 8, 2 (1998) pp. 165-181.
- Kirby R. (1996) **Hartland Point to Brean Down: Summary of existing knowledge of coastal trends and stability**. Ravensrodd Consultants.
- Landmark Trust's Lundy Island website. **Emergency Appeal to save lifeline to Lundy**. *http://www.lundyisland.co.uk/appeal.htm*. Date accessed: 20/10/2008.
- Long A.J., Dix J.K., Kirby R., Lloyd Jones D., Roberts D.H., Croudace I.W., Cundy A.B., Roberts A., and Shennan I. (2002). **The Holocene and Recent Evolution of Bridgwater Bay and the Somerset Levels**.
- Lundy Field Society website[1]. **The Island**. *http://www.lundy.org.uk/inf/island.html*. Date accessed: 22/10/2008.
- Lundy Field Society website[2]. **The Geology of Lundy, by Sandy Smith**. *http://www.lundy.org.uk/lfs/is/geology.html*. Date accessed: 22/10/2008.
- Manning C. (2007). **Braunton Marsh Management Study 2007**. Taw Torridge Estuary Forum.
- May V J (2003a). **Braunton Burrows**. Geological Conservation Review Volume 28: Coastal Geomorphology of Great Britain – Chapter 7: Sandy beaches and dunes – GCR site reports. Joint Nature Conservation Committee website (*http://www.jncc.gov.uk/pdf/gcrdb/gcrsiteaccount3213.pdf*). Date accessed: 12/12/2008.
- May V J (2003b). **Blue Anchor – Watchet - Lilstock**. Geological Conservation Review Volume 28: Coastal Geomorphology of Great Britain – Chapter 4: Soft-rock cliffs – GCR site reports. Joint Nature Conservation Committee website (*http://www.jncc.gov.uk/pdf/gcrdb/gcrsiteaccount3213.pdf*). Date accessed: 12/12/2008.
- May V J (2003c). **Westward Ho! Cobble Ridge**. Geological Conservation Review Volume 28: Coastal Geomorphology of Great Britain – Chapter 6: Gravel and 'shingle' beaches – GCR site reports. Joint Nature Conservation Committee website (*http://www.jncc.gov.uk/pdf/gcrdb/gcrsiteaccount3213.pdf*). Date accessed: 12/12/2008.
- McTernan M. and Wilson H. (1999). **Coastal Management in Porlock Bay: A Case Study and Role Play for A-level and GCSE Geographers**. Reprinted from *Field Studies Vol. 9 No. 3 (1999).*
- OMReG website. **Details for Walborough, Axe**. Internet site: http://www.abpmer.net/uploads/omreg/details1.asp?ID=32&lstLocation=Axe. Date accessed: 12/03/2010.
- Orford, J.D., Carter, R.W.G. and Jennings, S.C. (1996) **Control domains and morphological phases in gravel-dominated coastal barriers**. Journal of Coastal Research, 12, 589–605.
- Orford J. (2003). **Porlock Gravel Barrier**. Extracted from Geological Conservation Review Volume 28: Coastal Geomorphology of Great Britain – Chapter 6: Gravel and 'shingle' beaches – GCR site reports. May V.J. and Hanson J.D. Joint Nature Conservation Committee website (*http://www.jncc.gov.uk/pdf/gcrdb/gcrsiteaccount3213.pdf*). Date accessed: 12/12/2008.
- Orford J. (2005). **Further Geomorphological Advice in Respect of Westward Ho! SSSI**. English Nature, October 2005.

- Orford J. and Bradbury A. (2008). **Westward Ho! Future Scenarios for the "Pebble Ridge": Geomorphology Scoping Study**. Technical Officers Group for Taw/Torridge Estuary/Bideford Bay, May 2008.
- Pethick J. (2002). **Porlock Bay: Future Development**. Presentation given at a conference hosted by the National Trust at Porlock, 9th October 2001.
- Pethick J. (2007). **The Taw/Torridge Estuary: Geomorphology and Management**. Report to Taw/Torridge Estuary Officers Group (February, 2007).
- Plymouth Coastal Observatory (2008). **Minehead 2008**. South West Strategic Regional Coastal Monitoring Programme.
- Posford Haskoning (2003). **Report on Regional Extreme Tide Levels**. Environment Agency South West Region.
- Royal Haskoning (2004). **Washford River and Watchet: Pre-Feasibility Studies 2002/2003 batch, Final Report**. Environment Agency and Somerset Local Flood Defence Committees, January 2004.
- Royal Haskoning (2007). **Weston-super-Mare Sea Defences Project Appraisal Report**. North Somerset Council, June 2007.
- Royal Haskoning (2008). **Hinkley Point Scoping Report**. Final Report. Report produced for British Energy, November 2008.
- Sedgemoor District Council (2008). **Level 1 Strategic Flood Risk Assessment**. Sedgemoor District Council. August 2008.
- Slade G.D. (2009). **A report on coastal erosion at Westward Ho!, North Devon**.
- Spearing H.G. (1884) **On the Recent Encroachment of the Sea at Westward Ho!, North Devon**. Quarterly Journal of the Geological Society 1884; v. 40; p. 474-478.
- Torridge District Council (2006). **Westward Ho! Beach Management Plan 2007/8**. Torridge District Council, May 2006.
- Taw-Torridge Estuary Forum, 2007. **Braunton Marsh Management Study 2007**. Produced by Clare Manning for the Taw Torridge Estuary Forum.
- United Kingdom Hydrographic Office (2008). **Admiralty Tide Tables Volume 1 2009: United Kingdom and Ireland (including European Channel Ports)**.
- White, J.L. (2009). **Recording Gravel Transport at a Barrier Beach**. Journal of Coastal Research, SI 56 (Proceedings of the 10th International Coastal Symposium), 5-9. Lisbon, Portugal.

C.6.2 Relating to Section C.2

- Giffords Associated Consultants (2000). **Severn Estuary Shoreline Management Plan**. Severn Estuary Coastal Group, December 2000.
- Halcrow (1998). **Bridgwater Bay to Bideford Bay Shoreline Management Plan**. North Devon and Somerset Coastal Group, June 1998.
- Halcrow (May 2009). **National Flood and Coastal Defence Database (NFCDD): Hartland Point to Anchor Head NFCDD update.**

C.6.3 Relating to Section C.3

- Cazenave, A. et al., (2009) **Sea level budget over 2003-2008: A reevaluation from GRACE space gravimetry, satellite altimetry and ARGO**. Global and Planetary Change 65, 83-88. Taken from The Copenhagen Diagnosis (2006).
- Church, J. A. & N. J. White, (2006) **A 20th century acceleration in global sea-level rise**. Geophysical Research Letters 33, L01602. Taken from The Copenhagen Diagnosis

- **The Copenhagen Diagnosis, 2009: Updating the World on the Latest Climate Science**. I. Allison, N.L. Bindoff, R.A. Bindschadler, P.M. Cox, N. de Noblet, M.H. England, J.E. Francis, N. Gruber, A.M. Haywood, D.J. Karoly, G. Kaser, C. Le Quéré, T.M. Lenton, M.E. Mann, B.I. McNeil, A.J. Pitman, S. Rahmstorf, E. Rignot, H.J. Schellnhuber, S.H. Schneider, S.C. Sherwood, R.C.J. Somerville, K. Steffen, E.J. Steig, M. Visbeck, A.J. Weaver. The University of New South Wales Climate Change Research Centre (CCRC), Sydney, Australia, 60pp.
- Defra and Environment Agency (2002). **UK Climate Impacts Programme 2002 Climate Change Scenarios: Implementation for Flood and Coastal Defence: Guidance for Users (R&D Technical Report W5B-029/TR)**.
- Defra (2006). **Flood and Coastal Defence Appraisal Guidance FCDPAG3 Economic Appraisal: Supplementary Note to Operating Authorities – Climate Change Impacts**.
- Hulme M., Jenkins G.J., Lu X., Turnpenny J.R., Mitchell T.D., Jones R.G., Lowe J., Murphy J.M., Hassell D., Boorman P., McDonald R. and Hill S (2002). **Climate Change Scenarios for the United Kingdom: The UKCIP02 Scientific Report**. Tyndall Centre for Climate Change Research, School of Environmental Sciences, University of East Anglia, Norwich, UK. 120pp.
- IPCC (2007). **Climate Change 2007: The Fourth Assessment Report**. United Nations Intergovernmental Panel on Climate Change.
- POL website. **PSMSL Monthly and Annual Mean Sea Level Station Files (Avonmouth**). Internet site: http://www.pol.ac.uk/psmsl/psmsl_individual_stations.html. Date accessed: 12/03/2010.
- Pye K. and Saye S. (2005). **The Geomorphological Response of Welsh Sand Dunes to Sea Level Rise over the next 100 years and the Management Implications for SAC and SSSI Sites**. Countryside Council for Wales (CCW) Contract Science Report No. 670, February 2005. 219pp.
- UKCIP (2005). **Updates to regional net sea-level change estimates for the UK**.
- UKCIP08 (2007). **The Climate of the United Kingdom and Recent Trends**.
- UKCP09 (2009). **The Climate of the UK and Recent Trends.** UK Climate Projections website: http://ukclimateprojections.defra.gov.uk/content/view/816/9/. Date accessed: 22/09/2009.