South Coast Dredging Association

Regional Environmental Assessment: Coastal Characterisation

Technical Note DDR4323-02

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1. Introduction

This Technical Note summarises the coastal characterisation phase of a wider Regional Environmental Assessment (REA), which will form the background for future studies of proposed marine aggregate dredging in the study area.

When applications are made for continuing extraction from a marine aggregate dredging area that is already licensed, or from a proposed new part of the seabed, it is necessary to carry out an Environmental Impact Assessment (EIA). Such dredging will inevitably alter the seabed and water depths in the extraction area, thereby altering the waves and tidal flows in and around that area. However, there can be changes in the physical environment further a field, and the EIA will need to consider the possibility of changes in waves, tidal currents or sediment movements along nearby coasts.

Coastal characterisation maps, see Maps 1 to 3, have therefore been produced to inform future EIAs of likely sensitivities at the coastline. The information for this study has largely been gathered from existing sources of information such as Shoreline Management Plans, FutureCoast (Halcrow 2004), Coastal Impact Assessments for previous aggregate extraction applications, and coastal defence strategy studies. This has also been supplemented by dedicated site visits by an experienced engineer.

The area considered in this report includes the coastlines of Dorset as far west as Durlston Head; of Hampshire between Chewton Bunny and Hurst Castle; the Isle of Wight from the Needles to Ryde; of Hampshire east of Gilkicker Point; and, of West Sussex. The tidal harbours of Poole, Christchurch, Portsmouth, Langstone, Chichester, Pagham and Shoreham have been excluded. The extent of the region considered in this study is shown in Figure 1a, along with the location of the presently licensed aggregate extraction areas.

The coastal characterisation maps are accompanied / supplemented by the text within this report which covers the key issues that are often associated with dredging. The study area coastline has been divided up into 12 Coastal Units and firstly provides a general description of the existing coastal morphology. A description of the sediment transport patterns is then provided, as one concern from dredging is that it may affect the supply of sediment to the coastline (i.e. altering transport pathways). Therefore by identifying the predominant sediment transport pathways, the effect of dredging can be assessed. For example, if the sediment supply is from alongshore and not from offshore then any proposed dredging will not interfere directly with this process.

Another concern is that the coastal morphology could also be affected if beach material is lost into the depressions in the seabed left by dredging, termed “beach drawdown”. During storms material is eroded from the beach and deposited offshore, being brought back onshore during calmer weather. To avoid any possibility of dredging removing beach material when it is drawn down, a landward limit is placed on commercial dredging, which is typically several kilometres from the shoreline. A study of conditions on the East Coast of England by Sir William Halcrow & Partners (1991) suggests a maximum limit of 7 metres depth for seasonal beach fluctuations. As part of this study a further analysis of beach and nearshore seabed profiles has been undertaken to try to identify the toe of the active beach for each coastal unit.

Finally the report covers any environmental or archaeological sites of particular interest and provides a description of the coastal vulnerability.

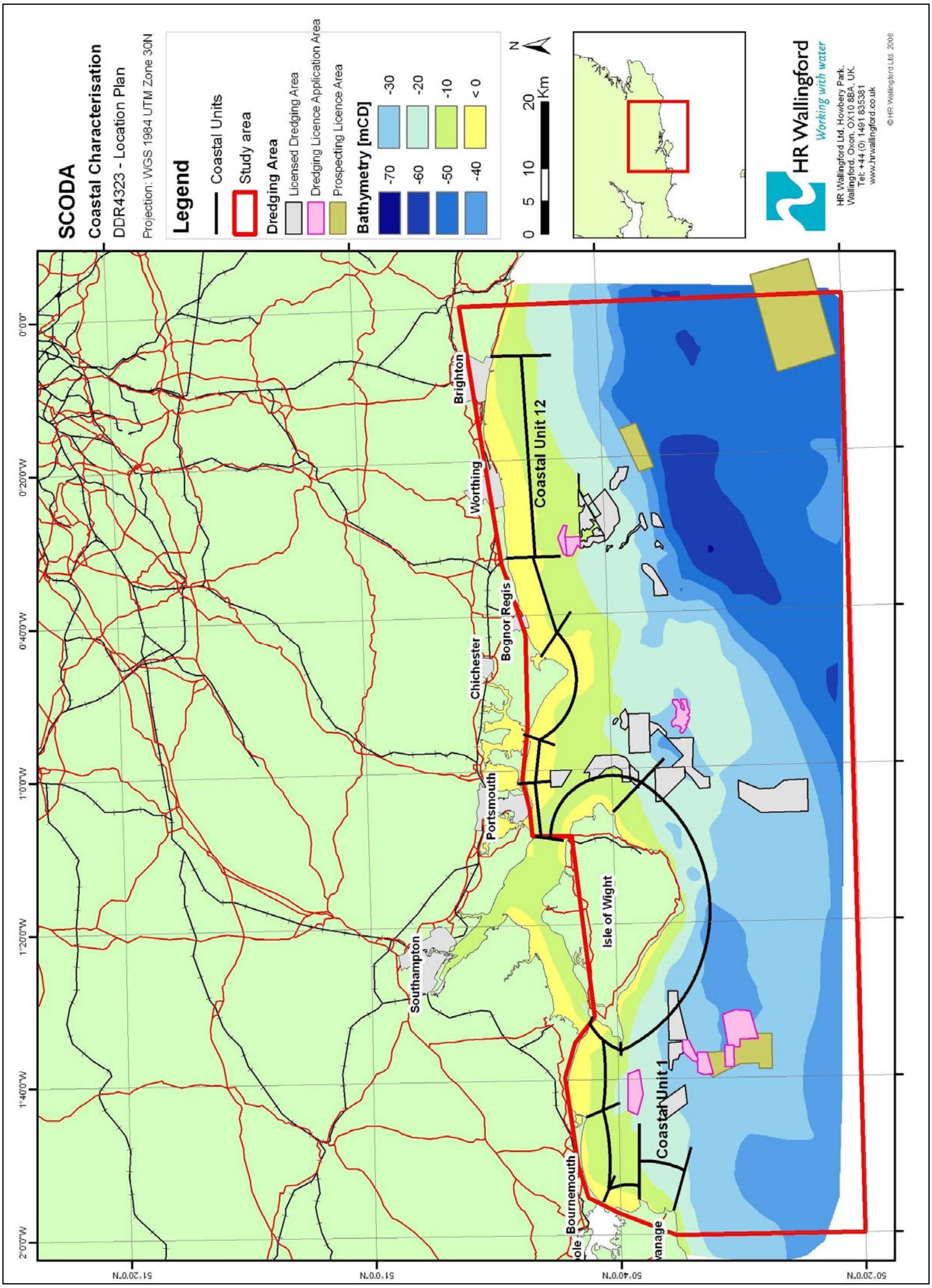


Figure 1a Location plan showing study area and licensed or proposed dredging areas

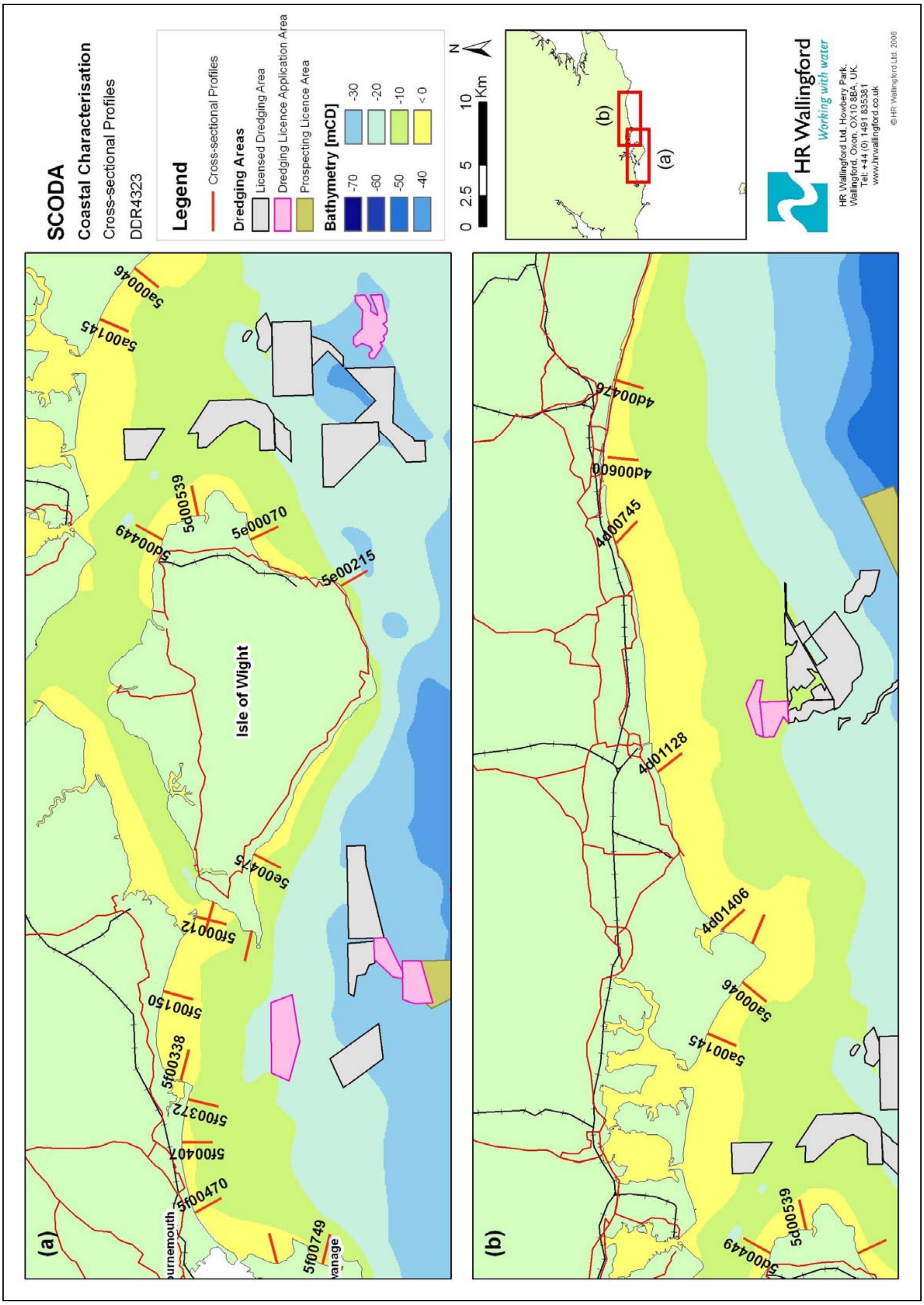
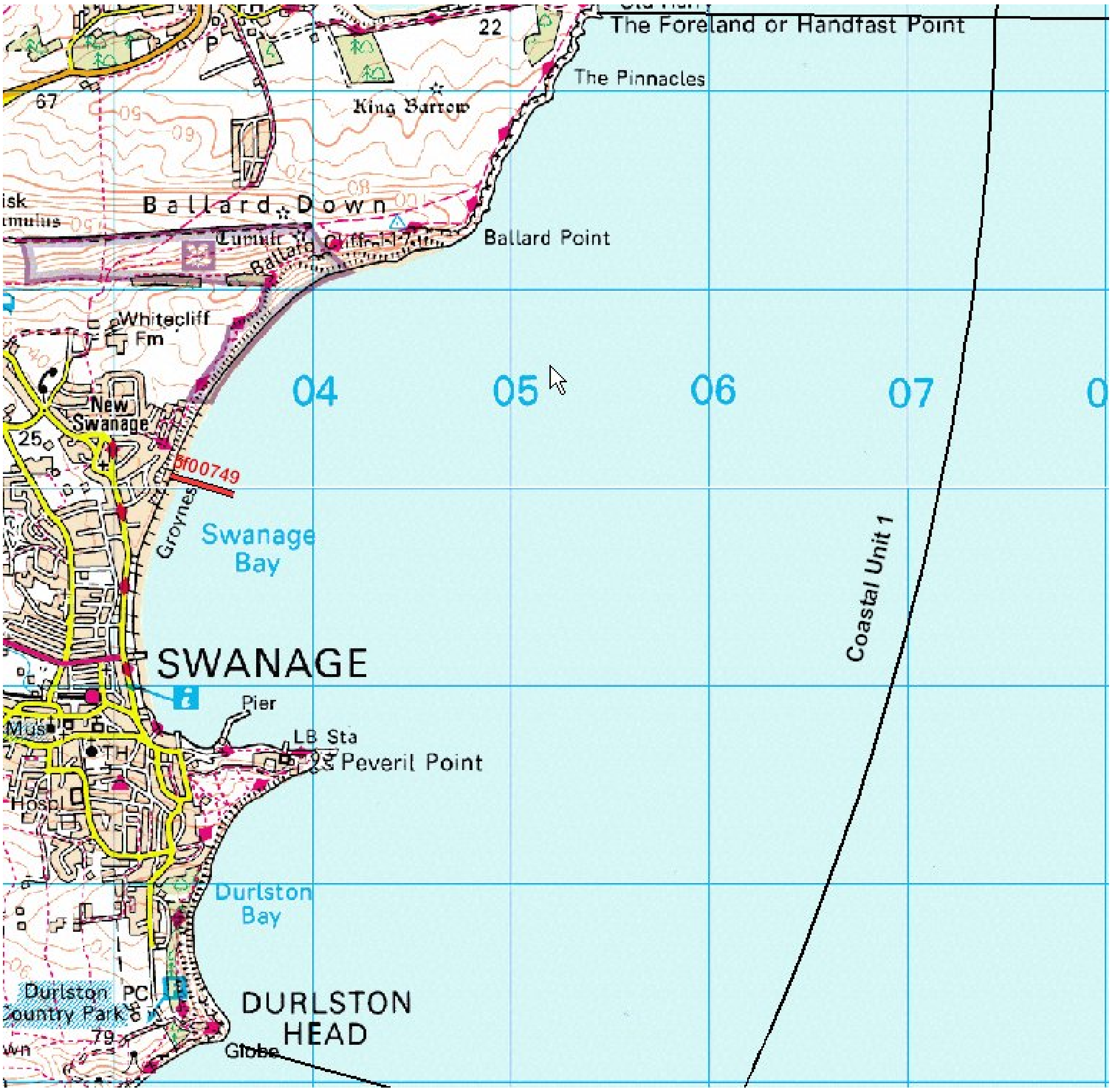


Figure 1b Plan showing location of cross-sectional profiles

2. Coastal Characterisation

2.1 COASTAL UNIT 1: DURLSTON HEAD TO HANDFAST POINT



2.1.1 Description of the coastline

Durlston and Swanage Bays are two eastward facing embayments that are enclosed by large promontories and isolated from adjoining stretches of coastline.

Durlston Bay is constrained by Peveril Point to the North and Durlston head to the south. Further west of Durlston Head the coastline is rugged with little beach material available for transport. As a result Durlston Bay has a narrow, rocky shoreline largely free of beach deposits (Map 2). The backshore is characterised by high cliffs (Map 1) that are unstable and rapid cliff top retreat is threatening cliff top properties (Map 3). A basal cliff recession rate of $0.13 ma^{-1}$ for the area between Durlston Flats and Peveril

Point is quoted by Halcrow (1999). The cliffs are only protected from erosion in the centre of the bay by a short rock armour revetment built in 1989 that protects the cliff toe.

Swanage Bay is contained by the chalk headland of Ballard Point to the North and the limestone headland of Peveril Point to the South. The beaches (Plate 1) within it are largely the result of local erosion of the cliffs which results in the release of sand and flint pebbles along with finer materials which are generally thought to be transported offshore. Beach material becomes finer in a southwards direction, with a relatively abrupt decrease in the proportion of upper beach gravel south of the most northerly section of seawall / promenade.

Plate 1 Central part of Swanage Bay post recharge (2008)

2.1.2 Sediment transport

In Durlston Bay, there is little definitive evidence of littoral drift (the shoreline is predominantly rocky), though it is assumed that any occurring would follow the same northward direction as in Swanage Bay since both have comparable orientations. There is little input from Durlston Bay to Swanage Bay as a result of the lack of moveable beach sediment and Peveril Point providing an effective barrier to longshore drift. Any fine sands, silts and clays that are released by erosion of the cliffs are transported offshore in suspension. There is also a net northward littoral drift within Swanage Bay (Map 2), so that it may be possible for sand to be transported northwards to Ballard Point.

Offshore transport of beach material to the nearshore zone induced by storm waves approaching from the east / south-east is a frequent occurrence. Storms often remove all but the upper backshore accumulation of gravel (Bray et al, 1991b). During these periods, which normally occur in winter, the clay / sandstone substrate is exposed. Swanage Bay is sheltered from swell wave activity from the south-west, because of its eastward facing aspect. This may have an impact on beach recovery after storms. Lack of swell wave action could be the reason why sand transported offshore in severe storms has not returned to the beaches in subsequent periods of calm weather.

The net direction of sediment movement some 0.5km to 1km seawards of the coastline is southwards (Brampton et al, 1998). In deeper water, offshore sediments become progressively finer eastwards, with an area of rippled sand about 4km east of inner Swanage Bay (Bray et al, 1991b). Movement there appears to be in a predominantly south-west direction out towards the English Channel (Fitzpatrick, 1987).

From what little is known of the composition and mineralogy of seabed sediments it appears that little or no material is moving onshore from offshore. Diver inspections report that seabed gravels and sandy gravels are colonised by weed and are therefore presumed to be immobile (Bray et al, 1991b).

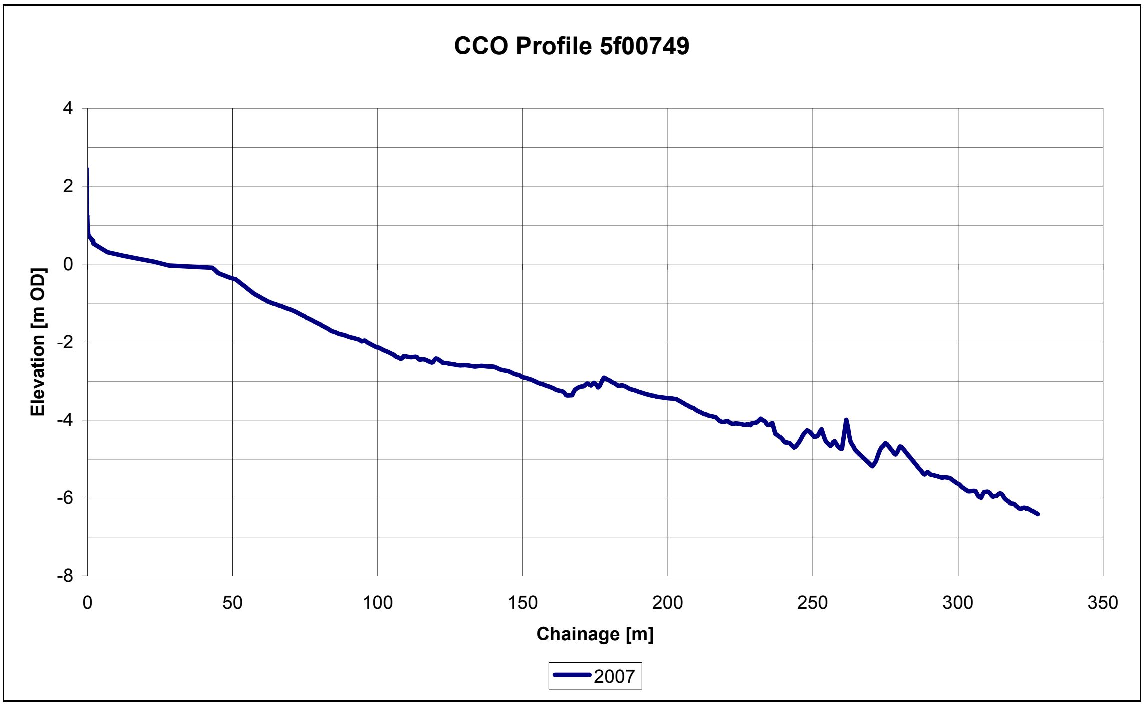


Figure 2 Profile 5f00749, central Swanage Bay (Source: CCO)

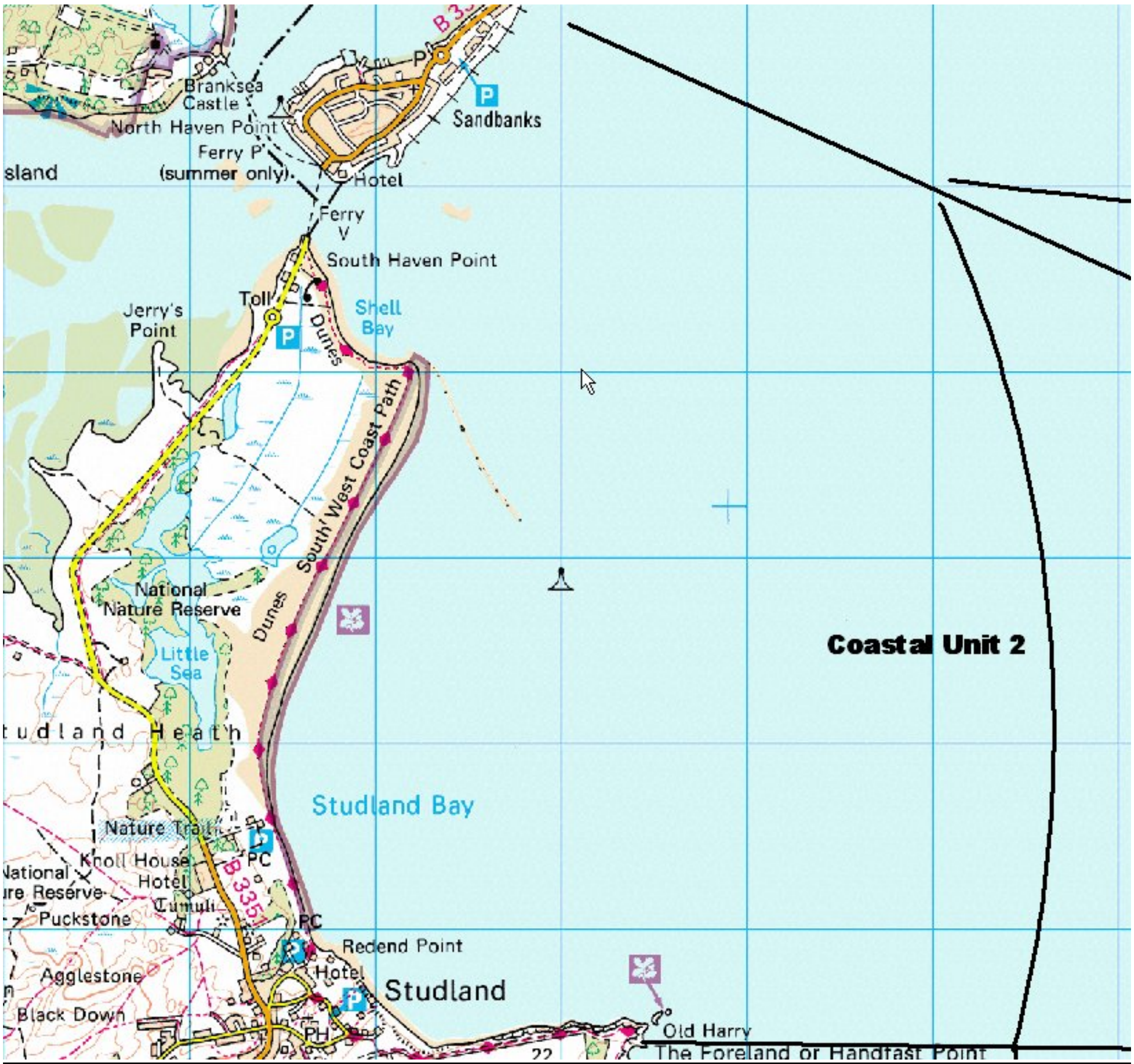
2.1.3 Beach toe limit

Examination of a typical beach and nearshore seabed cross-section has been undertaken to try and determine the toe of the beach, i.e. the point of intersection of the beach with the seabed. Survey data obtained from the Channel Coastal Observatory has been plotted for Profile 5f00749 in Figure 2. Figure 1b shows the location of the cross-sectional profile. A simple calculation of the slope (and the changes in slopes) reveals that the toe of beach appears to intersect the seabed around the -2.4m OD contour. Whilst this value is considerably shallower than the maximum limit of 7 metres depth for seasonal beach fluctuations suggested by Sir William Halcrow & Partners (1991), it is a maximum limit. The profile data, presented in Figure 2, exhibits a flatter and more irregular / uneven slope seaward of the -2.4m OD contour which could indicate a rocky seabed.

2.1.4 *Coastal vulnerability*

The southern section of Swanage Bay is protected from erosion by a seawall and promenade constructed in the late 19^{th} and early 20^{th} century. This has reduced the natural sediment supply to the beaches and there has subsequently been a net loss of sediment which places the cliff top dwellings at risk. Comparison of beach volumes between May 1998 and April 2002 revealed this to be an accelerating trend with a cumulative loss of $34,000m^3$ ($8,500m^3a^{-1}$) over this period (Bray et al, 1991b). As part of the ongoing management of Swanage Bay to address the beach erosion, the beach was improved in 2005/6 by the construction of new timber groynes (to replace the old ones that had fallen into disrepair) and the placement of $90,000m^3$ of sand as beach nourishment (Plate 1).

2.2 COASTAL UNIT 2: STUDLAND AND SANDBANKS



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2.2.1 Description of the coastline

The Studland and Sandbanks peninsulas are essentially two large sand spits that have developed across the mouth of Poole Harbour.

The southern end of Studland Bay is bounded by chalk cliffs, north of which there is a short stretch of cliffs formed of sands and clays, erosion of which has produced mixed sand and pebble beaches that extend northwards to Redend Point (Map 1). Wide, unprotected sand beaches backed by dunes (Plate 2) and lagoons are largely in a natural state (Map 1) and extend northwards from Redend Point to South Haven Point at the entrance to Poole Harbour. The beaches are volatile, but with a general tendency for erosion in the south and accretion in the north (Map 3).

The Sandbanks peninsula, which is backed by dunes and high value properties (Plate 3), extends from the harbour entrance northwards to Poole Head, from where the sand beaches continue below cliffs that are protected at their base by seawalls (Maps 1 and 3). Historically, beach levels were very volatile, but after groynes were built there was a general improvement that lasted until the 1980s. However, by then the groynes had become dilapidated and ineffective, resulting in a return to erosion that was particularly serious near the entrance to Poole Harbour. Prior to the construction of the seawalls and groynes within Poole Bay, the peninsula benefited from the erosion of the sandy cliffs within the bay.

Plate 2 The beach at Studland looking north from the Knoll Car Park (2005)

The tidal range in the area is small and has a "double high water" component, concentrating wave action on a small part of the shore-face. This means that, as in Swanage Bay, erosion after one or two severe storms may have lasting effects.

Plate 3 Sandbanks, east of Pavilion (2005)

2.2.2 Sediment transport

Studland Bay is partly sheltered against the prevailing south-westerly wave action, whilst Sandbanks is also partly sheltered by Hook Sands, an ebb shoal delta at the mouth of Poole Harbour. The wave energy thus increases gradually from south to north along the Studland frontage and from west to east along Sandbanks. Thus, the beaches of Sandbanks tend to be more vulnerable to erosion than the beaches within Studland Bay.

The direction of net sand transport in Studland Bay is presently northwards (Map 2) and this may account for the shoreline recession in the southern part of Studland Bay and the accretion in the northern part. Accretion within the northern part has also been ascribed to the onshore transport of sand.

Along the Sandbanks peninsula littoral drift is predominantly towards the north-east but can vary in magnitude as well as direction from year to year (Map 2). This is because the predominant waves impinge on this frontage at a very small angle, and drift reversals can occur when there are only small shifts in the direction of wave approach.

The high, ebb dominant flows at the entrance to Poole Harbour enable sand to be transported seawards and south-eastwards in suspension into the offshore region of Studland Bay. From there it is thought that waves may be able to drive the sand onshore, thereby feeding the beaches in the northern part of Studland Bay.

Under prolonged periods of westerly or south-westerly winds (blowing offshore), sand bars have been observed to develop and thereafter migrate onshore, thus expanding the width of the inter-tidal beach (May, 1997; Brampton *et al*, 1998).

There may also be sediment recirculation east of the entrance to Poole Harbour as part of the ebb shoal delta. Hook Sand is composed of sediments from Poole Bay. Part of the crest of Hook Sand lies above -1m OD causing refracted waves to break. It is suggested that this causes: (i) sand to be driven onshore from the crest (HR Wallingford, 2000) and (ii) some sediment to move offshore in the shallows of Poole Head and then southwards along the east side of the bank (Hydraulics Research 1986; 1991).

A well-defined south-westward sand transport pathway operates across the offshore bed of Poole Bay (Bray et al, 1991b). The final destination for this material remains uncertain, although it is possible that some could supply Hook Sand and some is lost to the south.

An extremely complex transport regime operates in the vicinity of Hook Sand and Poole Harbour entrance. Hook Sand may be fed from offshore sources, although much of its volume could be inherited from earlier intervals in the erosion of Poole Bay (Bray *et al*, 1991b). It is also fed by material drifting into Poole Harbour Entrance that is flushed seawards by dominant ebb tidal currents, although those fluxes appear quite weak. Waves drive material onshore from the crest of the bank to the Sandbanks Peninsula where it may either drift eastward along the beach or move west to become entrained by tidal currents at Poole Harbour entrance and be flushed seawards back towards Hook Sand. Large pulses of sediment also appear to move from Hook Sand south-westward into Studland Bay.

2.2.3 Beach toe limit

Examination of a typical beach and nearshore seabed cross-section has been undertaken to try and determine the toe of the beach, i.e. the point of intersection of the beach with the seabed. Survey data obtained from the Channel Coastal Observatory has been plotted for Profile 5f00686 in Figure 3. It is difficult to determine the location where the toe of the active beach intersects the seabed from the available data.

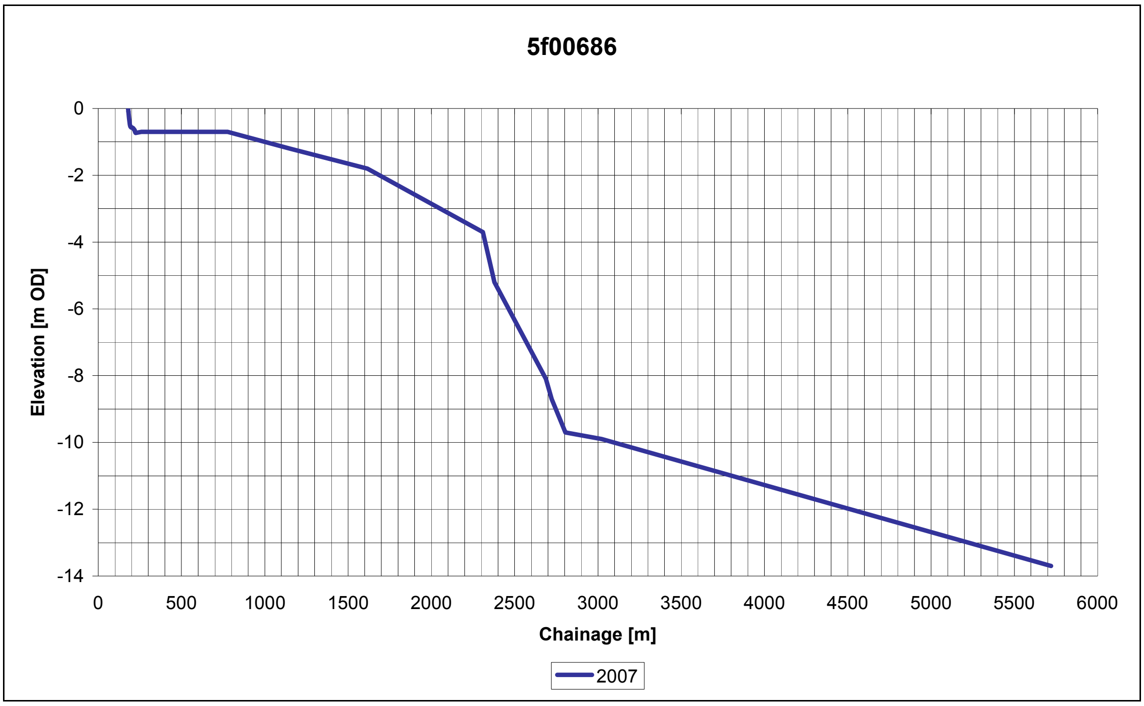


Figure 3 Profile 5f00686 (Source: CCO)

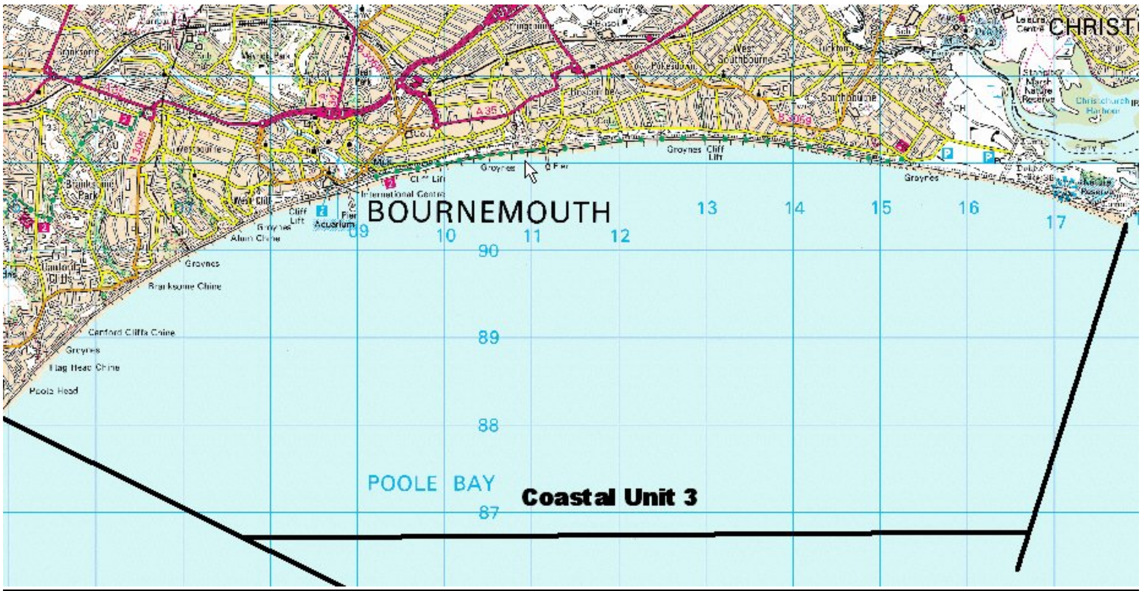
2.2.4 Coastal vulnerability

The beaches within Studland Bay are largely unprotected but two access points have gabion revetments. The frontage is also constrained by a 1500m long breakwater, which trains the tidal flows into and out of Poole Harbour and reduces the amount of sand transported northwards into the entrance channel (the Swash Channel). The sand beaches north of this training wall are affected by strong tidal currents and a rock revetment has been constructed southwest of the South Haven Point ferry to protect the shoreline inside Poole Harbour.

The sandbanks frontage, which is more exposed to storm wave action than the Studland frontage has had a history of coastal defence and management strategies. Following the deterioration of the groynes and the continued erosion in the late 1980s a series of rock groynes were built at the western end of Sandbanks in 1991/2 and were subsequently extended in 2006 towards Poole Head. These, in combination with nourishment using dredged spoil from the entrance channel to Poole Harbour, significantly widened the beaches and raised backshore levels by allowing some dunes to develop.

As with the Bournemouth frontage the prevention of cliff erosion has reduced the “sediment budget” so that beach nourishment is now the present long-term approach to managing the beaches in the area.

2.3 COASTAL UNIT 3: POOLE BAY



2.3.1 Description of the coastline

The beaches within Poole Bay extend from the entrance to Poole Harbour to Hengistbury Head. The beaches are predominantly sandy (Plate 4), but pebbles produced from the erosion of low cliffs at the eastern end of the frontage have produced mixed sand and pebble beaches between Solent Road and Hengistbury Head (Maps 1 and 2 and Plate 5).

The sandy cliffs within Poole Bay were eroding rapidly until the beginning of seawall construction in the 1870s providing wide sandy beaches and a low nearshore seabed gradient. By 1975, the whole frontage as far east as Solent Road had been protected by seawalls and groynes, resulting in a tendency for erosion and foreshore steepening. Reports by SCOPAC indicate that the sediment supply through cliff erosion east of Solent Road is now only about 4000 cubic metres per year.

From Solent Road eastwards to Hengistbury Head the low cliffs that contain sands and gravels are groyned which has slowed down the rate of cliff retreat. Backshore protection is restricted to a short length of gabion wall that protects the Double Dykes historic monument (Plates 4 and 5).

The long groyne at Hengistbury Head, built in the late 1930s has resulted in a build up of sand and pebbles on its west side as a result of the net eastward littoral drift (Map 2). This accretion provides some cliff toe protection west of the groyne but accelerating erosion on its eastern side. Sand can still be transported around the groyne by tidal currents, as is evident by the periodic sand accumulation at Mudeford Spit in Christchurch Bay, after beach nourishment within Poole Bay.

Since the 1970s beach nourishment has been used to maintain beach levels, either using marine dredged aggregate from offshore, or dredgings from the approaches to Poole Harbour. Nourishment volumes have been of the order 1 to 1.5 million cubic metres, with an average lifespan of 10-12 years. Smaller quantities of gravel have also been used for nourishment. These schemes have been found to have a typical “lifespan” of 10-12 years, after which the beaches are likely to have returned to the pre-nourishment volume.

Plate 4 Boscombe Pier (2005)

2.3.2 *Sediment transport*

The wave exposure along the margins of Poole Bay increases in an eastward direction as the shelter provided by Isle of Purbeck reduces in that direction. Thus, whilst the western end of the bay experiences only limited swell wave action from the west / southwest, the eastern end of the bay is exposed to both storm waves from a large sector as well as some residual Atlantic swell.

Net littoral drift is generally from west to east within Poole Bay (Map 2), although reversals in direction also occur. The complexity of the hydrodynamic regime means that there is little consensus about littoral drift rates.

Tidal currents within Poole Bay are generally weak but flows accelerate around the seaward end of the long groyne at Hengistbury Head and over Christchurch Ledge, a submerged rock platform that extends out from Hengistbury Head.

Offshore surveys have shown the presence of bedforms on the seabed that indicate a westward sand transport pathway across Christchurch Bay, before taking a more southerly course through the outer part of Poole Bay. This route is too far offshore to influence conditions at the shoreline (i.e. there is no sediment recirculation via this route).

Closer inshore there is a wide zone where the seabed is shallow and over which wave breaking occurs. Within this zone there is undoubtedly a potential for sediment exchange between the seabed and the beaches, as evidenced by the onshore transfer of dredged materials dumped some 400m seaward of the low water mark, as part of the 1974-5 sand nourishment scheme. Monitoring of the beach and nearshore seabed indicates onshore transport did take place at that time, but that sand was also lost offshore, so that by the early 1980s the beaches had eroded back to their pre-nourishment volume. Reports by SCOPAC have therefore concluded that whilst there is a potential for onshore transport, this is dependent on sediment availability within the nearshore zone (i.e. no “natural” onshore feed is likely in the absence of nearshore dumping of dredged material).

2.3.3 Beach toe limit

Examinations of typical beach and nearshore seabed cross-sections have been undertaken to try and determine the toe of the beach, i.e. the point of intersection of the beach with the seabed. Survey data obtained from the Channel Coastal Observatory has been plotted for Profiles 5f00470, 5f00407 and 5f00372 in Figures 4 to 6. A simple calculation of the slopes (and the changes in slopes) has been undertaken. For profile 5f00470 (Figure 4), Halcrow’s (1991) suggested maximum limit of 7 metres depth for seasonal beach fluctuations would seem to fit with the data; the profile flattens from a slope of approximately 1:30 to a slope of 1:100 seaward of this location. A bar feature is observed in the 2007 data at profile 5f00407 (Figure 5), seaward of this bar the profile has a slope of 1:40 until the profile reaches a depth of 10m where it flattens quite considerably. Profile 5f00372 (Figure 6) also has a slope of approximately 1:40. With the available data it is difficult to ascertain the active toe of the beach at profiles 5f00407 and 5f00372.

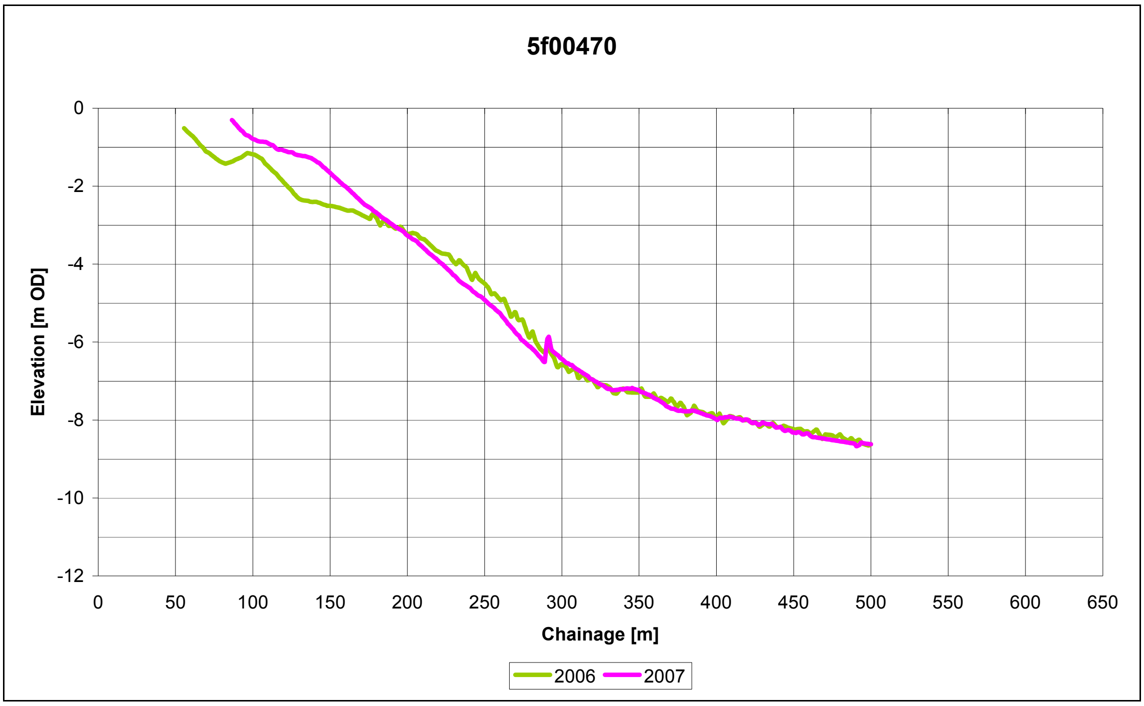


Figure 4 Profile 5f00470 located at West Cliff, Poole Bay (Source: CCO)

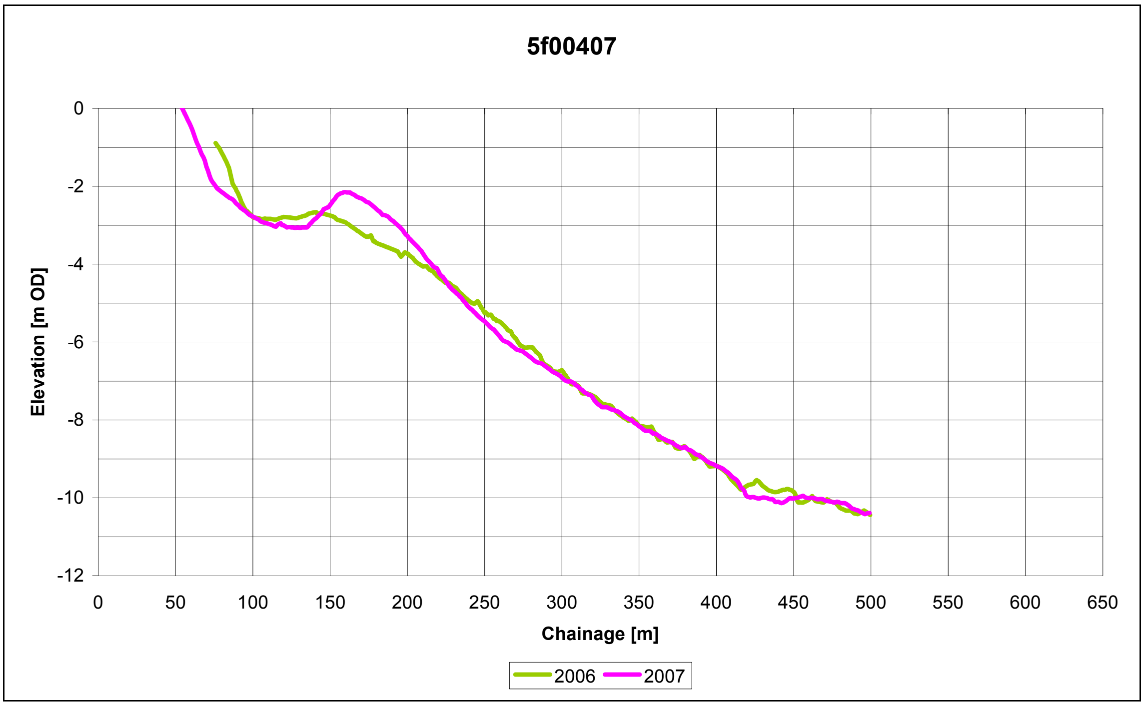


Figure 5 Profile 5f00407 east of Boscombe Pier, Poole Bay (Source: CCO)

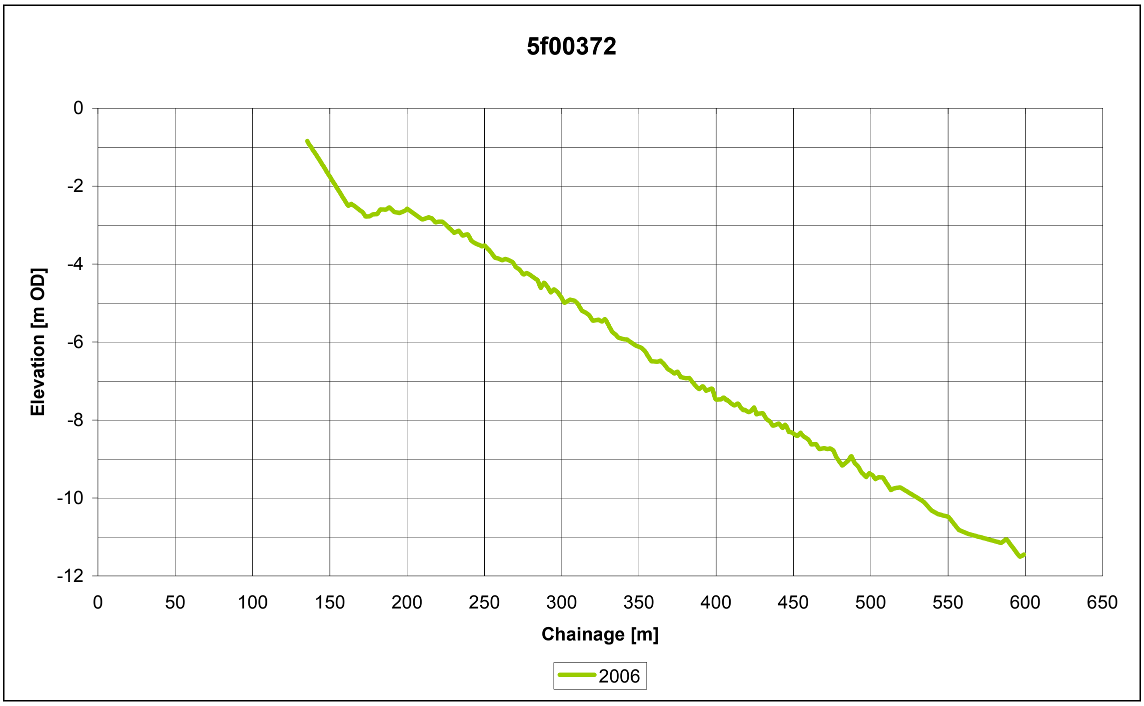


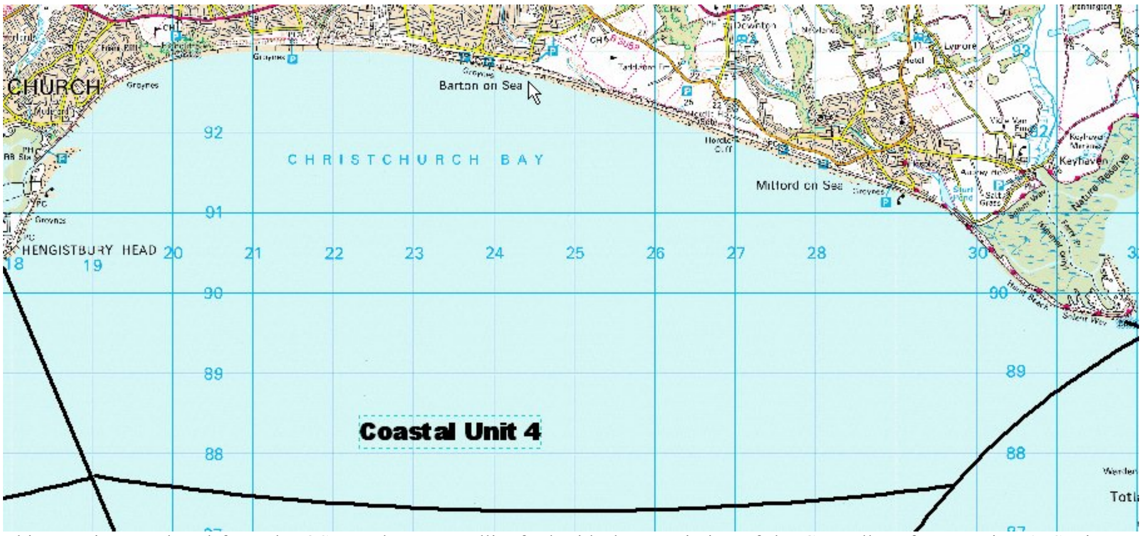
Figure 6 Profile 5f00372, Hengistbury Head (Source: CCO)

2.3.4 Coastal vulnerability

The tidal range in Poole Bay is small, as well as having a "double high water" component, concentrating wave action on a small part of the shore-face and thereby, concentrating wave erosion effects. Sustained wave activity can therefore significantly reduce beach width and reduce the lifespan of beach nourishment schemes (Map 3).

Plate 5 Double Dykes at the eastern end of Poole Bay (2005)

2.4 COASTAL UNIT 4: CHRISTCHURCH BAY



2.4.1 Description of the coastline

The varied coastline of Christchurch Bay extends eastwards from Hengistbury Head up to the mouth of the West Solent. It includes the sand and shingle spits at the mouth of Christchurch Harbour, unstable cliffs (Map 1) that extend eastwards to Milford on Sea and a shingle spit, Hurst Spit (Map 2), which extends into the West Solent.

At Hengistbury Head the cliffs of sands and clays have a mantle of gravels and were eroding rapidly prior to the construction of the long groyne in the 1930s. This resulted in beach accretion and reduced cliff erosion west of the groyne but accelerated erosion east of it. Therefore, in the late 1980s four rock groynes were constructed east of the long groyne. These filled very rapidly with sand, being carried in suspension around the groyne end. Some sand also feeds northwards towards Mudeford Spit (Plate 6).

Mudeford Spit extends northwards from Hengistbury Head across the mouth of Christchurch Harbour, leaving a narrow entrance, through which there are rapid tidal flows (there was also a small spit that extended southwards from the opposite shoreline of the Harbour but Mudeford Quay has been built over it so that it no longer exists as an identifiable feature).

The Mudeford frontage is dependant on sediment reaching it from Poole Bay. Before the long groyne was constructed the supply was so large that at times a shore parallel spit developed, extending several kilometres eastwards from the mouth of Christchurch Harbour. Recently constructed rock groynes have been successful in trapping suspended sediments and increasing beach width (Plate 6).

Along Mudeford Quay there is no beach, because of the scouring action of tidal currents through the entrance to Christchurch Harbour. However, only a short distance northward, Avon Beach has widened substantially after the construction of rock groynes.

Plate 6 Mudeford Spit (2007)

Further eastwards, the cliffs within Christchurch Bay consist of sands and clays, as well as a mantle of gravels. The supply of sand and pebbles has diminished and the eastward littoral drift interrupted by coastal defences (Plate 7). Some of the material derived from erosion is fine and carried offshore in suspension. The coastal defences (Map 3) consisting of rock revetments and groynes protect the cliff toe at Highcliffe and Barton on Sea, whilst at Milford there are seawalls and groynes with rock being recently added to strengthen them. At both Highcliffe and Barton on Sea there are areas of accelerated coastal erosion downdrift / eastward of the defended frontages, notably at Naish Farm. At Milford on Sea, however, the defences extend eastwards towards Hurst Spit, so downdrift effects are felt on the spit itself.

From Milford on Sea, Hurst Spit extends south-eastwards towards Hurst Narrows. The net eastward littoral drift (Map 2) provides shingle for the maintenance of the spit. However, the supply of material has declined in recent years following the installation of the coast protection schemes, which began in the 1960s and have been enlarged and extended since. In addition losses occur from the eastern extremity of the spit, from which shingle is transported south-westwards / offshore by rapid ebb flows. Being also exposed to the predominant south-westerly wave action, the spit is vulnerable to breaching and overtopping. As a result, the western part of the spit has been armoured with rock, whilst also being nourished with gravel on several occasions (Plate 8).

Beach nourishment has been increasingly used to improve beaches on managed and defended frontages (Map 3). At Highcliffe rock groynes began to be constructed in the mid 1980s, replacing timber groynes, whilst some 55,000m^3 of gravel, obtained from land based sources, was added to build up the upper beach. Further nourishment has been undertaken since, including some 18,000m^3 of gravel in 1991. Small-scale nourishment has also been carried out at Barton on Sea and Milford on Sea at various times.

Plate 7 Barton East (2007)

SCOPAC reports that Hurst Spit had also been nourished at an average rate of 1,000m^3 per annum between 1980 and 1985. Following extensive over-washing and up to 80m of landward retreat during winter storms in 1989 the spit was nourished with some 50,000 tonnes of gravel. Further nourishment was added in 1991 and 1994, followed by major nourishment with marine aggregate in 1996, using gravel.

The overall long-term trend in Christchurch Bay is thus one of erosion (Map 3), with sediment input due to cliff erosion being insufficient to make up the deficit in the sediment budget (much of the eroded material consists of fine sands, silts and clays that are lost offshore).

2.4.2 Sediment transport

Despite extensive studies there is no consensus about the strength of littoral drift in Christchurch Bay. SCOPAC, following a thorough examination of available data consider that the net eastward drift is spatially variable, being within the range of 5,000-20,000m^3 per year (Map 2). This is low in comparison with the volume available for transport as a result of cliff erosion. Thus, the greater proportion of fine material derived from cliff erosion must be transported offshore, rather than alongshore.

In the outer parts of Christchurch Bay there are areas where sediments tend to accumulate. The rapid ebb flows through Hurst Narrows are able to carry sand and shingle south-westwards / offshore through the Needles Channel to settle out on Shingles Bank and Dolphin Bank. Bedforms indicate that there is also a tendency for shingle to be moved north-eastwards along the west face of Shingles Bank, implying some sediment recirculation around the bank (Map 2). In fact the size grading of material has been found to be similar to that found on Hurst Spit, suggesting that material eroded from the spit and transported offshore finds its way onto the bank.

From the asymmetry of sand waves there is potential for westward transport of sand at a number of locations in the outer part of Christchurch Bay. Thus, a westward transport pathway is proposed, linking Dolphin Bank and Dolphin Sand, although how much transport of sandy material takes place along this route is not known. It is extremely unlikely that any of these sediments can be transported onshore, because of the low strength of the currents in the nearshore parts of Christchurch Bay.

Plume studies have shown that fine sediment may be transported in suspension off Hurst Spit to feed the shoreline in the West Solent (CIRIA, 1995).

2.4.3 Beach toe limit

Examinations of typical beach and nearshore seabed cross-sections have been undertaken to try and determine the toe of the beach, i.e. the point of intersection of the beach with the seabed. Survey data obtained from the Channel Coastal Observatory has been plotted for Profiles 5f00338, 5f00150 and 5f00012 in Figures 7 to 9. Profile 5f00338 (Figure 7) at Mudeford Spit is very flat, the slope has been calculated to be approximately 1:280. Profile 5f00150 (Figure 8) is also flat with a slope of approximately 1:140. Profile 5f00012 (Figure 9) extends to a depth of 16m before it joins with Shingles Bank off Hurst Spit centered on this profile at a chainage of around 700m. Again, given the data available it is difficult to determine the active beach toe at each of these profiles.

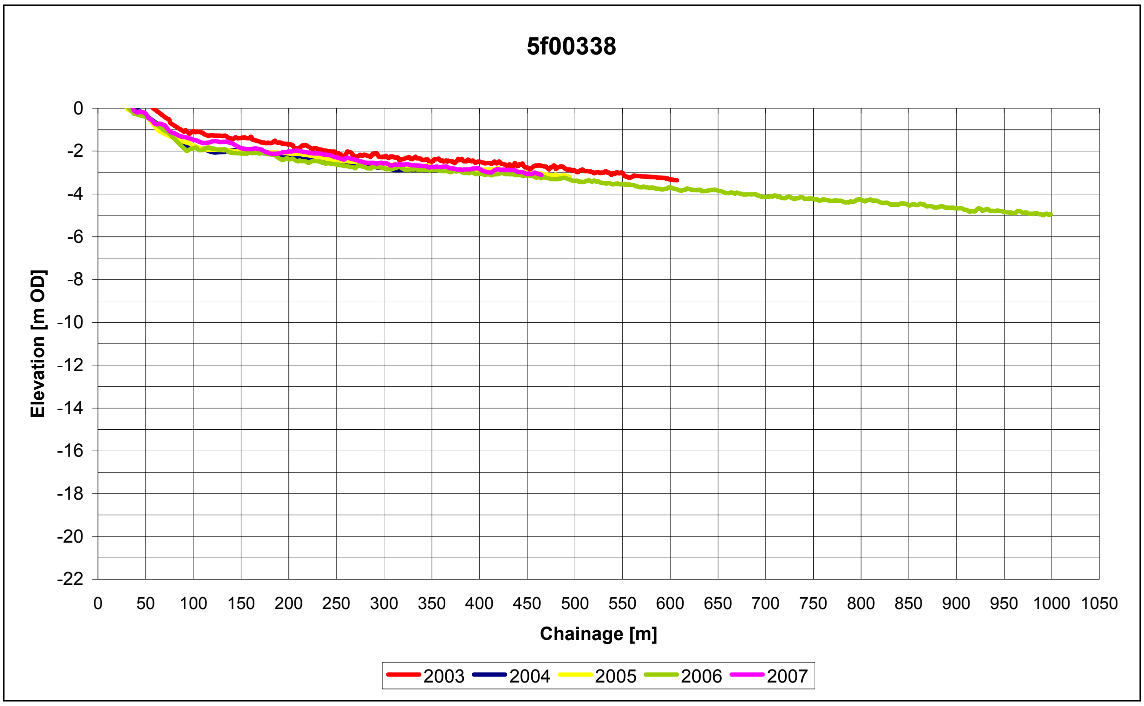


Figure 7 Profile 5f00338, Mudeford Spit (Source: CCO)

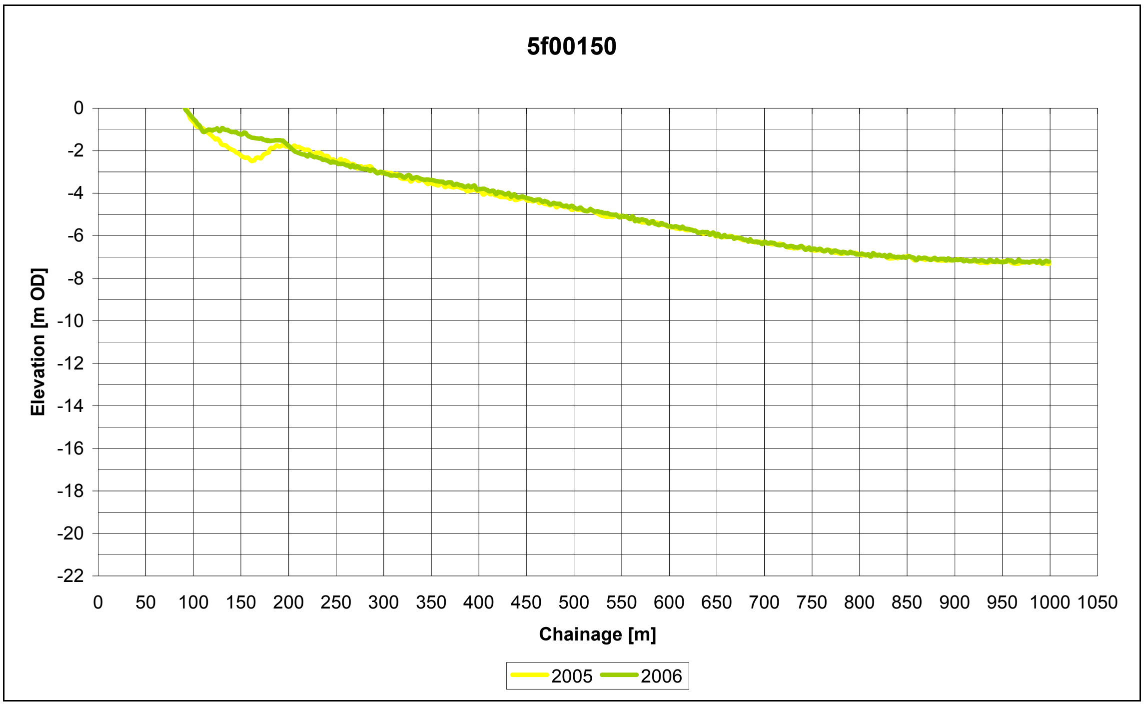


Figure 8 Profile 5f00150, Barton on Sea (Source: CCO)

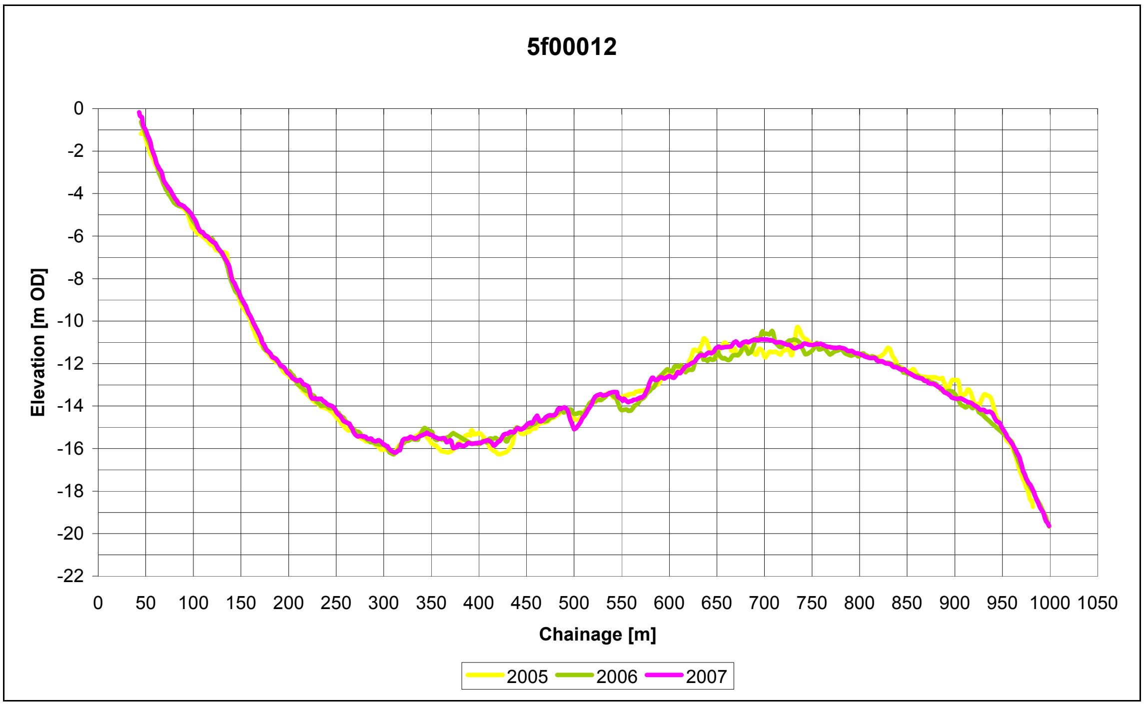


Figure 9 Profile 5f00012, Hurst Spit (Source: CCO)

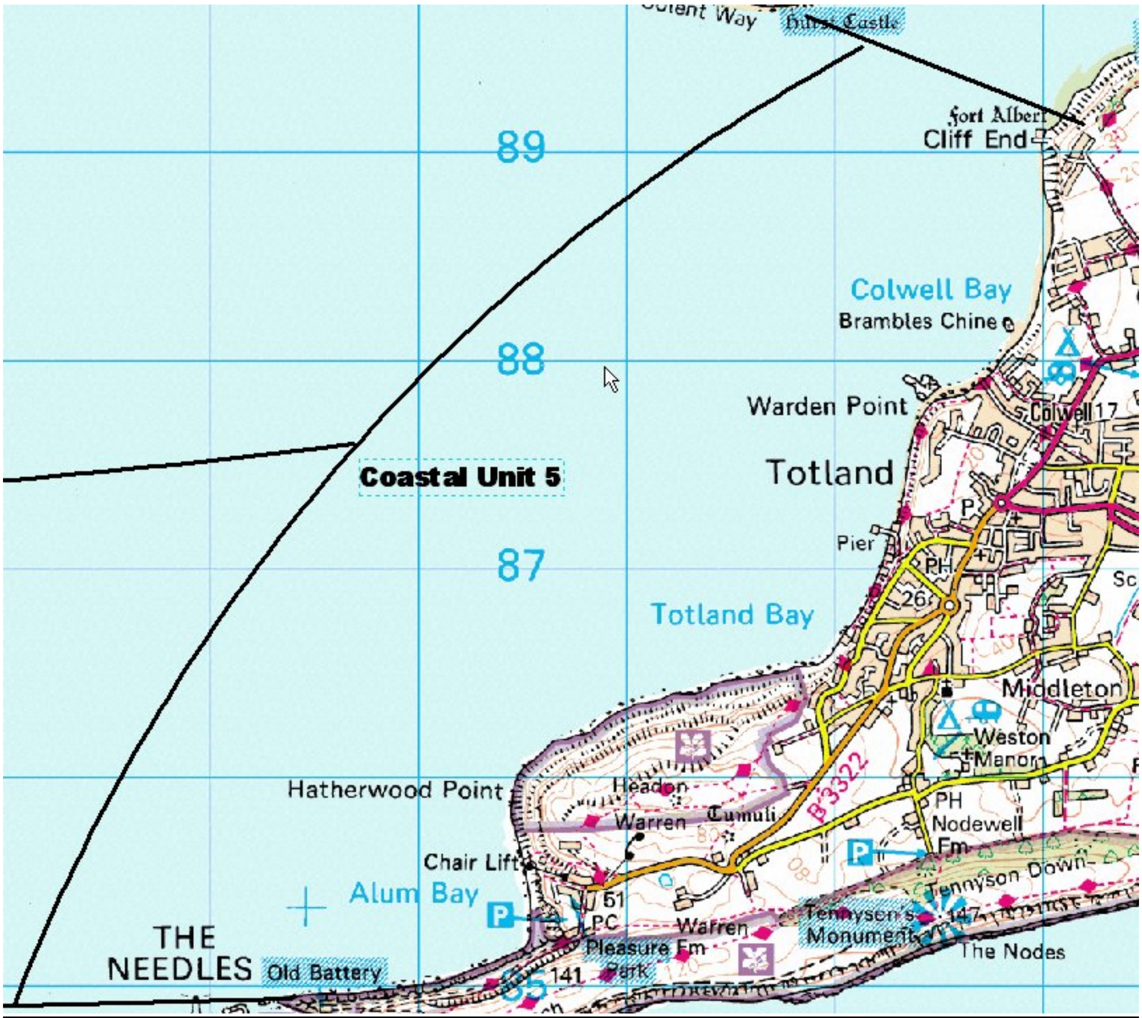
2.4.4 Coastal vulnerability

The whole of Christchurch Bay is very vulnerable to wave erosion (Map 3). The very small tidal range concentrates wave action on a small part of the shore-face, thereby concentrating the erosion effects. The soft cliffs in Christchurch Bay are thus particularly sensitive to changes in the wave climate, particularly eastward / downdrift of defended frontages (i.e. at Naish Farm).

Hurst Spit is prone to breaching and landward retreat, it is also sensitive to changes in the wave climate.

Plate 8 Hurst Spit (2005)

2.5 COASTAL UNIT 5: ISLE OF WIGHT - NORTH WEST COAST



2.5.1 Description of the coastline

The north-west coast of the Isle of Wight is soft easily erodible cliffs (Map 1), most of which are prone to slippage. Being exposed to severe wave action from the west, almost all unprotected stretches are eroding rapidly.

Alum Bay, to the north of the Needles has a pebble beach (Map 2) derived from the erosion of the chalk cliffs to the south. The clays and sandstones within the cliffs provide mainly fine sediments that are quickly lost offshore. The flint pebbles tend to be transported northwards by the net littoral drift, but their movement is intercepted at Hatherwood Point. Further north at Headon Warren there are unstable limestone cliffs, which have a stepped profile due to slumping. The foreshore (Map 2) in front of these cliffs is rocky and coarse material tends to be transported into the southern part of Totland Bay.

The unstable cliffs in Totland Bay that contain sands and clays and are now protected by a continuous seawall that extends northwards into Colwell bay (Plate 9). The lower foreshore is sandy, whilst the upper beach is of varying width and consists of pebbles of varying sizes (Map 2). Even at minor changes in seawall alignment some groyne compartments hold little coarse sediment. This may be due to the large incidence of westerly wave action which produces a strongly zigzag beach plan shape, helping to empty some of the groyne compartments. There is also an increase in beach width to the south of the pier and a corresponding reduction to the north of it.

Warden Point and Warden Ledge inhibit the northward transport of beach material. In addition, a number of rock groynes intercept the movement of coarse material from Totland Bay to Colwell Bay. As a result, beach levels in front of the seawall are low and strong wave overtopping occurs around Warden Point.

The deterioration of the beach at the south-western end of Colwell Bay led to small scale nourishment with fine gravel and sand at various times between 1977 and 1993. However, the beaches are predominantly sandy, with pebbles only being found in isolated groyne compartments. To the north of the seawall there are unstable cliffs of sands and clays and soft limestones that are eroding and are prone to landslips, despite the presence of groynes (Plate 10). The input of sands and clays by erosion provides little beach material, most of it being transported offshore.

Cliff retreat around Fort Albert has resulted in it acting as a headland, preventing coarse sediment from being transported around it. In fact, there has been very little beach build up against this structure.

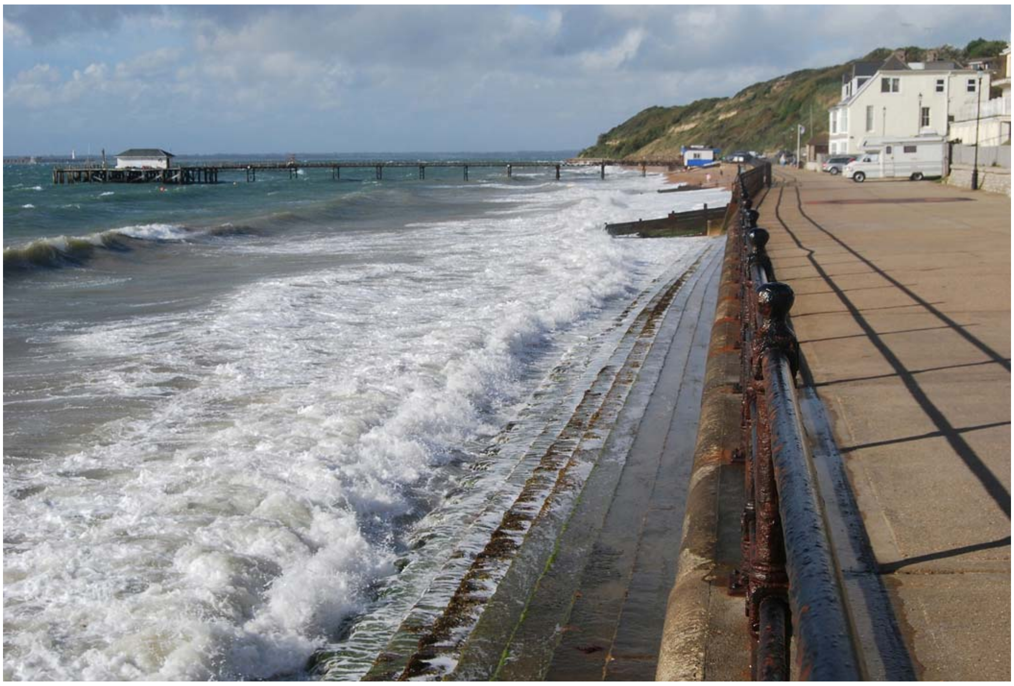


Plate 9 Totland Bay (2008)

2.5.2 Sediment transport

The north-west coast of the Isle of Wight is exposed to Atlantic swell waves, hence the drift potential is high. Coarse sediment released by cliff erosion is transported predominantly northwards by the net littoral drift (Map 2). However, headlands form discontinuities in the alongshore sediment transport pathways, so that little material is transported between Alum Bay and Totland Bay, Totland Bay and Colwell Bay and little or no beach material is transported around Fort Albert to the north coast of the Isle of Wight. Much of the sediment derived from cliff erosion is transported offshore (Bray *et al*, 1991a).

The seabed dynamics offshore of the Isle of Wight have been described in the description of Christchurch Bay, so only a brief description is provided here. The rapid ebb flows between Hurst Spit and the Isle of Wight are able to carry sand and shingle south-westwards/offshore onto Shingles Bank and Dolphin Bank. However, bedforms indicate westward sand transport along a route linking Dolphin Bank and Dolphin Sand, taking sediments away from the Isle of Wight coast, not towards it.

2.5.3 Beach toe limit

Examinations of typical beach and nearshore seabed cross-sections have been undertaken to try and determine the toe of the beach, i.e. the point of intersection of the beach with the seabed. Survey data obtained from the Channel Coastal Observatory has been plotted for Profiles 5d00079 and 5d00006 in Figures 10 and 11. Profile 5d00079 (Figure 10) has a slope of approximately 1:30 to a depth of 3m before flattening for 150m, the slope is then flatter at approximately 1:60 until the end of the profile. Profile 5d00006 (Figure 11) exhibits similar characteristics with a slope of 1:40 to a depth of 7m where it plateaus for 150m and then 1:50. The toe of beach may intersect the seabed at -3m and -7m (respectively) where the profiles flatten however, given the available data it is difficult to confirm whether this is the case.

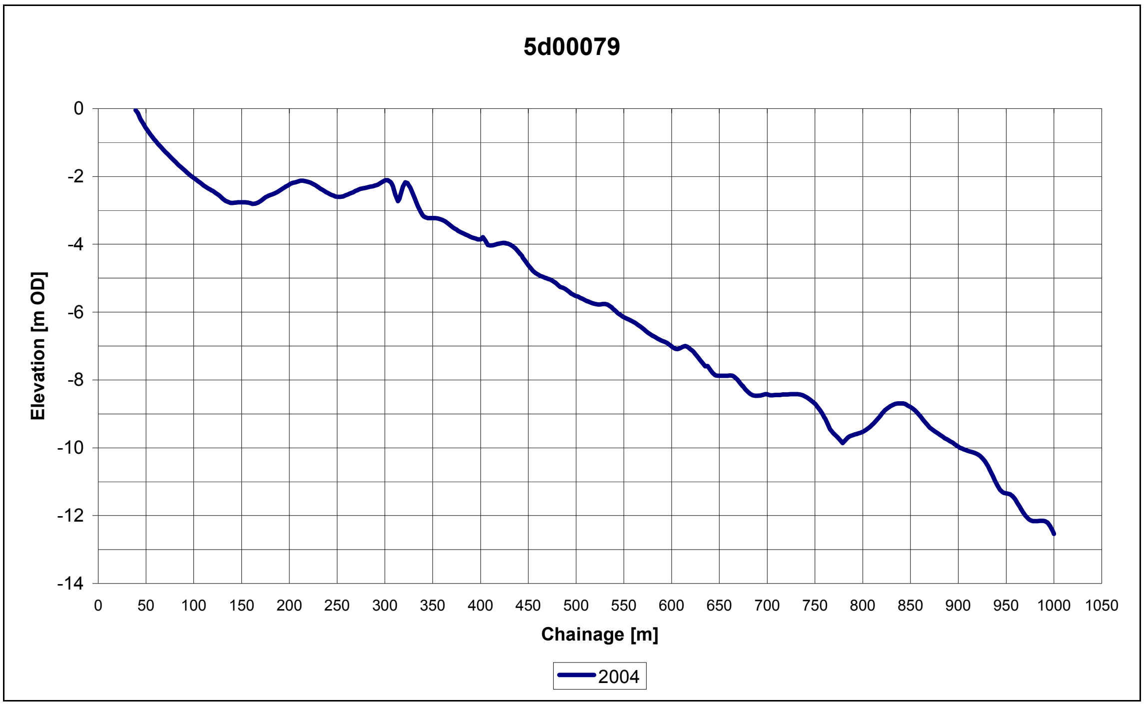


Figure 10 Profile 5d00079, Colwell Bay (Source: CCO)

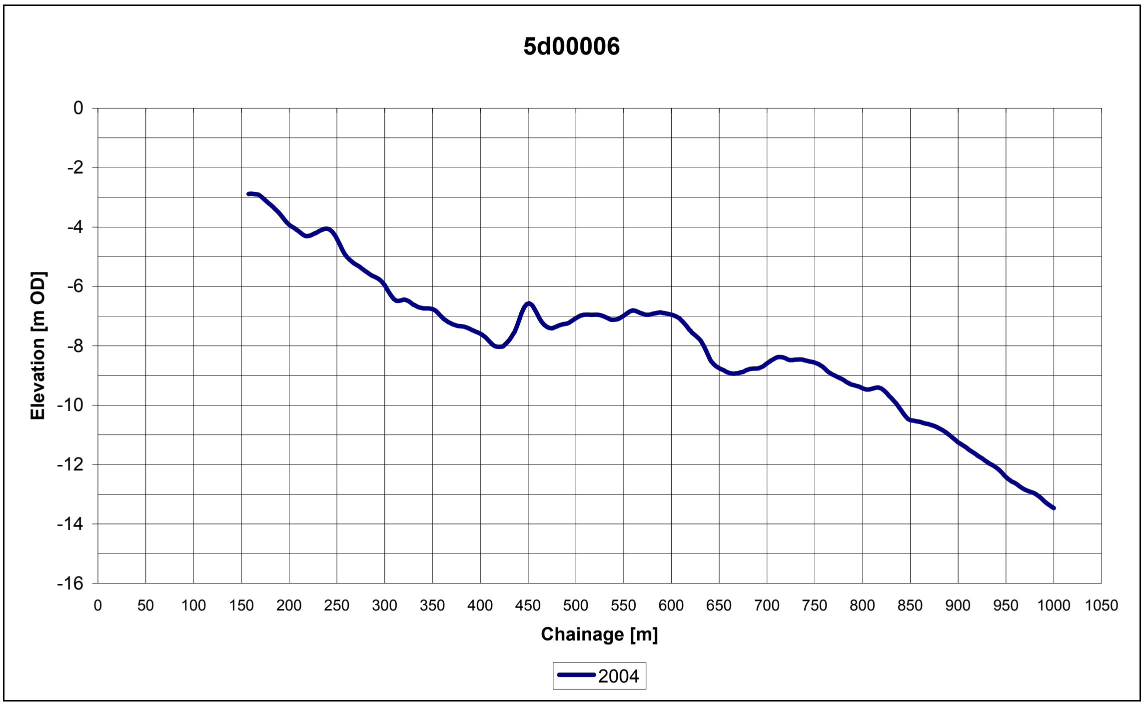


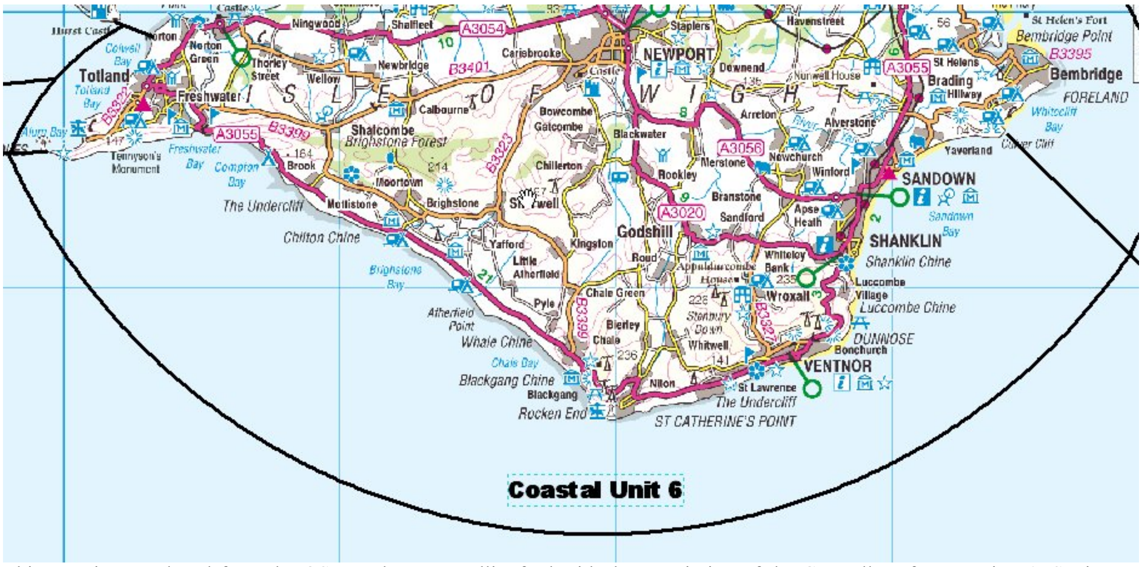
Figure 11 Profile 5d00006, Alum Bay (Source: CCO)

2.5.4 Coastal vulnerability

The exposure to wave action from the west (including Atlantic swell) results in the defences being exposed to strong wave action. As a result the sea defences are exposed to heavy wave forces and there is also a considerable amount of wave overtopping. Thus, in places, the seawalls only form partial protection to the toe of the cliffs. If the coastline was unprotected there would be a high potential for erosion (Map 3).

Plate 10 Colwell Bay (2008)

2.6 COASTAL UNIT 6: ISLE OF WIGHT - SOUTH COAST



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2.6.1 Description of the coastline

Much of this coastline consists of soft easily erodible cliffs (Map 1), with landslips being widespread. They are exposed to wave attack from a wide sector, but the predominance of south-westerly waves produces a net eastward drift over virtually the whole frontage (Map 2).

Chalk cliffs extend from the Needles to Freshwater Bay. Their slow erosion releases small quantities of flint pebbles, which are transported eastwards in the direction of the net littoral drift (Map 2).

In Freshwater Bay the pebbles collect to form a substantial beach, but the constant pebble movement has resulted in damage to the seawall and groynes, requiring them to be reconstructed on several occasions (Map 1). Chalk cliffs continue eastwards to Compton Bay. Cliff retreat (Map 3) has posed a threat to the "Military Road" which runs close to the cliff line.

Between Compton Bay and Blackgang Chine the eroding cliffs contain sands, clays and shales in places. Their erosion has produced predominantly sandy beaches that are wide and flat but which do not provide much protection to the cliff toe, and most material eroded from the cliffs are being transported predominantly offshore (Plate 11). In Chale Bay, the near vertical shale cliffs are overlain by the harder sandstone beds, which form a terrace due to land slippage. Muds flow over this terrace and then spread out onto the foreshore. Cliff top retreat in this area has resulted in the loss of the coast road and a number of properties in the recent past.

Plate 11 Compton (2008)

Plate 12 Ventnor Bay (2008)

The south coast of the Isle of Wight east of Rocken End, around St Catherine's Point and eastward to Dunnose Head is largely undeveloped and is typified by terraced cliff slopes, formed as a result of slippage of the Chalk over the underlying Gault Clay. Between St. Catherine's Point and Ventnor there are several pocket beaches of fine gravel overlying coarse sand, but much of the foreshore is covered by landslide debris. There is a short length of seawall / rock revetment in Reeth Bay and a continuous line of sea defences from Steephill Cove, Ventnor to Monks Bay and Bonchurch (Map 1). Plate 12 illustrates the indented nature of this coastline and the fragmentary beach deposits. Many stretches of seawall are now fronted by rock revetments, whilst the short undefended backshore between Horseshoe Bay and Monks Bay, Bonchurch is now protected rock groynes. The defences finish at the massive landslip at Dunnose, now an important recreational area.

From Dunnose to Shanklin, the cliffs have a wide range of geological strata, their erosion releasing sand that is transported northwards into Sandown Bay. Sand beaches begin at Luccombe Bay, but have intermittent gravel berms as far northward as Shanklin Chine.

North of Shanklin Chine and extending to Yaverland (Plate 13) there is a continuous stretch of revetments / seawalls, fronted by groynes of varying dimensions and spacing. There are a number of long groynes along this frontage, being the result of fragmentary development of defences. Therefore, the beach width along this frontage is somewhat variable and there has been some undermining on the north faces of some of the larger groynes in the recent past. Littoral drift along this frontage is northwards (Map 2) and there are wide sandy beaches to the south of the largest groynes.

To the north of the Yaverland seawall the wide sandy beach is backed by a pebble berm that extends eastwards to Culver Cliff. Littoral drift along this frontage is weak, but predominantly eastwards (Map 2).

Plate 13 Yaverland (2008)

2.6.2 Sediment transport

The south coast of the Isle of Wight is exposed to Atlantic swell waves, hence the drift potential is high. The net littoral drift is predominantly eastward along the whole frontage (Map 2). However, much of the fine sediment released by erosion is transported offshore. The beaches are a varying mixture of sand and pebbles, depending upon the availability of coarse sediment and their ability to be transported alongshore past various obstructions, such as landslips, headlands etc.

Fine sands and clays are quickly dispersed offshore from their point of origin by the strong wave action and there is no evidence of onshore sediment transport along this coastline.

The complex sediment processes within Christchurch Bay are thought not to affect sediment processes along the Isle of Wight coastline (the predominant westward seabed transport pathways would tend to move material away from the Isle of Wight).

Similarly the accumulation of sediments on Pot Bank, south-west of the Needles is also thought not to feed the beaches of the Isle of Wight. A map of postulated sand transport pathways around the Isle of Wight (Dyer, 1985), indicates a net onshore to offshore movement away from the approximate location of Hanover Point and possibly seawards of Freshwater Bay.

2.6.3 Beach toe limit

Examinations of typical beach and nearshore seabed cross-sections have been undertaken to try and determine the toe of the beach, i.e. the point of intersection of the beach with the seabed. Survey data obtained from the Channel Coastal Observatory has been plotted for Profiles 5e00475, 5e00215 and 5e00070 in Figures 12 to 14. Profile 5e00475 (Figure 12) is the flatter of the three with a slope of approximately 1:80. Profile 5e00215 (Figure 13) is flatter across the first 200m of the profile to a depth of 3m, with a slope of approximately 1:100, before steeping to a slope of 1:25. Profile 5e00070 (Figure 14) extends with a fairly uniform slope of 1:40 to a depth of 11m where it may then intersect the base of Culver Cliff. Given the data available, it is difficult to determine the location of the limit of the active beach toe.

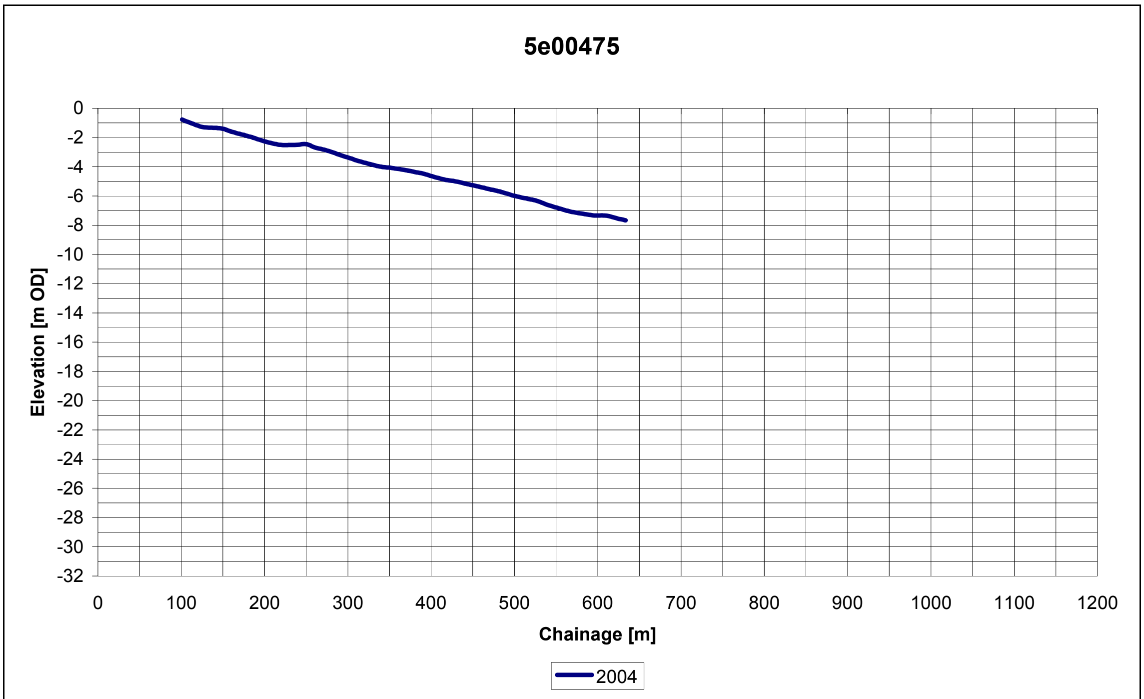

Figure 12 Profile 5e00475, Compton Bay (Source: CCO)

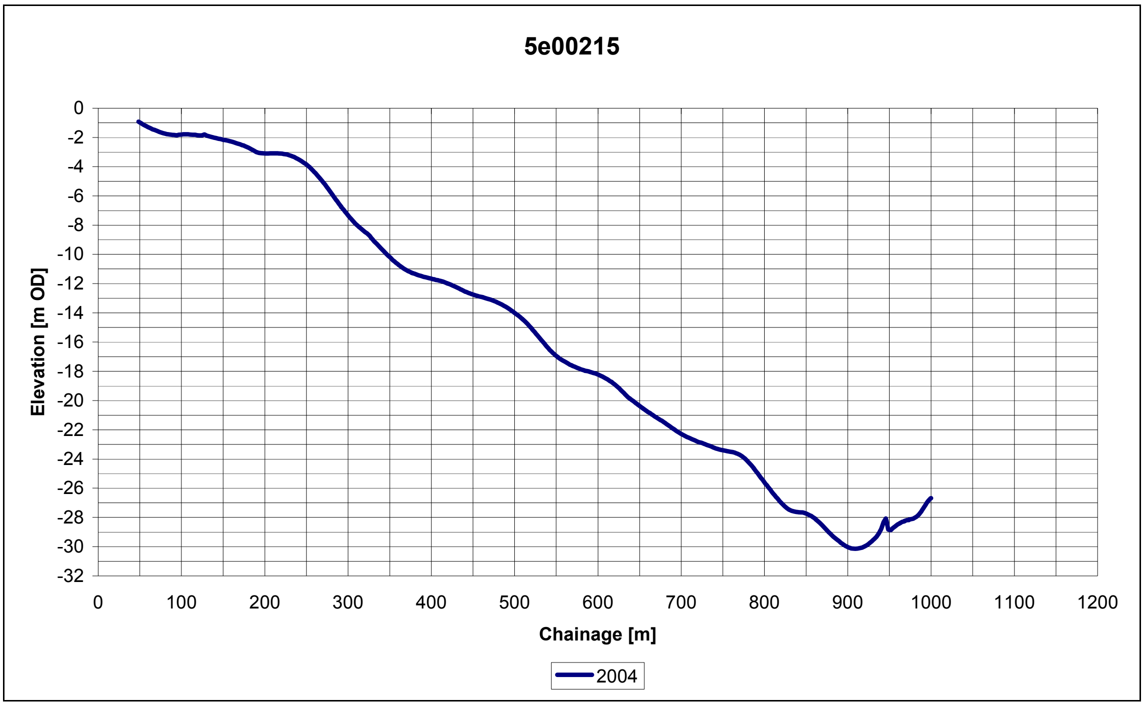

Figure 13 Profile 5e00215, Ventnor (Source: CCO)

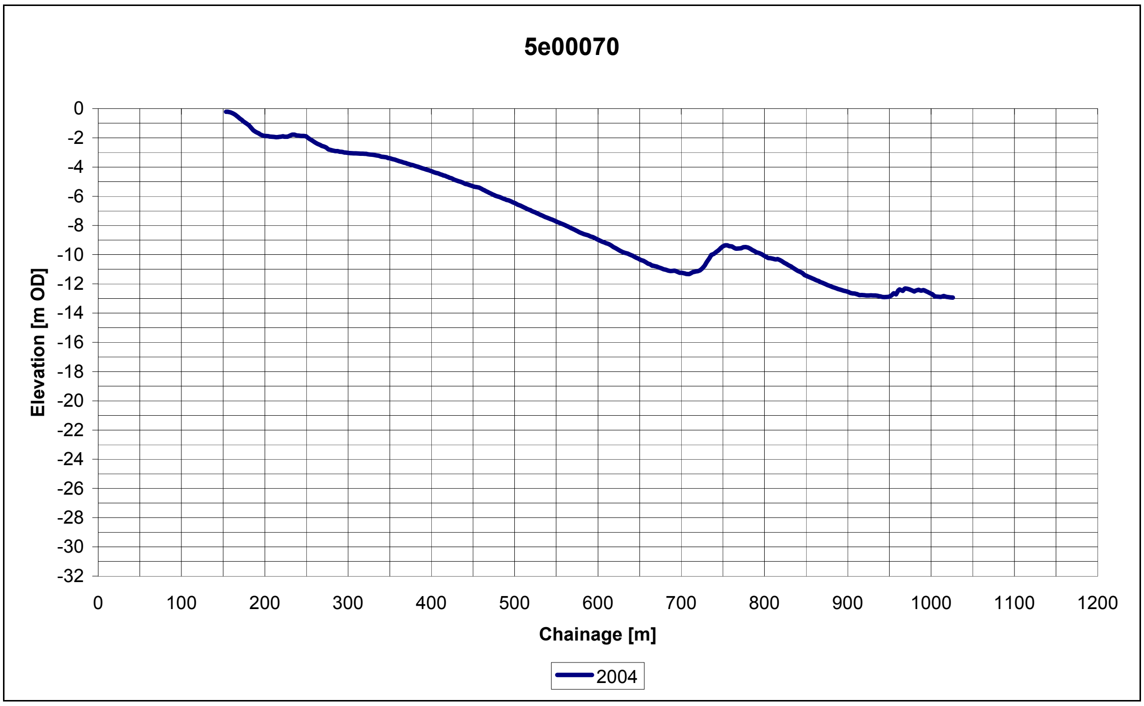

Figure 14 Profile 5e00070, Yaverland (Source: CCO)

2.6.4 Coastal vulnerability

The combination of soft cliffs and strong wave exposure results in rapid cliff erosion at undefended stretches of coastline. Despite cliff toe protection, some areas such as Bonchurch, nevertheless remain vulnerable to landslips (Map 3).

2.7 COASTAL UNIT 7: ISLE OF WIGHT – NORTH EAST COAST

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2.7.1 Description of the coastline

The Culver Cliff headland forms the boundary between the south and the north facing coasts of the Isle of Wight. The headland with its extensive rock ledges effectively separates the beaches in Sandown Bay in the south from Whitecliff Bay to the north.

The soft cliffs (Map 1) of sands, clays and limestones, which extend northwards from the Chalk headland of Culver Cliff to Foreland, are largely unprotected and are subject to landslips/mudslides. They are the source of material for the wide, sandy beaches within Whitesand Bay (Map 2), as well as providing a supply of sediments for the beaches to the northward. The short length of private defences has little impact on the processes of cliff erosion.

At the northern end of Whitecliff Bay there are extensive limestone reefs and ledges, which extend in front of low cliffs, northwards around Foreland to Bembridge Harbour. There are short stretches of seawall at Foreland, together with permeable timber breastworks, short stretches of rock revetment and permeable timber groynes being found closer to Bembridge Harbour (Plate 14). These cliffs are capped raised beach and fluvial deposits, providing pebbles, sands and clays by their erosion.

Plate 14 Bembridge Point (2008)

Bembridge Harbour is a sink for fine sediments; trapping some of the northwards sand transport, but also accumulating fine sand and silt from offshore (the harbour is very sheltered against wave action). Dredging in both the harbour and its approaches has been necessary in order to maintain navigation. Dredgings have included sand and gravel in the harbour approaches and predominantly mud within the harbour basin. A concrete seawall (the Duver) sheaths the sand spit on the north side of the harbour entrance, but beyond that the coastline is largely unprotected as far northward as Nettlestone. Although the net drift along this coastline is predominantly northwards there may be a local reversal in drift direction along the Duver wall.

Apart from some short stretches of defences, continuous seawalls begin in Seagrove Bay (Map 3). There has been some coastal slope instability in the southern part of Seagrove Bay, but defences that were constructed in 2000 have provided added stability.

From Seagrove Bay to Ryde there is now a continuous line of backshore defences. This frontage once had intermittent stretches of seawall, so that the defences contain structures of various types, age and condition. In places the freeboard of the seawalls was small, threatening flooding of the coast road in Spring Vale, for example. This wall has now been reinforced with a concrete “wave return” and rock added in front of it (Plate 15). This frontage also has a number of groynes that are generally absent elsewhere.

The mixture of sand and pebble beaches extending westwards to Puckpool Point, beyond which the beaches are predominantly sandy. Beyond Puckpool Point there is a dramatic widening of foreshore width and the sediment accumulation at East Ryde Sands extends 2km offshore at its maximum limit (Plate 16). This frontage thus constitutes a major sediment sink. The beaches are sandy and the net littoral drift is westward, although offshore there may be some movement of sediment in the opposite direction.

At Ryde itself there are several large, curved concrete groynes that have collected sand east of each, whilst near Ryde Pier there is a marina that has accumulated a wide sandy beach. Accretion to the east and erosion to the west of these structures indicates the presence of a strong westward littoral drift, despite the modest wave climate.

Plate 15 Spring Vale (2008)

Plate 16 Ryde East Sands (2008)

2.7.2 Sediment transport

The seabed transport to the east of the Isle of Wight has been studied in detail in earlier dredging related studies.

Investigations of bedforms within the Eastern Solent and Spithead indicate a westward wave induced transport of sand close inshore (Map 2), supplying Ryde Sands with sandy material. Mineralogical analysis of sediments at Ryde Sands shows them to have similar characteristics to the sands in Sandown Bay.

The South Coast Seabed Mobility Study (HR Wallingford, 1992 and 1993) shows that further offshore there is a net eastward tidal current induced transport of sand within Spithead. It is therefore likely that some of the sediments reaching Ryde East Sands as a result of wave action may then be transported eastwards / offshore by tidal currents.

2.7.3 Beach toe limit

Examinations of typical beach and nearshore seabed cross-sections have been undertaken to try and determine the toe of the beach, i.e. the point of intersection of the beach with the seabed. Survey data obtained from the Channel Coastal Observatory has been plotted for Profiles 5d00539 and 5d00449 in Figures 15 and 16. The elevation of Profile 5d00539 (Figure 15), at Bembridge shows some fluctuations between the two surveys around 200m chainage. At Ryde Sands (Profile 5d00449, Figure 16), the profile extends to a depth of 2.75m with a slope of 1:120 before flattening for 350m where the beach rises more steeply; the beach at Ryde Sands extends 2km offshore at its maximum limit due to the deposition of sediment. The data available is insufficient to determine the active beach toe.

2.7.4 Coastal vulnerability

The coastline from Culver Cliff to Foreland is more exposed to the predominant south-easterly waves than the coastlines further northward. Any increase in wave activity could accelerate cliff erosion and landslips within this frontage (Map 3).

The sea defences north of Bembridge Harbour are of varying age and condition. Whilst the threat of flooding at Spring Vale is now reduced, other stretches of wall remain vulnerable to wave induced damage, despite the modest wave climate.

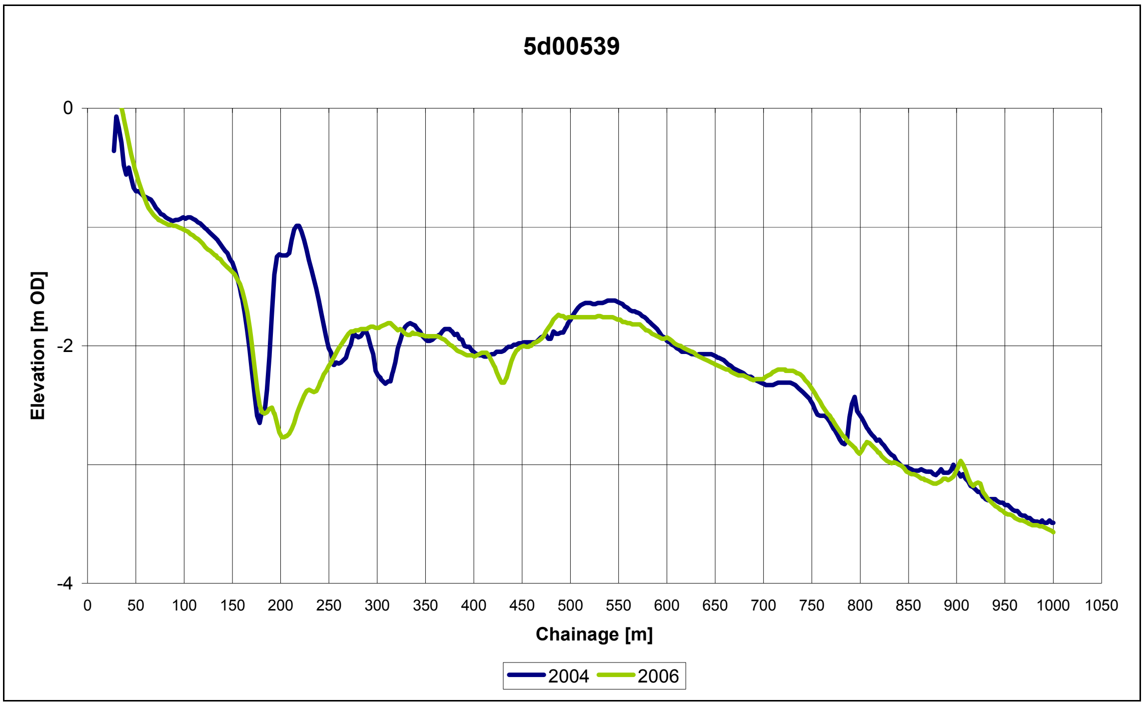


Figure 15 Profile 5d00539, Bembridge (Source: CCO)

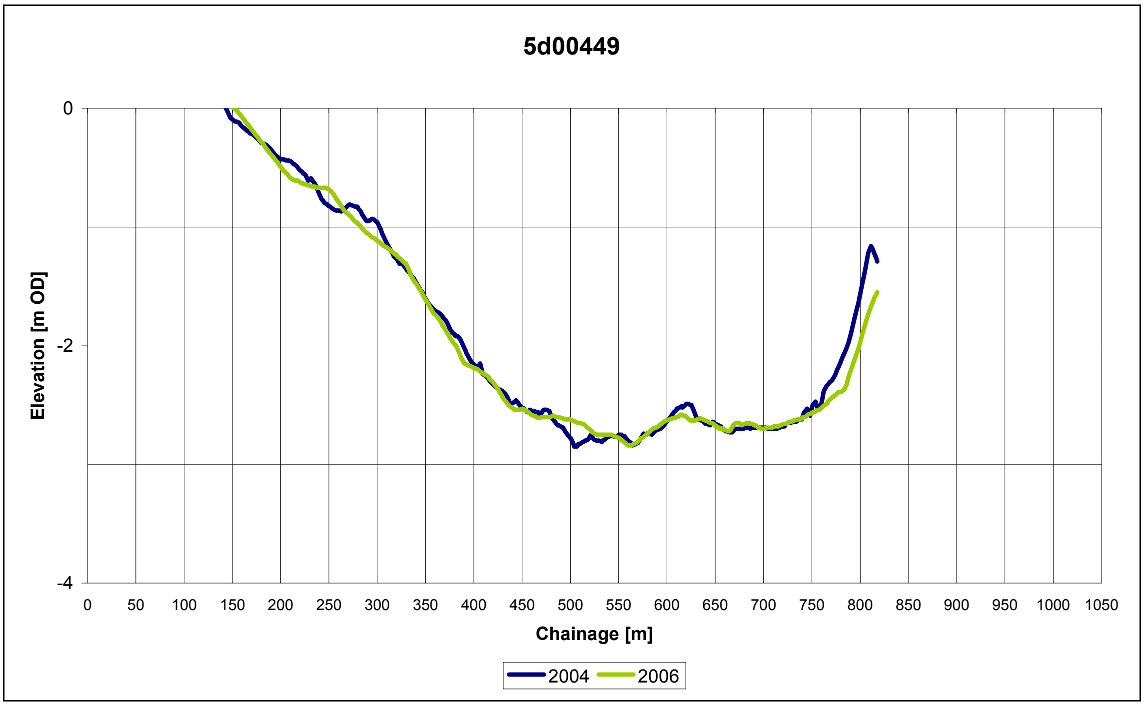
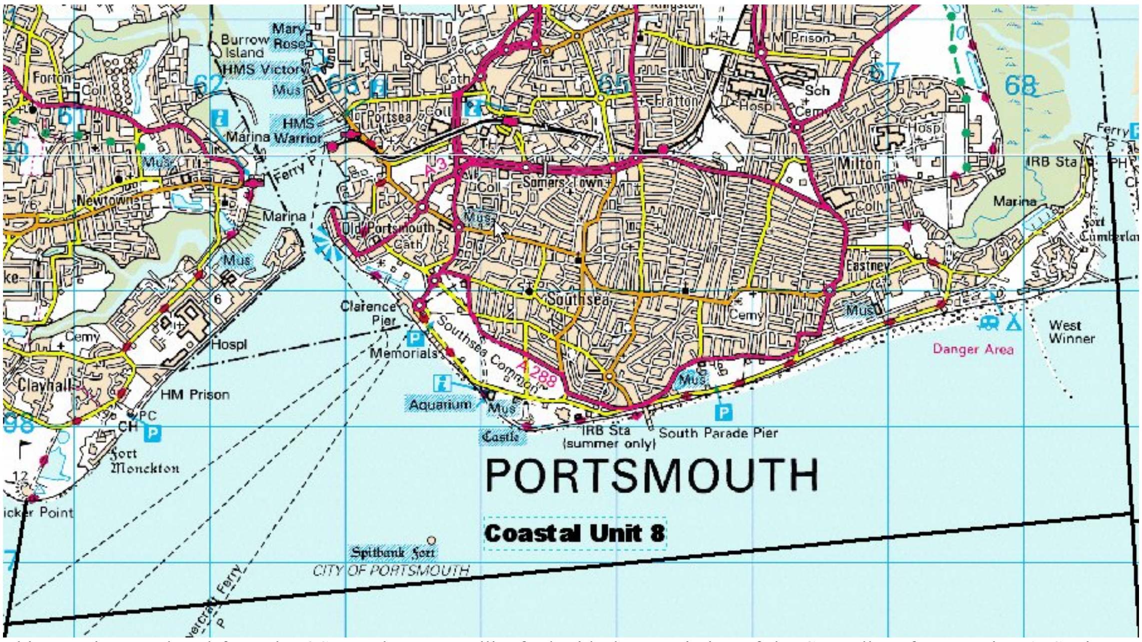


Figure 16 Profile 5d00449, Ryde Sands (Source: CCO)

2.8 COASTAL UNIT 8: GILKICKER POINT, GOSPORT TO EASTNEY, PORTSMOUTH



2.8.1 Description of the coastline

This low-lying coastline bordering the East Solent is essentially a series of barrier islands separated by shallow lagoons (Figure 1 and Map 1). These islands are formed of river deposits (sand and gravels) that were pushed northwards by wave action as sea level rose following the last period of glaciation. Wave action at the ends of each barrier island caused “recurves” to develop, so that the harbours entrances are typically bounded by sand and shingle spits, which extend northwards into the harbours. The land behind these spits is predominantly former marshland, at or below sea level.

The shingle foreland (Map 2) at Gilkicker Point has probably developed as a result of a balance between waves generated in the West Solent and those passing in through the Eastern Solent. Some erosion has taken place at Gilkicker in recent years and the shingle beaches to the east of it are protected by a short length of seawall and groynes (Map 3). Seawalls extend eastwards into the mouth of Portsmouth Harbour, effectively enveloping the shingle ridge that was once there. There is now very little beach, even at low water along the Haslar frontage and hence littoral drift is very small.

Portsea Island, on which Portsmouth is sited, is heavily developed and the greater part is protected by seawalls (Map 3). Ancient masonry walls at the mouth of Portsmouth Harbour have their toe submerged for most of the tidal cycle. The net littoral drift is in a net westward direction but the volume of material transported is small (Map 2). Further eastwards and extending to Southsea Castle there is a narrow sand and shingle beach, with little contemporary sediment input from alongshore and which therefore has a tendency to erode (Plate 17 and Map 3).

Plate 17 Southsea (2006)

Southsea Castle itself is on promontory and separates the Southsea beaches from those to the east. To the east of Southsea Castle, there is a wide, sand and pebble beach that extends eastwards to the entrance to Langstone Harbour (Plate 18). Littoral drift is predominantly westward, with periods of reversal (Map 2). At Eastney there is a drift divide (Map 2), and material is also being transported onshore periodically in this area from an ebb delta shoal.

A narrow pebble spit called Eastney Spit extends from Fort Cumberland into Langstone Harbour. It undergoes periodic erosion and is partly protected by gabion baskets, timber breastworks and groynes. It is very steep and would be vulnerable to breaching, were it not for the mild wave climate.

2.8.2 Sediment transport

The longer duration of the flood tide encourages a net input of suspended sediments into Portsmouth and Langstone Harbours, while the greater flow speeds on the ebb tide are responsible for flushing coarse sediments seawards. As a result there are submerged spits / ebb deltas that contain a mixture of sand and pebbles to the seaward of both harbour entrances.

There is insufficient wave action at the entrance to Portsmouth Harbour to drive coarse sediments ashore from the nearshore ebb-delta. However, at Langstone Harbour, there is an intermittent onshore feed of sand and pebbles from the West Winner shoal (part of the ebb delta system). The sediments are driven onshore by wave action.

Plate 18 Eastney (1992)

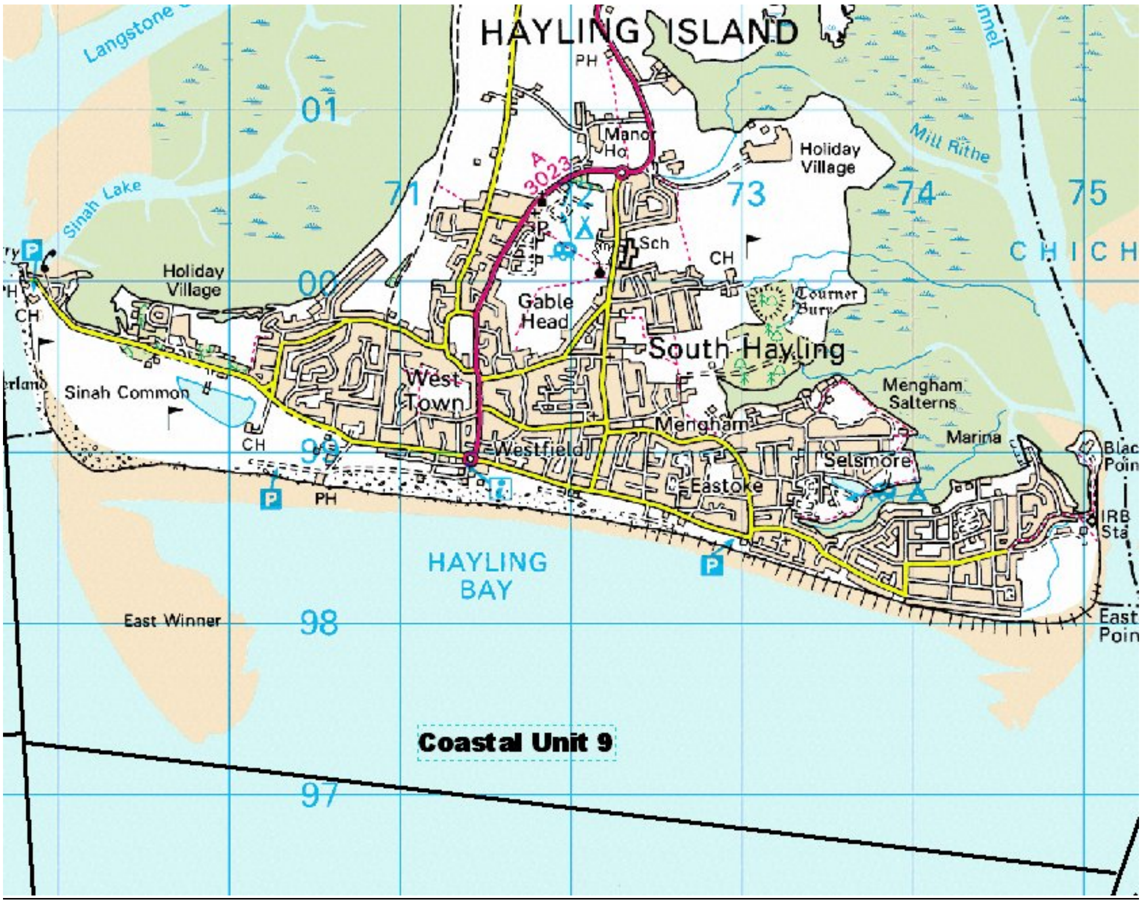
2.8.3 Beach toe limit

It was not possible to obtain topographic survey data obtained for this coastal unit. Therefore, it has not been possible to determine where toe of beach appears to intersect the seabed.

2.8.4 Coastal vulnerability

Eastney Spit undergoes periodic erosion, is very steep and would be vulnerable to breaching, were it not for the mild wave climate. The narrow sand and shingle beach around Southsea Castle has little contemporary sediment input from alongshore and has a tendency to erode.

2.9 COASTAL UNIT 9: HAYLING ISLAND



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2.9.1 Description of the coastline

Hayling Island is essentially a gravel barrier island (Map 2) that was formed of river deposits, pushed northwards / landwards by wave action, as sea level rose following the last period of glaciation. Wave action at the ends of the island has caused "recurves" to develop, which extend northwards into Langstone and Chichester Harbours. The land behind these spits is predominantly former marshland, so that much of the land behind the barrier beaches is at or below sea level. Along the main frontage of Hayling Island the net littoral drift is westward (Map 2). As material has accumulated in the west so the shoreline has tended to retreat in the east, putting shorefront properties at Eastoke at risk of erosion and coastal flooding.

At the western end of the island is the sand and shingle foreland called Gunner Point (Plate 19). Sediment tends to be transported there by the westward littoral drift along the island frontage (Map 2). From here sediment is pushed along the spit into the harbour mouth. Some material is also transported offshore by the rapid ebb tidal currents onto the ebb delta off the entrance to Langstone Harbour. Some of this material is "recycled" back onshore via an anticlockwise circulation around the East Winner shoal that is part of the ebb delta. It is thought that some material is also transported westwards onto the West Winner shoal and then onto the Eastney frontage.

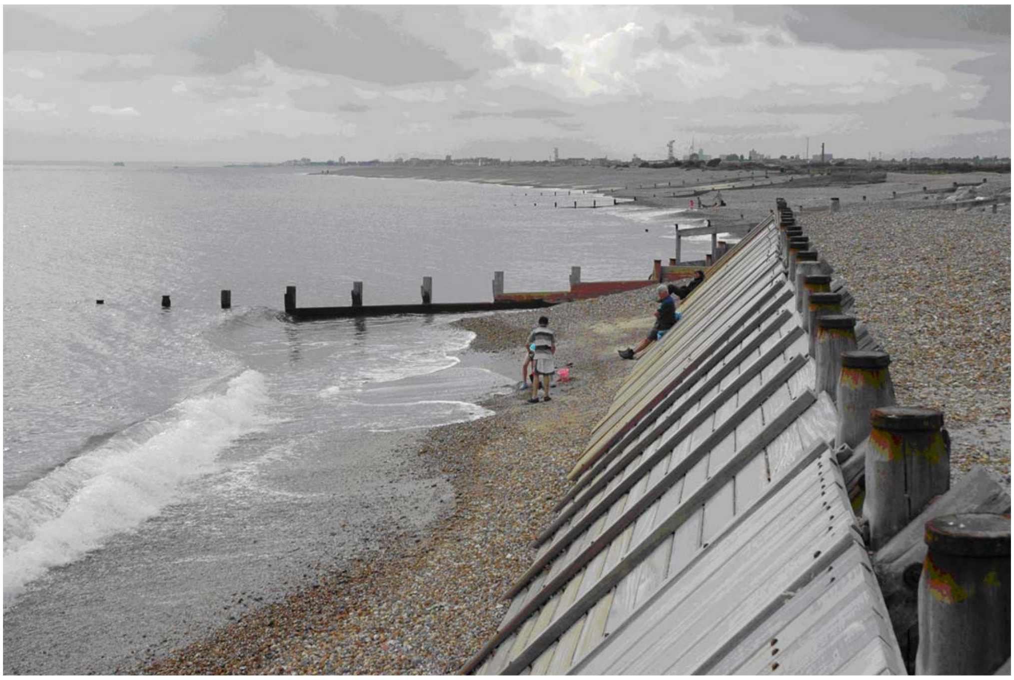


Plate 19 Looking towards Gunner Point (2007)

To the east of Gunner Point there is a short frontage that is groyned. However, phases of accretion occur, so that the groynes constructed to control erosion, are sometimes "landlocked".

There is a length of timber revetment and groynes protecting the shoreline immediately east of the "Inn on the Beach", as shown in Plate 19. There is then a length of unprotected shoreline over the central frontage, with a wide pebble beach overlying a sandy foreshore that is only exposed at low tide. Towards the east there is another timber revetment and groynes, again constructed to reduce shoreline recession west (downdrift) of the Eastoke seawall.

Shorefront development is concentrated at Eastoke, in the eastern part of the island. Here seawalls and groyne systems have been utilised since the 1930s to maintain beach levels and minimise wave overtopping. With the tendency for shoreline retreat, the beach levels in front of the Eastoke wall continued to fall and in 1985 a major nourishment scheme, using 520,000m^3 of marine aggregate was carried out, material being dropped by split-bottomed barges on the low water mark and bulldozed landwards. This has been followed up by minor renourishment and a regular programme of shingle recycling from areas of accretion (Plate 20). The wide beach that is being maintained by nourishment / recycling has reduced the flood risk. It has also protected the old seawalls, extending their useful life.

Whilst the western half of Hayling Island is partly sheltered, the eastern end is exposed to swell wave action from the south-west. The drift divide at Eastoke has also tended to accelerate beach lowering there. It has therefore been necessary to recycle material that is transported eastwards and settles out at Eastoke Point, before it is lost into the mouth of Chichester Harbour. Using regular recycling the Council has been able to retain a substantial beach in front of the Eastoke seawall (compare the typical beach conditions in 2005, as shown in Plate 20, with those in 1985, as shown in Plate 21).

Plate 20 Eastoke beach maintained by recycling (2005)

Plate 21 Eastoke beach (1985)

The shingle beach extends to Eastoke Point and some is then transported northwards along the sand and shingle spit to Black Point. This frontage has been vulnerable to changes in sediment supply and has had periods of both severe erosion and accretion. This has posed major management problems; too much accretion results in material being pushed into Chichester Harbour entrance and thereby hindering navigation and too much erosion means the threat of breaching, either at Eastoke Point itself, or along the spit that extends to Black Point.

In 1990 there was a period of intense erosion and the shingle ridge around Eastoke Point was nearly breached. Therefore, shortly afterwards, a rock revetment and rock groynes were constructed to maintain beach width and reduce the possibility of future breaching.

2.9.2 Sediment transport

Ebb tidal deltas at the mouths of Chichester and Langstone Harbour have an important influence on the coastal processes. Because of the rapid ebb flows (reaching 3m/s) both sand and shingle are transported offshore onto these deltas. The ebb-deltas provide a route by which coarse sediments are transferred from the Selsey peninsula to Hayling Island and from Hayling Island to Portsea Island.

Chichester Harbour has a larger intertidal volume than Langstone Harbour and is also more exposed to wave action. The ebb delta at Chichester Harbour is thus larger and extends further offshore than the one off Langstone. There is a feed of sediment from Selsey onto this delta. Material feeds onto the Eastoke frontage from this delta, but it is thought that some is also transported alongshore, possibly feeding the East Winner shoal at the other end of the island.

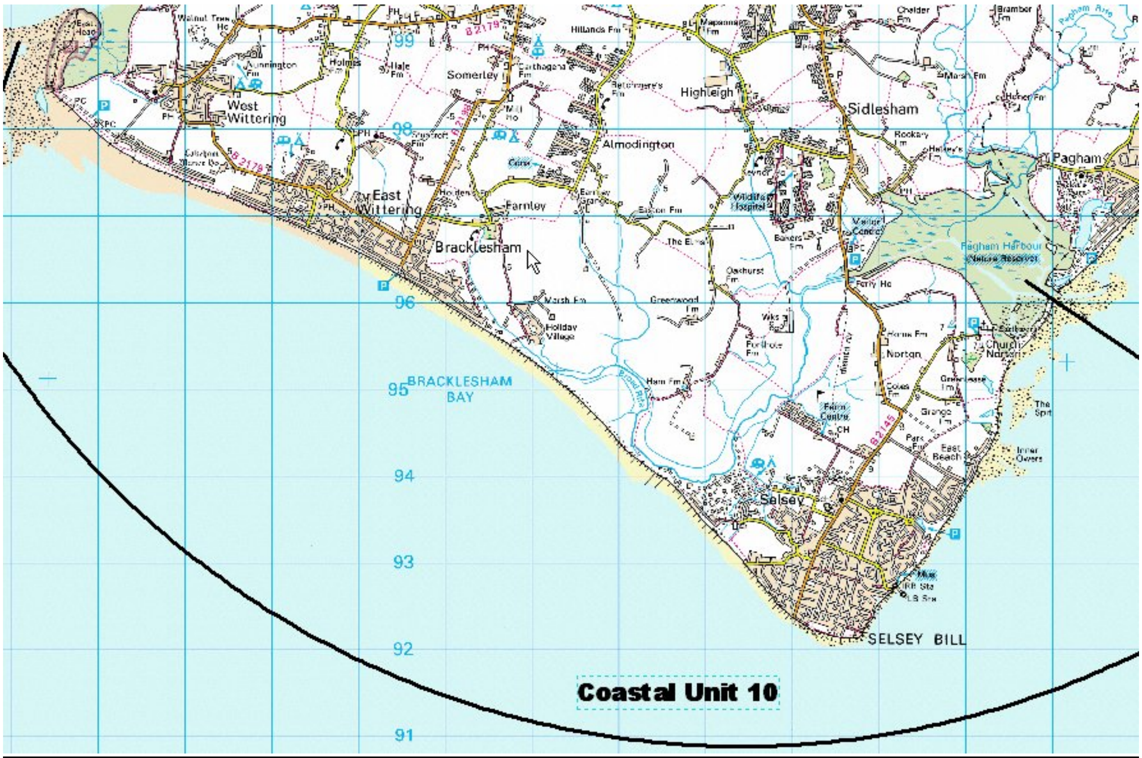
2.9.3 Beach toe limit

It was not possible to obtain topographic survey data obtained for this coastal unit. Therefore, it has not been possible to determine where toe of beach appears to intersect the seabed.

2.9.4 Coastal vulnerability

Eastoke, at the eastern end of Hayling Island suffered falling beach levels, wave overtopping and flooding of the hinterland before the trend of falling beach levels was countered by nourishment. If the present beach sediment recycling operations ceased this trend would take place again.

2.10 COASTAL UNIT 10: EAST HEAD TO PAGHAM HARBOUR



2.10.1 Description of the coastline

The Selsey peninsula owes its shape due to the sheltering effect of nearshore reefs and mobile spits that shelter it against wave action, the latter also providing an onshore sediment supply. However, it has had a history of erosion, with nearly $8ma^{-1}$ of cliff retreat having been recorded east of Selsey Bill before construction of defences in the 1940s-50s.

East Head spit, on the east side of the entrance to Chichester Harbour is actually a line of sand dunes extending northwards into the harbour (Map 1). It was once a shingle spit that stretched westward across the harbour entrance but when the supply of pebbles was reduced (due to coast protection works updrift) it dwindled and rotated clockwise. There have been problems in maintaining continuity with such a coastal alignment. The dunes are vulnerable to erosion (Plate 22). Recent breaching has resulted in the neck of the spit now being reinforced with a rock berm.

Along the open coastline to the east the low-lying coast has been defended by a mixture of revetments and seawalls at West Wittering, East Wittering and Bracklesham (Map 3). The beaches along this frontage consist of a pebble berm over flat sandy lower foreshore (Map 2). The net littoral drift along this section of the frontage is westwards and groynes are extensively used to maintain upper beach levels (Map 2). The pebble beaches undergo phases of erosion and accretion, material arriving in pulses from updrift (supply being dependant on the beach nourishment / recycling operations on the barrier beach at Medmerry. However, the underlying trend is erosion (Map 3).

Plate 22 Erosion at East Head (2005)

From Bracklesham to Medmerry the land is below sea level (Map 1) and is protected by a large barrier beach that was groyned and maintained by nourishment from inland sources. The bank has been overtopped on several occasions (Plate 23) and at the holiday camp near Medmerry there is short length of bank that is now being maintained privately-the remainder is no longer maintained by groynes and is being allowed to retreat. Judging by its past history (before it was maintained by the Water Authority) the bank is likely to be breached or overtopped at some stage in the future. The net littoral drift along this frontage is westwards but drift reversals do occur.

Plate 23 Waves overtopping Medmerry beach (2002)

The land rises to the east of Medmerry (Map 1) and the bank extends eastwards for a short distance as a shingle beach in front of low cliffs containing sands and gravels. These cliffs once extended around Selsey Bill, but now only a short length of cliff-line remains unprotected.

There is a continuous line of seawalls from just east of Medmerry to Selsey Bill itself. This frontage once had a pebble beach overlying the sandy lower foreshore. As can be seen in Plate 24, upper beach levels have fallen and the seawalls are now exposed to heavy wave action at high tide. This has led to wall failure in the recent past. The area is also a drift divide, so that beach lowering is inevitable during times when there is no onshore shingle supply.

Plate 24 Selsey West Beach (2006)

With the exception of a short length of unprotected bank at the Bill itself, which is sheltered by nearshore banks, seawalls and groynes protect low-lying land at East Beach. The beach is narrow and steep (partly due to an inshore tidal channel). However, nearshore shingle banks provide a measure of protection against southerly and easterly waves, whilst Selsey Bill and nearshore reefs provide shelter against south-westerly waves. The net littoral drift along this frontage is north-eastward (Map 2).

From East Beach to the entrance to Pagham Harbour there is a sand and shingle spit, which has required nourishment and recycling to maintain it. At present the shingle spit is fronted by a massive accumulation of shingle transported landwards from the Inner Owers. The accumulation is so large that littoral drift has caused the entrance channel to Pagham Harbour to be deflected north-eastwards (Plate 25). However, when the present accumulation becomes dispersed, the spit may require maintenance to prevent it from being breached.

Plate 25 Shingle accretion off Pagham Harbour (2007)

2.10.2 Sediment transport

The condition of the beaches on the Selsey peninsula is dependant, to a degree, on the periodic shoreward transport of shingle. Selsey Bill, by virtue of its plan shape, is a littoral drift divide (Map 2). Without a supply of material from offshore, the beaches around the Bill would have eroded faster than they have. Kirk Arrow Spit is a shingle spit, less than 0.5km offshore from the Bill. Material from this spit is periodically transported onshore and replenished from further seaward (the seabed is carpeted with shingle). The long term rate of transport of pebbles reaching Selsey Bill from offshore has been estimated as being of the order of 5,000m^3 per year.

Pebbles also periodically migrate onshore from the Inner Owers system of banks, although this appears to be a less regular occurrence than the onshore transport at the Bill itself (the Bill is more exposed to wave action).

Phases of intense onshore movement, usually during prolonged south-westerly wave action, can result in major shoreline changes. Plate 25 illustrates how the entrance to Pagham Harbour has been almost blocked by onshore transport in 2007.

2.10.3 Beach toe limit

Examinations of typical beach and nearshore seabed cross-sections have been undertaken to try and determine the toe of the beach, i.e. the point of intersection of the beach with the seabed. Survey data obtained from the Channel Coastal Observatory has been plotted for Profiles 5a00145, 5a00046 and 4d01439 in Figures 17 to 19. It is difficult to determine where the toe of the beach appears to intersect the seabed at profile 5a00145 (Figure 17), it may be at the 4.5m OD contour where the profile flattens slightly. The toe of the beach could intersect the seabed at two locations along profile 5a00046 (Figure 18). The first at 2.5m OD and the second at 6m OD, both are points where the profile slope changes. At profile 4d01439 (Figure 19), east of Selsey Bill, the first part of the profile is steep (slope of 1:15) then the beach profile flattens where it may intersect the seabed indicating that the limit of the active beach toe could be at a depth of 4m OD.

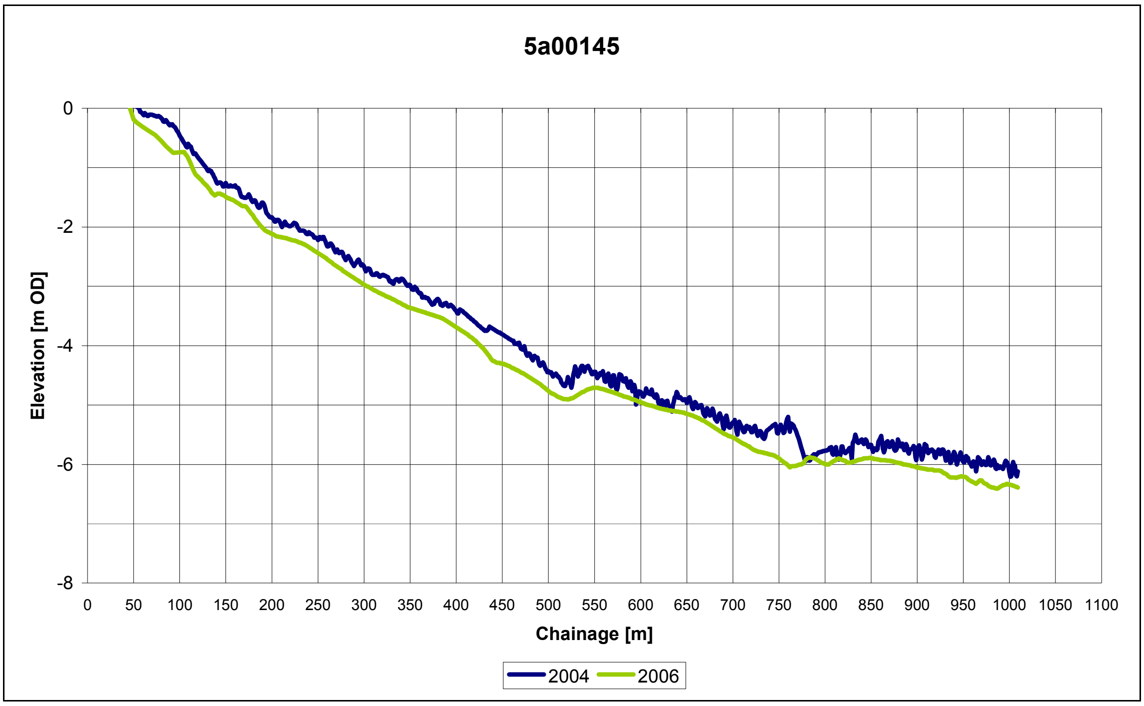


Figure 17 Profile 5a00145, Bracklesham Bay (Source: CCO)

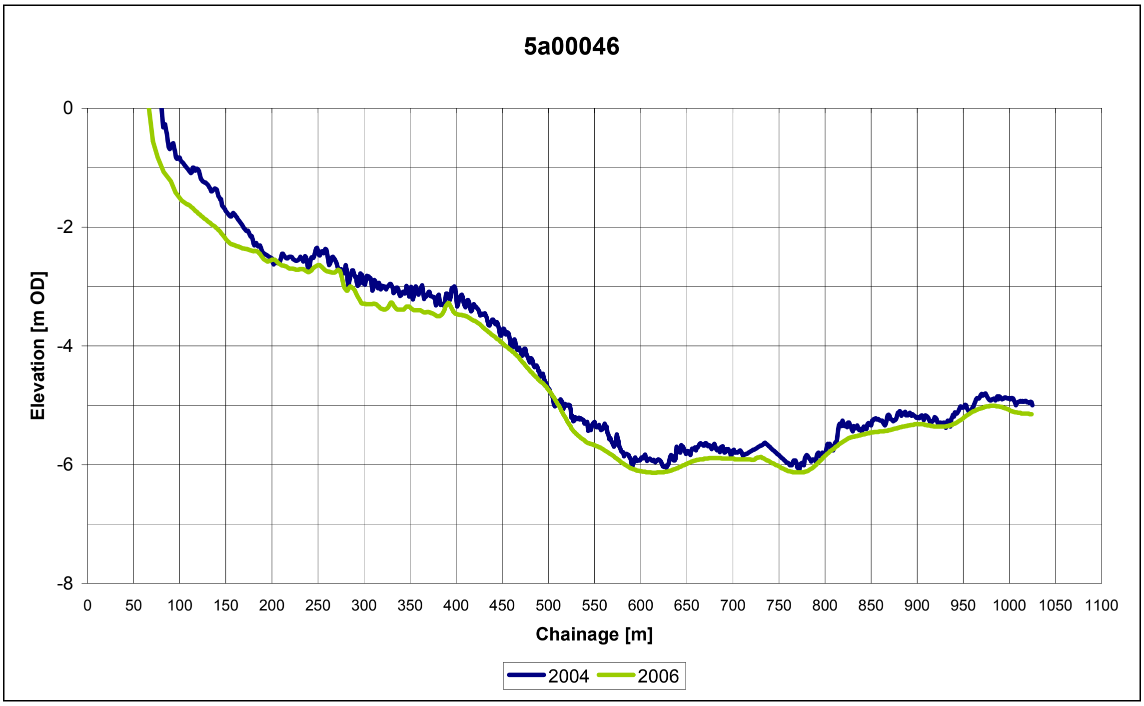


Figure 18 Profile 5a00046, west of Selsey Bill (Source: CCO)

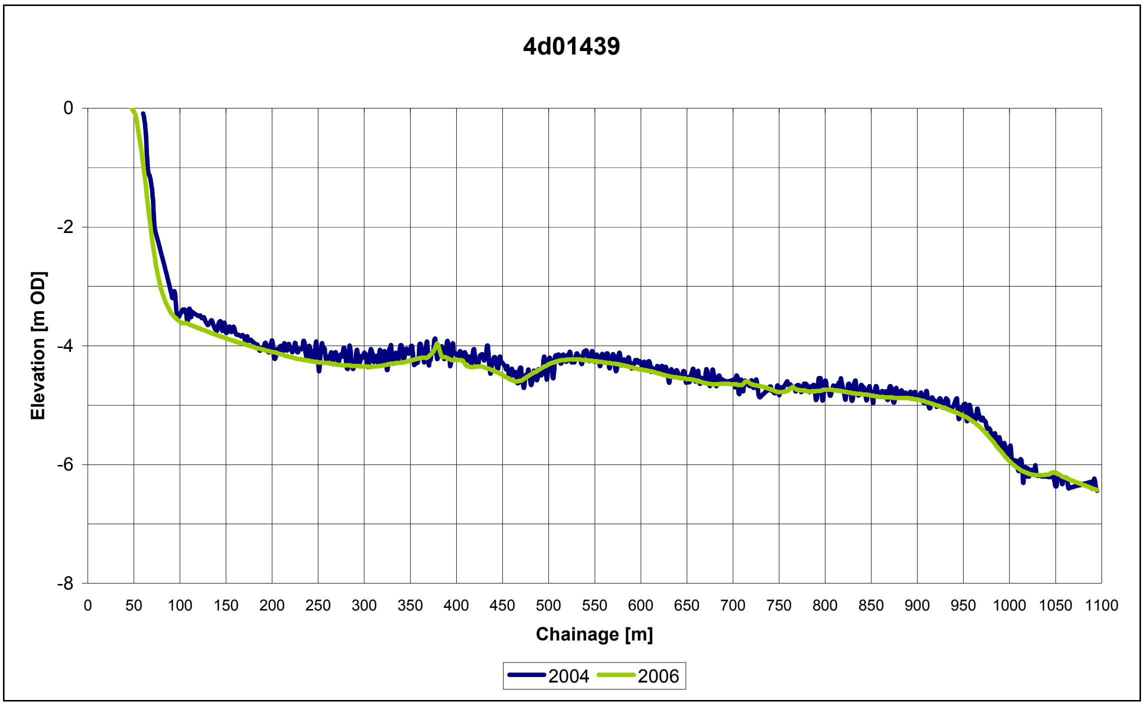


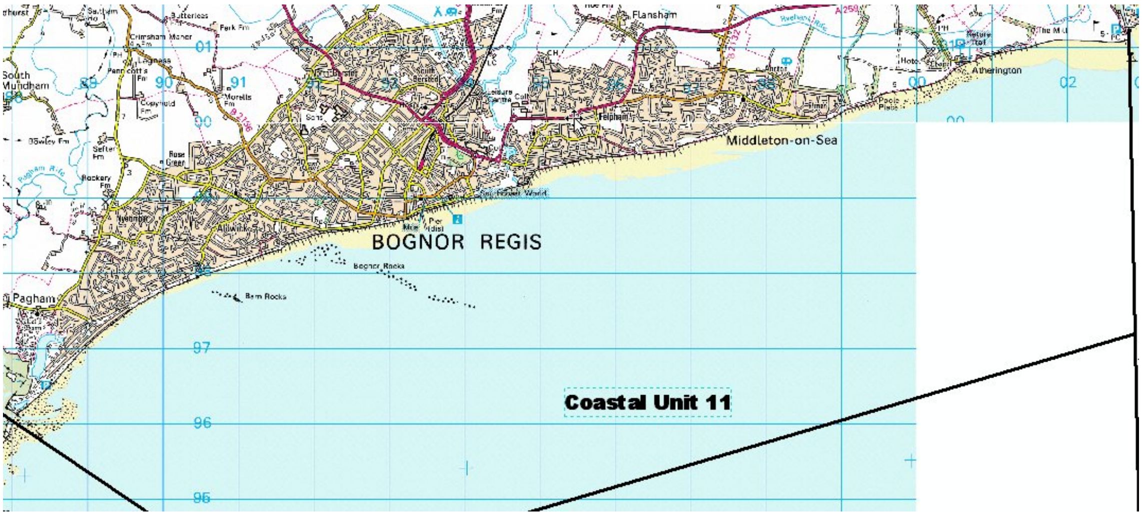
Figure 19 Profile 4d01439, east of Selsey Bill (Source: CCO)

2.10.4 Coastal vulnerability

The beaches of the Selsey peninsula have a tendency to erode, whilst large frontages are also vulnerable to flooding (Map 3). Sea defences at Selsey Bill have virtually cut off the supply of material by cliff erosion. The contemporary supply of shingle is from offshore, but this is intermittent.

The practice of beach nourishment and recycling at Medmerry has been discontinued, increasing the risk of breaching/landward migration of the barrier beach. The spit at the southern entrance to Pagham Harbour is presently “reinforced” by a wide shingle plateau, which has developed as a result of onshore shingle transport from the Inner Owers shingle banks. Once this material is dispersed the ridge will again become vulnerable to breaching/overtopping.

2.11 COASTAL UNIT 11: PAGHAM HARBOUR TO LITTLEHAMPTON



2.11.1 Description of the coastline

The Pagham to Littlehampton frontage is part of a coastal plain that is backed by the chalk hills of the South Downs (Map 1). The steep shingle “barrier beaches” overlie a flat, sandy lower foreshore that has areas of exposed bedrock in places (between Bognor and Middleton, for example). In places the beaches are backed by low-lying land that is vulnerable to flooding.

Whilst there are areas of accretion and erosion (due to variations in littoral drift) the overall trend is one of erosion and this has led to construction of groynes throughout much of the frontage (Map 3). Beach nourishment has slowed or halted this trend in places. Littoral drift is low because of the extensive groyne systems.

There is now very little input of sediment as a result of backshore erosion, as much of the frontage is now protected by seawalls. Even in the less developed areas the shingle berms protect the backshore deposits in all but the most severe storms. The major input into the system is by sediment bypassing Pagham Harbour intermittently.

Net littoral drift is eastwards with periods of reverse drift occurring in the “shadow zone” of the Pagham Harbour (Map 2). Shingle transported across the harbour entrance ultimately feeds through to Littlehampton and beyond. The drift is interrupted by discontinuities in seawall alignment with set-backs having developed east / downdrift of individual stretches of seawall, before the defences were linked by continuous seawalls. Major discontinuities in coastal plan-shape occur at Aldwick, just east of Aldingbourne Rife outfall, Hannah’s Groyne (Felpham), Middleton Point and Poole Place (Elmer). There is thought to be some offshore sediment transport at some of these discontinuities, for example at Middleton Point, where it is difficult to retain the upper shingle beach (Plate 26), which poses difficulties for beach management.

Plate 26 Middleton Point (2001)

The shingle beach at Pagham Beach Estate has developed as a result of the onshore migration of a massive shingle spit that had extended eastward across the entrance to Pagham Harbour. The spit became attached to the shoreline and was then used for shorefront housing. Recent storms have resulted in a further pulse of material being transported onshore from the Inner Owers, and a spit extending eastwards past the harbour entrance. With shingle being trapped “offshore” on this spit, the sediment supply to Pagham Beach Estate has halted. This together with the divergence of drift in this area means that the beach at Pagham Beach Estate is experiencing erosion (Plate 27).

The pebble beach narrows to the east at Aldwick where the shoreline is prevented from retreating by a massive seawall. From there eastward to Elmer the whole frontage is backed by either seawalls or timber revetments and it is only at the timber revetment at Middleton that backshore erosion is possible. Along this frontage the upper beach varies in width, tending to be narrowest at coastline discontinuities such as Aldingbourne Rife and Middleton Point. Plate 28 shows wave overtopping damage at Aldingbourne Rife due to low beach levels. The defences along this frontage were upgraded as a result of a joint management operation between the Local and Water Authority. Beach nourishment, seawall and groyne reconstruction have strengthened the defences so that seawall overtopping and damage to the rear face no longer occurs.

A similar jointly managed scheme has resulted in a series of detached, shore-parallel breakwaters being built at Elmer in 1993 (Plate 29), where erosion was causing wave action to badly overtop the seawall and breach the barrier beach to the east of it. In addition, the beaches were nourished with some 200,000m^3 of sand and gravel.
To the east of Elmer the low-lying relatively undeveloped land has been protected by intermittent stretches of seawall and groynes. The defences at Elmer reduce the littoral drift to this frontage and the beaches have been managed by recycling material from the beach built up against West Pier, Littlehampton.

Plate 27 Recent erosion at Pagham Beach Estate (May 2007)

Plate 28 Wave damage at Aldingbourne Rife (1984)

Plate 29 Elmer breakwaters (2005)

2.11.2 Sediment transport

There is intermittent onshore transport of pebbles at Pagham Harbour from the Inner Owers shoals, which bypass the harbour entrance and feed the beaches to the Pagham Beach Estate and eastward.

There are areas of mobile sands and gravels carpeting the nearshore seabed, which is very shallow and subject to multiple wave breaking. This results in coarse sediments on the seabed being transported in a net eastward direction (Map 2), enabling sediment to bypass the entrance to Littlehampton Harbour, for example.

2.11.3 Beach toe limit

Examinations of typical beach and nearshore seabed cross-sections have been undertaken to try and determine the toe of the beach, i.e. the point of intersection of the beach with the seabed. Survey data obtained from the Channel Coastal Observatory has been plotted for Profiles 4d01406 and 4d01128 in Figures 20 and 21. It is difficult to ascertain where the toe of the beach meets the seabed at profile 4d01406 (Figure 20) from the available data. A simple calculation of the slope (and the changes in slopes) at profile 4d01128, shown in Figure 21, reveals that the toe of the beach appears to intersect the seabed around the -4m OD contour. Seaward of this contour the profile exhibits a flatter slope which could indicate a rocky seabed

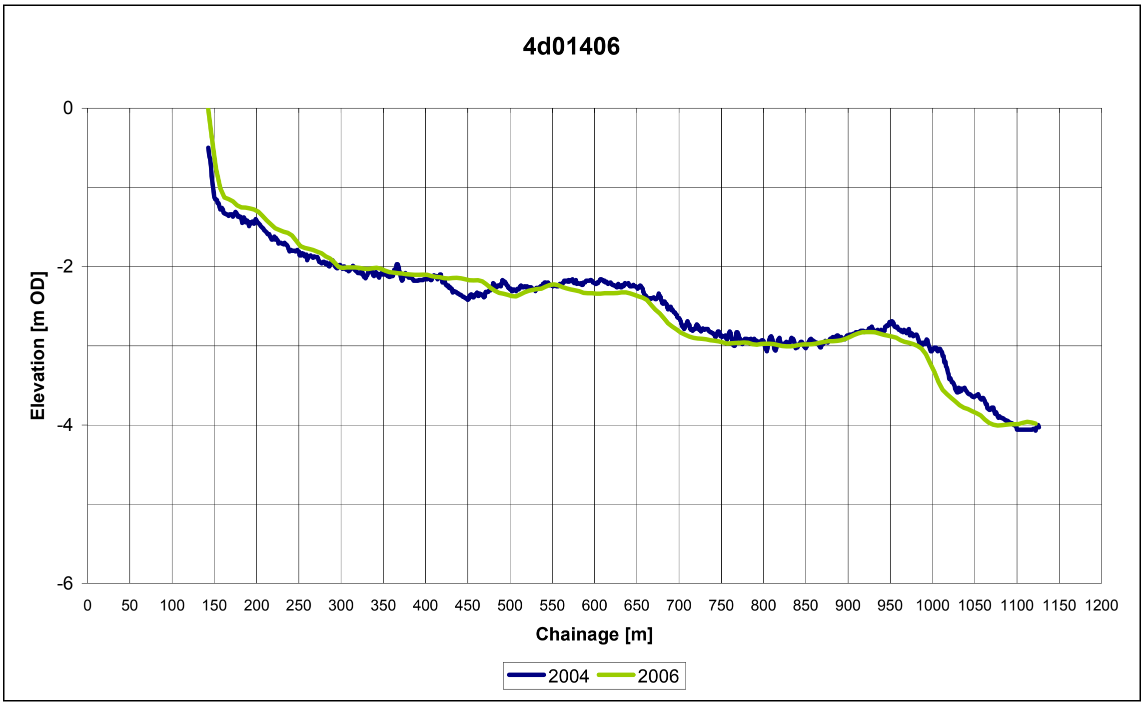


Figure 20 Profile 4d01406, close to Pagham Harbour entrance (Source: CCO)

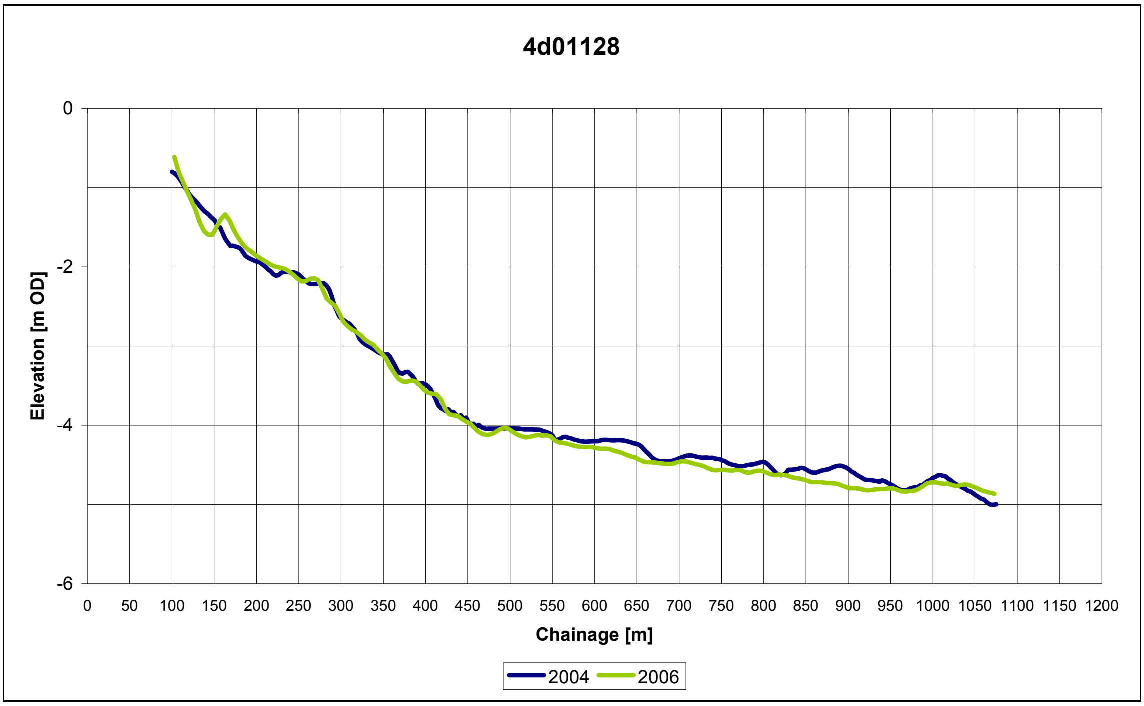


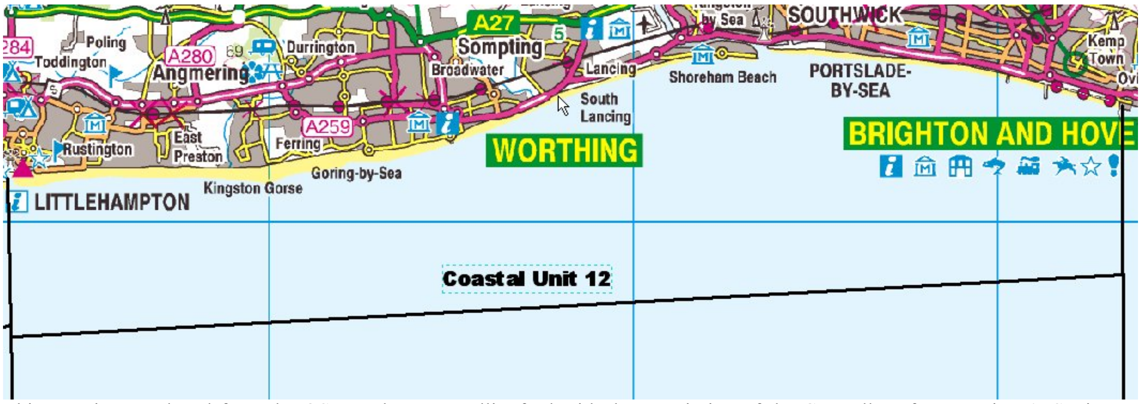
Figure 21 Profile 4d01128, between Bognor Regis and Littlehampton (Source: CCO)

2.11.4 Coastal vulnerability

The barrier beaches along this frontage are narrow due to erosion and are vulnerable to breaching (Map 3). This could result in flooding of the hinterland, particularly at Elmer and Atherington.

There is the potential for serious erosion downdrift of a number of setbacks in coastal alignment, notably at Felpham, directly east of the Aldingbourne Rife and at Middleton Point.

2.12 COASTAL UNIT 12: LITTLEHAMPTON TO BRIGHTON



2.12.1 Description of the coastline

The steep pebble “barrier beaches” between Littlehampton and Portslade overlie a flat, sandy lower foreshore (Map 2). Because of the wave exposure and the narrowness of the upper beach, the land behind is vulnerable to flooding in some areas (e.g. Lancing and Goring-on-Sea). There are seawalls in the most developed frontages and revetments in the less populated areas, with only short stretches of coastline where the backshore is unprotected. The whole region is groyned with the exception of a short length of accreting beach west of Shoreham Harbour, where the shingle drift is blocked by the harbour arms. Littoral drift, which is eastwards, is therefore low (Map 2).

The underlying long-term change is erosion (Map 3) and beach nourishment has been carried out in several areas. At vulnerable points, rock berms have been used to reinforce the beach crest (Plate 30).

The training walls at Littlehampton Harbour only partially intercept littoral drift and sediments not only settle out in the entrance channel, from which they are periodically dredged, but also bypass the harbour to feed the beaches immediately eastward. Littlehampton’s East Beach is largely sandy as a result.

From Littlehampton to Rustington, seawalls protect the coast road. The pebble content of the upper beach increases quickly eastwards. Beyond Rustington and as far east as Worthing the beaches are backed by seawalls in heavily developed frontages, with timber revetments or rock berms in less populated areas. There are also a few short stretches where there is no backshore protection. Beach nourishment has been carried out on a small scale in several areas (e.g. at Rustington, Ferring-Worthing).

At Worthing the seawalls have been overtopped by wave action during particularly severe storms and rock berms have been added at critical points to reinforce the beach crest (Plate 30).

Plate 30 Beach armoured with rock at Worthing (1997)

To the east of Worthing at Brooklands the coast road runs very close to the shore and this is an area that is vulnerable to flooding. Further eastward to Lancing there is a barrier beach and at the Widewater Lagoon there is housing that would be flooded if the shingle barrier beach was breached. This frontage has therefore been nourished on two occasions and rock groynes have replaced the timber ones in the recent past (Plate 31). The short length of seawall opposite the Widewater Lagoon is now fronted by a wide pebble ridge.

Plate 31 Nourished beach at South Lancing (2005)

The beach east of Lancing was once part of a massive shore parallel spit that deflected the mouth of the river Adur eastwards as far as Portslade-by-Sea. When the river entrance was stabilised at its present location, the old river channel was utilised to develop the dock system. As the harbour arms were enlarged and extended seawards, so more of the littoral drift became intercepted and from then on the pattern has been of updrift accretion at West Beach and downdrift erosion at East Beach. The West Beach has been used by the Port Authority to nourish the East Beach by mechanical bypassing, involving an average transfer of about 8,000m^3 of pebbles. This has not only benefited East Beach but the downdrift beaches eastwards to Brighton. The rate of bypassing has been monitored and has been maintained at approximately half the rate of accretion at the West Beach, thus avoiding unwelcome impacts on the Lancing frontage.

The East Beach is now protected by a sloping revetment of concrete armour units, whilst further eastward there are sheet piled walls and old timber revetments. At Portslade the defences are piecemeal and there are several shorefront properties at risk of wave damage (Plate 32).

Beyond Portslade, the frontage as far eastward as Brighton Marina is protected by seawalls and massive groynes. This frontage, extending eastward to Brighton Marina has pebble beaches overlying a narrow sandy lower foreshore (Map 2). Whilst the long-term trend is erosion (Map 3), currently these beaches appear to be quite healthy.

The beach width increases near Brighton Marina as a result of the net eastward littoral drift (Map 2).

Plate 32 Portslade-by-Sea (2005)

2.12.2 Sediment transport

There are areas of mobile sands and gravels carpeting the nearshore seabed off Bognor - Littlehampton, which is very shallow and subject to multiple wave breaking. This results in sediments on the seabed being transported in a net eastward direction (Map 2), enabling sediment to bypass the entrance to Littlehampton Harbour. Tidal flushing has created an ebb delta off Littlehampton Harbour that forms a transport route for sediments to bypass the harbour mouth and that can then be transported onshore (the seabed immediately east of the harbour entrance is very shallow). Shoaling in the entrance channel has necessitated maintenance dredging.

Whilst there is thought to be an eastward transport of sand and shingle off Bognor-Littlehampton there is insufficient information to determine whether this is part of a continuous transport pathway or not. SCOPAC reports indicate that surveys by the British Geological Survey reveal the presence of sandwaves off Shoreham and Brighton, whose cross-sectional profiles indicate a net eastward potential transport.

2.12.3 Beach toe limit

Examinations of typical beach and nearshore seabed cross-sections have been undertaken to try and determine the toe of the beach, i.e. the point of intersection of the beach with the seabed. Survey data obtained from the Channel Coastal Observatory has been plotted for Profiles 4d00745, 4d00600 and 4d00476 in Figures 22 to 24. A simple calculation of the slopes (and the changes in slopes) reveals that the toe of the beach appears to intersect the seabed around the -6m OD contour for profiles 4d00745 and 4d00600. Seaward of this contour, at profiles 4d00745 and 4d00600 (Figures 22 and 23), the profiles flatten. It is difficult to ascertain where the toe of the beach intersects the seabed at profile 4d00476 (Figure 24) from the available data.

2.12.4 Coastal vulnerability

The beaches along this frontage are steep and narrow and where the hinterland is low-lying there is the potential for flooding (e.g. Ferring, Goring-by-Sea, Brooklands and Lancing. There is also the risk of serious erosion to the east of Shoreham Harbour, as well as at the short length of lightly defended frontage at Portslade-by-Sea.

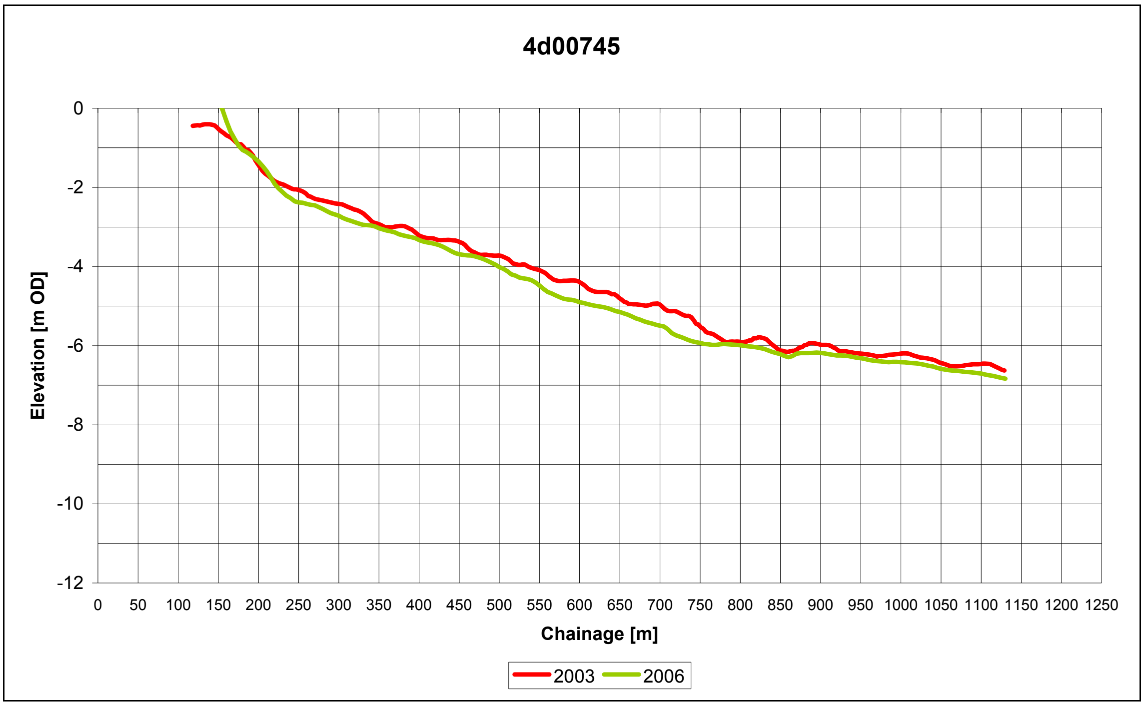


Figure 22 Profile 4d00745, South Lancing (Source: CCO)

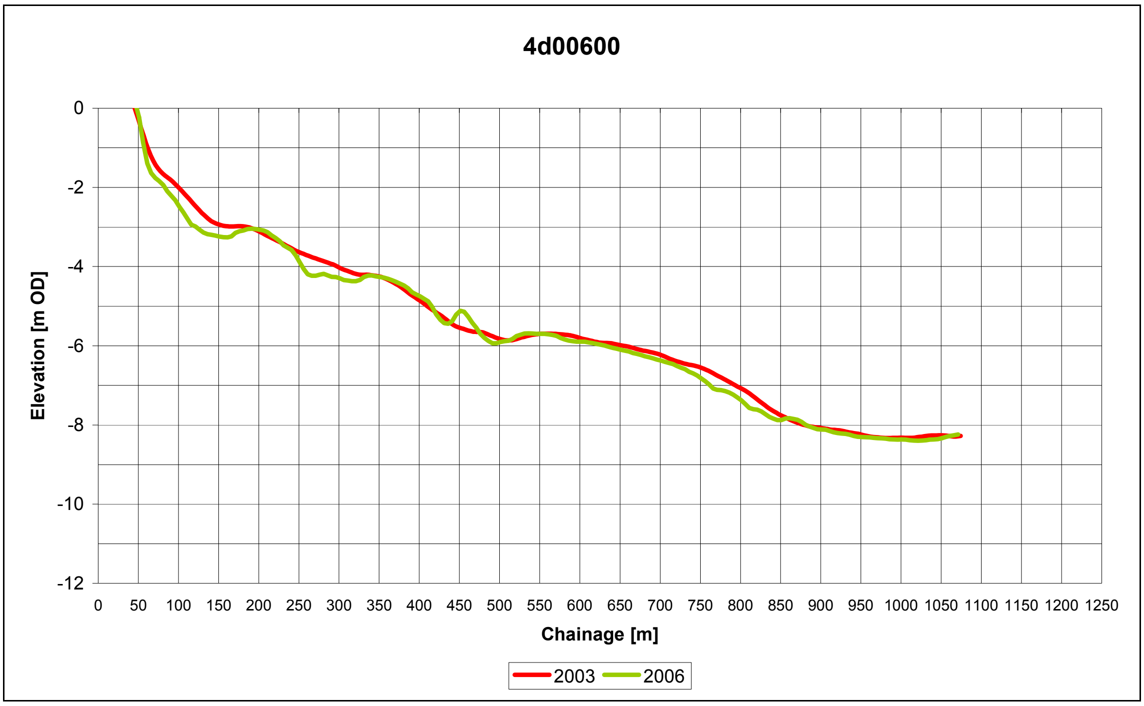


Figure 23 Profile 4d00600, Portslade-by-Sea(Source: CCO)

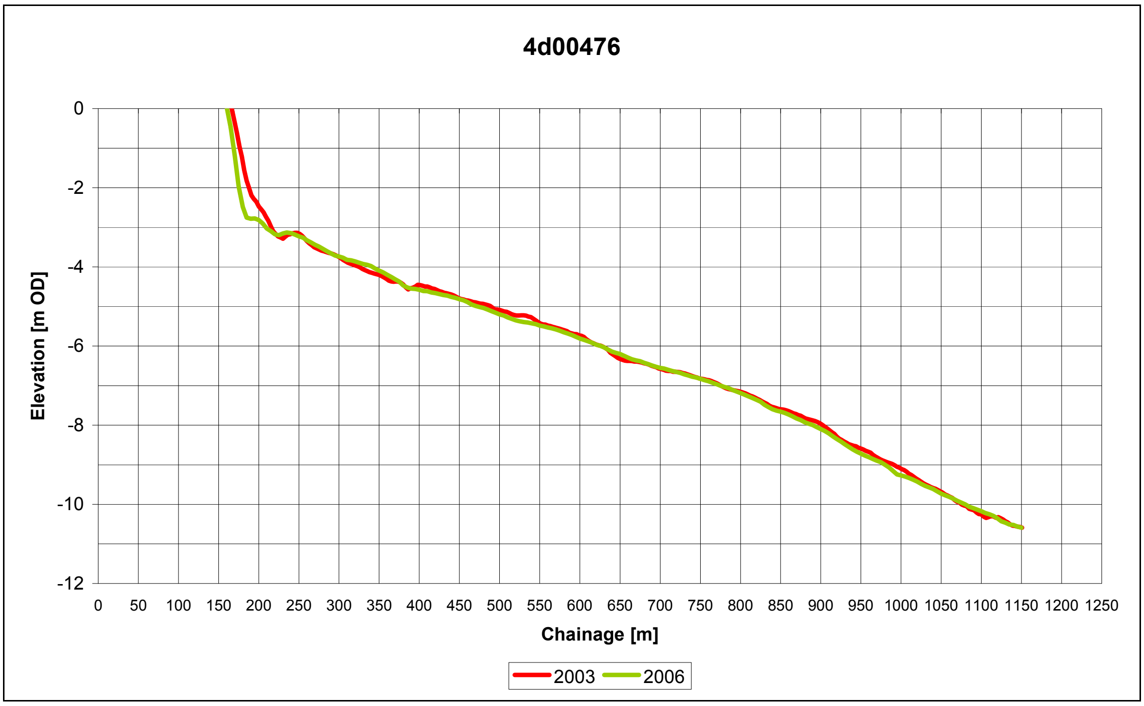


Figure 24 Profile 4d00476, between Brighton Pier and Brighton Marina (Source: CCO)

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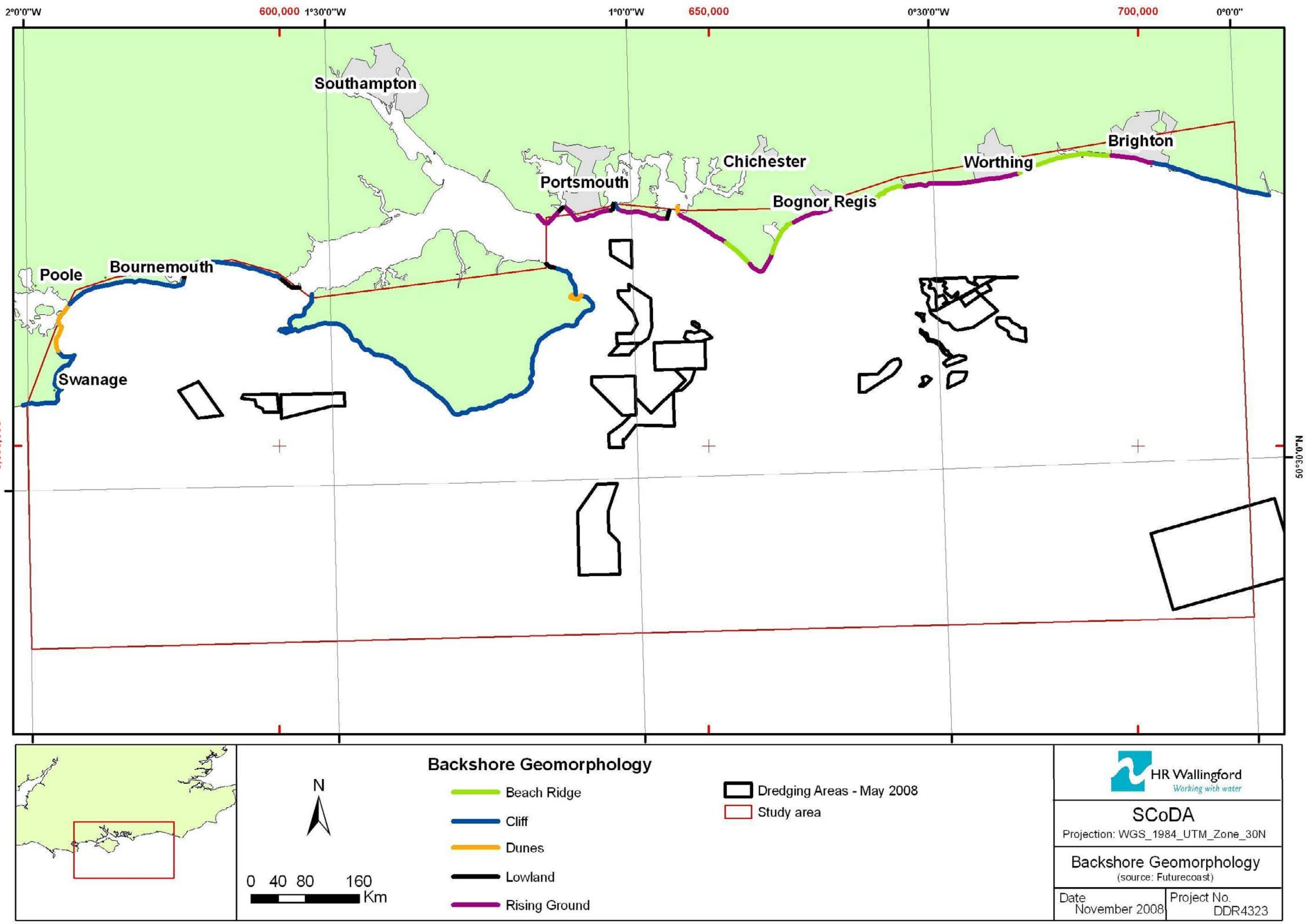
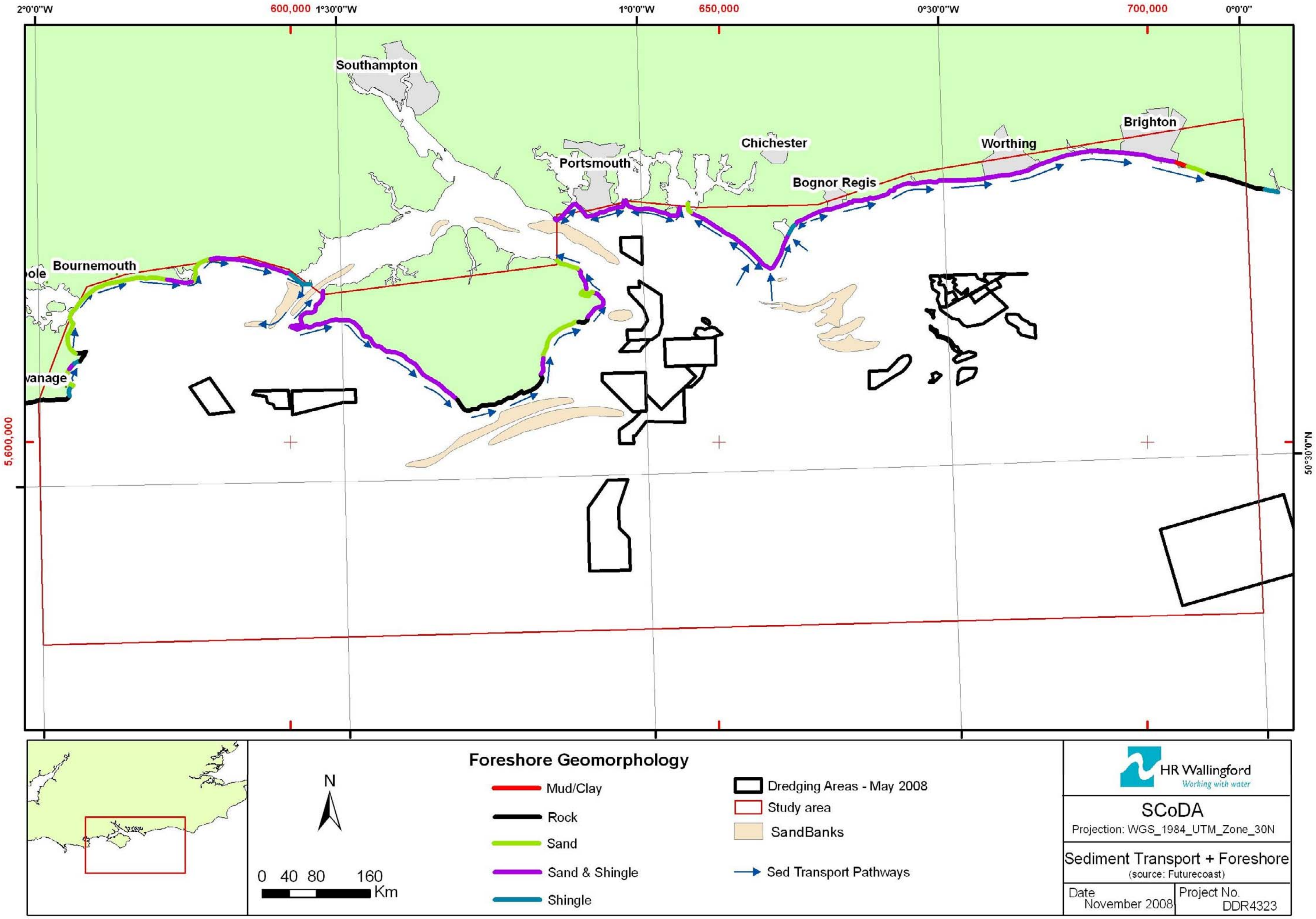
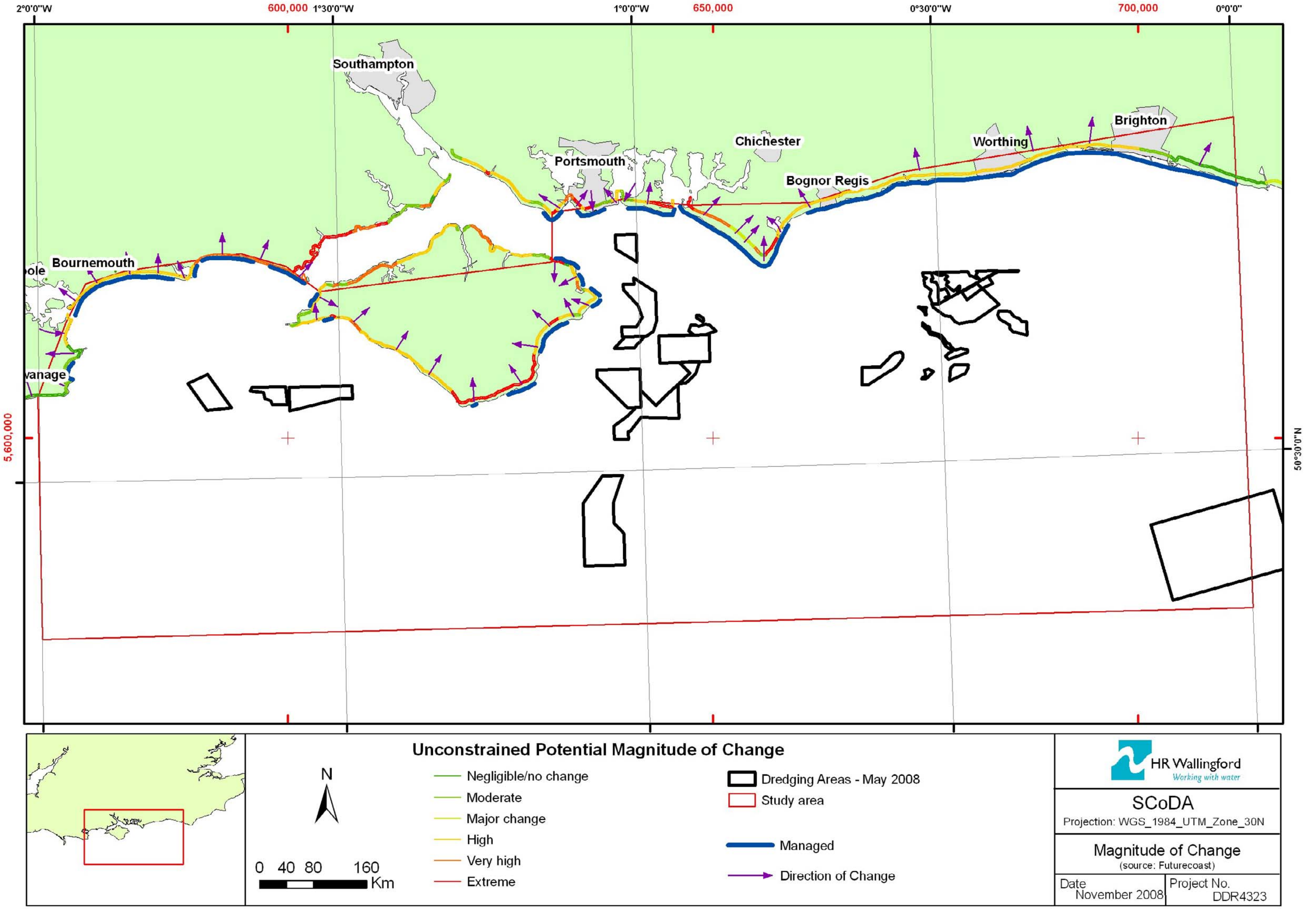


Map 1: ***Backshore geomorphology and managed coastline***



Map 2: Foreshore geomorphology and sediment transport pathways



Map 3: ***Unconstrained potential magnitude of change***