HR Wallingford

A MACRO REVIEW OF THE COASTLINE OF ENGLAND AND WALES

Volume 5. The South Coast. Selsey Bill to Portland Bill

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ABSTRACT

This report reviews the coastline between Selsey Bill and Portland Bill on the south coast of England. In it are described the various natural and man-made processes which affect the behaviour of this particular stretch of Britain's shoreline. The report includes a description of the major coastal defences, areas of erosion and accretion and various other aspects of beach development. Stretches of coastline which for coastal engineering purposes can be treated as independent or semi-dependent cells are also identified.

This is the fifth report of a series, which Hydraulics Research are carrying out for the Ministry of Agriculture, Fisheries and Food. It was written by Mr J Welsby and Mr J M Motyka of the Coastal Processes Section of the Maritime Engineering Department, Hydraulics Research Limited, who should be contacted for further information.

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1 INTRODUCTION

In 1985, the Ministry of Agriculture, Fisheries and Food commissioned Hydraulics Research, Wallingford to carry out a review of the coastline of England and Wales. The principal aim of this review is to provide information on various factors affecting the development of the coastline, including the physical processes, any coastal defences which may affect these processes, as well as natural factors such as the coastal geology, geomorphology, winds, waves and tidal action. Also included is a bibliography containing details of reports, studies and papers describing this particular coastline.

In this review the coastline of England and Wales has been sub-divided into regions, with each major region being covered by a separate report. The present report is Volume 5 of the series, and covers the central southern region of the British coastline, from Selsey Bill to Portland Bill.

One of the fundamental objectives of this review is to identify those stretches of coast which can be treated, from a coast protection viewpoint, as individual units or cells. Such cells are judged to be self contained in those areas where it is found that beach or nearshore changes within a particular cell have no significant effect on processes taking place in adjoining cells. In certain areas (such as the West Solent) consideration also has to be given to the offshore boundaries of such cells, if one such cell is believed to feed material to other areas of the coastline. Identification of littoral cells is intended to help planners determine the length of coastline likely to be affected by coastal works in any particular area.

It is hoped that this type of 'overview' will assist in the understanding of the coastal system as a whole and may lead to a more unified approach to the planning of coastal defences.

Throughout these reviews the phrase 'Schedule 4 boundary' is often used. This is a term from the 'Coast Protection Act of 1949' which defines the boundary, chiefly on rivers and estuaries, upstream of which the Act ceases to apply. It is used here for convenience to establish a cut off point with regard to coast protection.

Briefly the Coast Protection Act establishes relevant maritime authorities as the 'coast protection authority' giving them general powers to carry out coast protection work within their specified boundaries. The other relevant Act of Parliament is the 'Land Drainage Act of 1976'. This deals (among other things) with the prevention of flooding by the sea, ie 'sea defence', and is usually the responsibility of regional Water Authorities.

The major points derived from this review are summarised in Chapter 2 and the more important coastal features also highlighted. Chapter 3 describes the geology and recent coastal evolution. General information on winds, waves, tides and tidal currents is given in Chapter 4. The main body of the report is contained in Chapter 5, which describes the coastal defences and their effect on coastal processes.

2 EXECUTIVE SUMMARY

This report reviews the coastal regime of central southern England, from Selsey Bill in West Sussex, the whole of the Hampshire coastline, the Isle of Wight, and westwards to Portland Bill in Dorset.

2.1 The mainland

The predominantly low lying coastal strip at the eastern end of this region is very varied with regard to the density of development. It includes large stretches of unprotected coastline in Langstone and Chichester harbours and along much of the coastline from the Solent westwards to Hurst Castle Spit and also part of the fringe of both Christchurch and Poole Bays. There are also almost totally undeveloped stretches of cliffed coast at the western end, stretching from the Isle of Purbeck to Portland Bill. By contrast there are highly developed areas in Southampton Water and Portsea and the seaside resorts of Selsey, Hayling Island, Southsea, Bournemouth, Swanage and Weymouth.

The coastline from Selsey Bill almost as far west as Lee on Solent, is low lying and consists of easily erodible brickearths and plateau gravels. The frontage between Selsey Bill and West Wittering is eroding at a rate which is giving rise to serious concern. Beach material is transported in a net westerly direction and part of it collects on a shoal called the Winner, in the entrance to Chichester Harbour. A large part of the drift is also swept offshore onto Chichester Bar by the rapid ebb flow velocities. Some of this material reaches Hayling Island via the bar which flanks the western side of the harbour entrance.

Erosion at the eastern end of Hayling Island has been a particularly serious problem, with sand and shingle transported westwards towards Gunner Point but with little replacement now taking place from the Selsey frontage. Material, mainly sand, also accumulates on the West Winner, a large bank off Gunner Point. This far westward the protection afforded by the Isle of Wight is quite pronounced and it is unlikely that there is a significant transport of material from Hayling Island, across the mouth of Langstone Harbour, to Portsea Island. Thus, from a coast protection point of view the frontage from Selsey Bill to the west end of Hayling Island can be treated as an almost independent cell. Similarly, there is little evidence of beach material being able to cross the entrance to Portsmouth Harbour, and the Island of Portsea can also be treated in isolation to adjacent coasts from the point of view of coast protection.

To the west of Portsmouth Harbour the Ministry of Defence frontage is protected by a massive seawall and the littoral zone is very narrow from Fort Blockhouse west to Gilkicker Point. The shoreline west of Gilkicker Point is increasingly more exposed to waves generated from the southwest across the Solent. It is largely unprotected except for the seawall at Lee on Solent. Cliff retreat and downdrift erosion are common problems, with the coastal defences having a 'knock on' effect on adjoining beaches. Littoral drift is generally from northwest to southeast although there is a zone of divergence just south of the River Hamble where protection is afforded from the south-westerly waves by Calshot Spit. The frontage from Portsmouth Harbour entrance, northwest to the River Hamble, can thus be considered as one coastal unit.

On the west side of Southampton Water the coastline south to Calshot can also be treated as one unit. Here the wave climate is relatively mild and changes in the tidal regime are as important as any wave induced changes. Apart from areas protected by reclaimed land at Hythe, the saltings along most of this frontage form the primary defence against the sea. Any future coastal defence works should be carried out with minimal disturbance to the vegetative cover, as this is already in a poor condition.

Much of the Western Solent shoreline from Calshot to Keyhaven is privately owned and here also saltings form am important part of the coastal defences. The saltings are now generally in a state of decline. This whole stretch needs to be treated as one coastal unit especially as the saltings have reached a critical state along the whole frontage. Erosion of the saltings in one area will allow greater wave penetration and hence lead to further saltmarsh deterioration adjacently.

Christchurch Bay to the west of the Solent is one large coastal unit, as also is the adjacent Poole Bay. The stabilisation of the cliffs at Highcliffe and Barton and at Milford have resulted in severe downdrift erosion to the east of each frontage. The entrance to Christchurch Harbour is not a sufficient barrier to prevent material from being transported eastward from Mudeford Spit towards Friars Cliff. Similarly, material continues to travel into Christchurch Bay from the west around the long breakwater at Hengistbury Head. Due in part to the protection afforded by the Isle of Wight, the nett drift in this area is mainly from west to east. There is a nett south westward drift, however, along the western part of Poole Bay from Durley Chine to Sandbanks. Wherever groynes are constructed in either Christchurch or Poole Bay, downdrift erosion problems occur along the ungroyned stretches of coast. Ideally the whole of the coastline encompassing Poole and Christchurch Bays should be considered one large inter dependent cell. Clearly changes in Poole Bay have an impact in Christchurch Bay, but due to the largely uni-directional littoral movement in these bays, the opposite is not the case.

The rocky coastline of the Isle of Purbeck and the Dorset coast as far west as Weymouth Bay is strongly indented, with no strong littoral transport of material. It is generally undeveloped. Swanage Bay is an exception and could therefore be treated as a sub unit. Coastal defence works (most of which have been built up by private owners) are on such a small scale that they have little effect on adjacent beaches and certainly do not affect the behaviour of the coastline as a whole.

Weymouth Bay at the western end of this coast is partly sheltered and shows evidence of lateral sorting of beach material. From Bowleaze to Lodmoor the beaches are fairly open to wave action. They consist of shingle overlying sand. The drift is generally west to east in the north part and north to south in the south western part of the Bay, the littoral divide appearing to be in the vicinity of Lodmoor. In the south part of the Bay wave activity is mild and only sand is transported towards the harbour entrance. Thus there is a wide sand beach fronting the town and shingle beaches to the north. Although somewhat 'open' at its eastern end, the Bay should be treated as one unit. The coastal defences within the Bay are unlikely to have any serious effect elsewhere, although the rapid erosion of the soft, unprotected cliffs could be accelerated by any major works made locally.

The Isle of Portland forms a natural littoral boundary. The Bill of Portland extends a considerable distance seawards of the general trend of the coast. The Island is generally rocky, with little likelihood of wave induced transfer of material from Chesil Beach east into Weymouth Bay and even less in the opposite direction. Currents off the Bill are rapid, and any sediment borne in suspension will not be intercepted by coastal works inshore.

2.2 The Isle of Wight

The Island has a wide range of geological strata which run in a series of bands in an east - west direction. One of the main elements is chalk, a broad band of which runs through the centre of the Island from the Needles, east to Culver Cliff. Chalk is also prominent in the south, from St Catherine's Point to Bonchurch. The soft unstable nature of much of the coastal fringe (except for the hard chalk at the Needles and Culver Cliff in the east) has led to large scale coastal problems, both in terms of beach and cliff erosion.

On the north facing coast of the Isle of Wight the land rises gently landward with low, mostly clay cliffs backing the beaches between Cowes and Yarmouth. These cliffs are intersected by a number of river valleys, through one of which runs the Newtown River. Littoral movement into the river mouth is evident from the development of the recurving spits which have grown inwards from both the east and the west shore. The spits are now in a state of decline and it is unlikely that the littoral transport of shingle and sand across the Newtown River entrance is very high. These cliffs rise to some 75m in the north west around Totland. Toe erosion, together with slippage of the cliff face, takes place along most of the unprotected frontage. The similarity of coastal defence problems indicates that the coastline from Cowes westwards to the Needles could be treated as one unit.

The south coast is more varied with cliffs of sand, limestone, clay, chalk or marl between the more low lying areas of Freshwater Bay, Ventnor, Shanklin, and Sandown.

The stretch from east of the Needles to just west of St Catherine's Point is composed of soft cliffs and rapid erosion is providing the wide foreshore platform with sand and some shingle. This part of the coast should be treated as one unit, though as yet man has made little impact on the coastal environment.

By contrast the coast from St Catherine's Point northeast to Culver Down is highly developed and this is where the majority of the coastal defences are to be found. Problems arise from the instability of the cliffs, with undercliffs being a notable feature from St Catherine's Point to Shanklin. The protection of much of the upper foreshore by means of "hard" defences has reduced the problems of cliff instability, except at Sandown Bay where the saturated sand cliffs are still liable to slippage. The coastline from St Catherine's Point to Culver Down should be treated as one littoral unit. For example there is evidence of pea shingle from erosion of the cliffs east of St Catherine's Point being transported as far as Shanklin (though the magnitude of drift is low and the transport is intermittent).

The large promontory of Culver Down and the rock ledges to seaward act effectively as a littoral barrier. The soft eroding cliffs of Foreland have similar problems as those to the north near Bembridge. There is little doubt that the transport of sand takes place over the wide foreshore at Bembridge and that the channel into the harbour entrance is by no means an effective littoral barrier. The direction of the nett littoral drift is from southeast to northwest. Littoral movement is active as far as Ryde, which appears to be a 'sink' for sand. Although the coast from Bembridge to Ryde is sub-divided by various promontories, there is nevertheless a northward transport of material over the lower foreshore. Thus the coast from Culver Down to Ryde could be considered as a large coastal unit, within which there are a number of partly-dependent cells such as Whitecliff Bay, Priory Bay etc. The foreshore at Ryde acts as a major sand trap, its development having little effect on adjacent stretches of coast, from which material is received. The eroding coastline from Ryde to Cowes forms a cell which can be treated in isolation to the rest of the north facing coast of the Isle of Wight.

3 COASTAL GEOLOGY AND TOPOGRAPHY

3.1 Geological Background

Geological structure and lithological variability have both exerted a strong influence on the morphology and the evolution of the coastline of Southern England which is of relatively recent origin on a geological time scale. The English Channel was formed after the end of the Pleistocene Ice Age (10000 years ago) as sea level rose with the melting of the ice sheets. Since this period the coastline has undergone very rapid change to its present configuration.

All the rock formations exposed at the coast are sedimentary, that is originally deposited under marine conditions, and represent a wide range of differing rock types. The rocks were laid down in the following sequence. The oldest rocks in this area are the various Jurassic clays such as the Oxford and the Kimmeridge clays (135-200m years ago). These were overlain by thick beds of limestone of the Portland and Purbeck Beds. During the following Cretaceous

Period (beginning 135m years ago) layers of sandstones and clays were covered by chalk. Finally during the Tertiary era (beginning 55m years ago) further layers of sands and clays were deposited in a shallow basin, now the Hampshire Basin. Following this but preceding the Ice Age the whole region experienced folding associated with the formation of the Alps. A series of anticlines or upfolds were formed aligned approximately east to west across southern England.

As these uplands were gradually eroded, so the older strata were exposed at the surface. Generally the youngest Tertiary rocks are from the mainland coast of Hampshire from Selsey Bill to Poole Bay and also along the north coast of the Isle of Wight. The chalk forms a spine running east-west across the Isle of Wight with Cretaceous deposits to the south. This is also exposed on the mainland west of the Isle of Wight at Swanage Bay while the older Jurassic beds are exposed on the Isles of Purbeck and Portland and in Weymouth Bay.

Although no part of this coastline was directly affected by the massive ice sheets that covered Britain north of the Thames, changes that took place during and after the Ice Age have played a major role in the development of the present coastline. At the end of the Ice Age, Britain was joined to Continental Europe and the coastline was further to the west, probably in a position between Cornwall and Brittany. Sea level was about 100m lower than present day levels. The Channel was occupied by a large river system draining westwards, combining the Seine and the Solent and may have included the outflow of the Thames and the Rhine at times when the ice blocked the North Sea.

The final retreat and melting of the ice sheets resulted in an overall global rise in sea level. The sea slowly advanced up the Channel and eventually through the Straits of Dover, causing separation from the Continent about 8600 years ago. Coastal recession proceeded rapidly and river valleys and low-lying areas were submerged. Gradually the valley of the River Solent and its tributaries became flooded leaving a narrow barrier of chalk running from the Isle of Purbeck across Poole Bay to the Isle of Wight. Eventually the sea breached this barrier and the Isle of Wight was separated from the mainland by the wide tidal channels of the East and West Solent. The submerged river valleys tributary to the Solent became large tidal inlets such as Poole, Portsmouth and Chichester Harbours and are now infilled with deep thicknesses of alluvium. The soft Tertiary rocks of the Hampshire Basin were eroded rapidly to form bays between promontories formed in more resistent rocks such as Handfast Point and Hengistbury Head.

The eroding cliffs provided a source of material for the beaches being distributed alongshore by littoral drift. However much of the coarse sediment is more probably derived from glacial gravels which were deposited in the Channel by the rivers after the retreat of the ice sheets. As sea level rose these sediments became sorted by wave action within the English Channel as the near shore zone advanced and were pushed onshore as shingle banks. Hurst Castle spit and other shingle accumulations along the coast are thought to have been derived in this way. Large banks of material in deeper water were fashioned by tidal currents to form the banks in Christchurch Bay and the Solent.

3.2 Coastal Processes

Cliff recession and falling foreshores predominate along exposed sections of the coast of Southern England. The rate of retreat varies greatly depending on the local geology and the intensity and direction of wave attack. Erosion is most rapid where the cliffs are formed in soft clays which yield easily to wave action and are vulnerable to landslips and mass movement for example in Christchurch Bay, along the south-west coast of the Isle of Wight and in Weymouth Bay. Cliffline changes are very slow where more resistant limestones and chalk form promontories such as on the Isle of Purbeck and The Needles and St Catherine's Point on the Isle of Wight.

The major reason for the loss of beach sediment and falling beach levels is the reduction of contemporary sources of supply. Cliff protection measures designed to halt shoreline retreat have reduced the input of coarse sediment to the beaches and the pattern of sediment distribution by wave induced littoral drift has been altered by the construction of groynes. Offshore banks in the Solent and Christchurch Bay are shown to play an important role in modifying wave activity and hence the rate of littoral drift. Foreshore erosion is combined with the long term slow shoreline recession associated with the continuing rise in sea level. Along the South Coast the effect of such a rise is compounded by the subsidence of the land relative to mean sea level due to the continued down-warping of the North Sea Basin. The overall rise in sea level is approximately 2mm/year (Ref 1).

Hurst Castle Spit is perhaps the most notable accretionary feature along this coast. Elsewhere coastal accretion is limited to areas sheltered from south-westerly wave action by headlands and takes the form of spit growth for example at the entrances to

Poole and Christchurch Harbours. Other smaller accumulations are found along the north coast of the East Solent. However the interruption of littoral supply of sediment has meant that many of these features are presently suffering recession e.g. at Hurst Castle Spit.

Saltmarshes have developed in many sheltered locations on the north coast of the Isle of Wight, in Southampton Water and in the natural tidal harbours but these are now deteriorating with a die-back in Spartina growth and erosion of the mud flats. The cause of this trend is not yet known but it raises considerable concern where the marshes provide a natural coastal defence such as at Keyhaven on the West Solent.

The direction of littoral drift is generally eastward from Portland Bill. The presence of many headlands and the changing orientation of the coastline vary the degree of exposure to wave action. Thus the net rate of littoral transport of sediment may vary locally in magnitude and direction. Strong tidal currents in and out of harbours and within the Solent have a significant effect on the pattern of sediment movement. The Isle of Wight plays an important role in modifying the wave climate along the mainland coast of east Hampshire by reducing the fetch of the prevailing south-westerly waves and increasing the predominance of south-easterly wave action. This produces a zone of drift divergence at Selsey Bill such that beach sediment generally moves west from the Bill towards Portsmouth. Thus changes in the coastal process along the adjacent coasts to the west of Portland Bill and to the east of Selsey Bill are unlikely to have any marked effect on the coast in between. However several sub-units of the coastline may be distinguished where the net transfer of sediment is now fairly limited for example between the Isle of Purbeck and Poole Bay and the East and West Solent across Southampton Water. The coastal processes and shoreline changes of each section of the coastline are discussed in more detail below.

The East Solent - Selsey Bill to the River Hamble

The coastline from Selsey Bill to the Hamble Estuary at the entrance to Southampton Water is generally low-lying, formed in Bracklesham Clays and overlain by gravel deposits. The shoreline westwards to Gilkicker Point forms a shallow broad bay facing the Isle of Wight to the south (Fig 1). West of the foreland at Gilkicker Point the coast of the east Solent faces south west. (Fig 2). The line of the coast is interrupted by three large tidal inlets, namely Chichester Langstone and Portsmouth Harbours. These large expanses of water are formed by the postglacial submergence of former river valleys of the Solent River but their present outlines reflect the results of marsh growth, reclamation and dock construction especially in the case of Portsmouth Harbour.

The open coastline is generally characterised by low cliffs of sand and shingle banks which show contrasting areas of accretion and severe erosion. From Selsey Bill sediment generally moves westwards towards Chichester Harbour due to the sheltering effect of the Isle of Wight against the prevailing south-westerly waves in the English Channel and increasing predominance of southerly and south-easterly waves. From Lee-on-Solent to Portsmouth Harbour entrance the net drift is in an easterly direction promoted by south-westerly waves travelling up the West Solent and approaching the coastline obliquely from the west. However, between Portsmouth Harbour and Chichester Harbour the direction and rate of littoral drift is variable and is strongly influenced by tidal currents in and out of the harbours and the presence of offshore banks. The harbour entrances act as convergence zones for sediment transported from the east and west. In each case the harbours are flanked by spit-like formations of sand and shingle which have developed under alongshore drift. Fine marine sediments are moved into the harbours under the dominant flood residual while coarser material is deposited at the entrance and shaped by tidal flows into sand and shingle banks and bars such as East and West Pole Sands, Chichester Bar, East Winner and Langstone Bar. These deposits provide a reservoir of sediment some of which is returned to the coastline under suitable wave conditions. They also modify the wave climate providing additional protection from wave action and promoting shoreline accretion as at Gunner Point. However, the reduction in the supply of sediment by coastal protection measures has led to a decline in the volume of these deposits and sometimes causing erosion at the coastline, for example on Hayling Island.

Salt marshes cover extensive areas of the mud flats which fringe the sheltered harbours. Localised erosion of the saltings does occur where waves are able to penetrate the narrow entrances. Deterioration of the marsh vegetation cover due to the die-back in Spartina growth has also exposed the muds to some tidal scour although this is not likely to be the fundamental cause of the erosion. Large areas of natural saltings still remain in Chichester Harbour while parts of Portsmouth and Langstone Harbours have been reclaimed for urban use. The cause of erosion is unlikely to be due to wave activity only. It may well be that the pattern of rapid growth and slow decay of Spartina is partly due to natural (e.g. biological) causes.

The coastline to the west of Selsey Bill has undergone continued longterm recession which reached an annual rate of the order of 6m/year prior to the construction of coastal defences (Ref 2). The erosion of the low cliffs of sandy clays and gravels had provided a large drift of coarse beach material alongshore to the west. While some has accumulated to form the spit at East Head much of the material has been transferred to the Chichester Bar at the entrance to the harbour.

Hayling Island, between Chichester and Langstone Harbours, has a coastal frontage of some 6km with spit features at each end. The position of both harbour entrances appear relatively stable but the shoreline has shown accretion at one end and erosion at the other. The whole of the Hayling Island frontage was once backed by a steep shingle ridge protecting low-lying land behind. The littoral drift is east to west along the majority of the Hayling island frontage and thus beach drifting has led to accretion at the western end of the island. However, a reversal in the general westerly drift creates a divergence of drift near the east end of the island (at the Beach Club) resulting in a net loss of beach material from this frontage. Problems due to the erosion of the ridge at the eastern end of the frontage began early this century and were exacerbated by post war residential development on the shingle bank crest. The main sea wall was built in 1946 since when beach levels have deteriorated further, resulting in the disappearance of almost all the shingle and leaving a flat sandy foreshore. Wave overtopping and flooding occurred with increasing frequency and there was a risk of a breach into Chichester Harbour.

Recent estimates of net littoral drift at the Beach Club were 5000m³ in an easterly direction and 17000m³ in a westerly direction leaving a deficit of 22000m³ which at one time was probably supplied by material coming ashore from the Chichester Bar (Ref 3). However, the depleted state of the beaches in this area during the 1970s suggests that this source of material may now be diminishing, possibly due to coastal protection works eastwards to Selsey Bill. Wave induced onshore movement is thought to be insignificant and net losses offshore are believed to be negligible. To remedy this situation 2.2km of beach was renourished in 1985 with 520,000m³ of shingle dredged from the Owers Bank.

Along the central section of Hayling between Beachlands and the golf course the sand and shingle beach is wide but has eroded some 60m between 1940 and 1980. At Sinah Common at the western end of the island long term accretion in the shelter of East Winner Sands is shown by the succession of 'fossil' curving beach ridges of shingle and shell behind the present storm beach at Gunner Point close to the entrance to Langstone Harbour. Harlow (Ref 4) estimates an annual rate of accretion over the past 380 years of 40000m³ but the present rate is reduced to 5000m³. 10000m³ of material which passes Gunner Point is believed to feed into the narrow entrance channel of Langstone Harbour each year. This material is distributed seawards onto Langstone Bar and East Winner, a shingle covered sand bar, and finer sediments are carried in suspension northwards into the harbour. Recent studies indicate that some erosion at Gunner Point is now taking place. It is not known whether this is due to a reduction in the littoral supply or due to increased storminess in the last decade.

Any material that succeeds in moving around the Langstone Bar is fed ashore to join the drift along Portsea Island in much the same relative position as on Hayling Island. Once onshore this supply of material exceeds the low drift capacity in this sheltered position (less than 2000m^3) and accumulation has therefore taken place. A wide shingle beach has gradually been accreting at the eastern end of the frontage although storm damage does occur during south-easterly gales. Some erosion is taking place along the spit north of Fort Cumberland, to the west of the Langstone Harbour channel and is being controlled by recycling beach material from accreting areas. At Southsea Castle the coastline turns abruptly north-west towards Old Portsmouth and the land is subject to occasional flooding during south-westerly storms. The position of Portsmouth Harbour entrance is fixed by sea walls as is the large part of the southern frontage within the harbour and thus there has been little change in the coastline here. There is a north-easterly drift from Gilkicker Point towards the harbour entrance but the rate is very low because of the limited fetch from the south across the East Solent.

From Portsmouth north-west to Lee-on-Solent the shore is formed of shingle banks which form foreland features at Gilkicker Point and Browndown. The beach in Stokes Bay appears to be accreting generally and is quite wide to the west of Gilkicker Point. At Lee on Solent a sea wall has been built to protect the low cliffs from erosion but has led to recent downdrift erosion at the south-eastern end of the wall. The River Meon is deflected to the south-east at Titchfield Haven by alongshore drift and the reduction in supply of material to the beaches downdrift (south) of the river has led to coastal recession at Hillhead. These beaches have recently been supplemented with material dredged from the harbour entrance.

North-westwards towards the River Hamble the coastline becomes increasingly sheltered from south-westerly wave action. At Solent Breezes the south-easterly net drift towards Gilkicker Point is reversed giving a net north-westerly drift towards the River Hamble where shingle is deposited as a recurved ridge on the south side of the entrance. The unprotected low cliffs of clay and gravel are being eroded both to the north and south of Solent Breezes leaving the short stretch of protected frontage lying forward of the general beach line.

Southampton Water

Southampton Water is a wide and very deep tidal channel formed by submergence. Wave activity is generally small since fetches are limited in all directions except for a very narrow window to the south-east. High tidal levels are more likely to be the cause of problems for sea defence. Much of the north-eastern shore of Southampton Water between the Rivers Test and Itchen is built up and modified by dock and wharf constructions or otherwise protected by various types of walls. South of the River Itchen low cliffs of Plateau Gravels produce much of the material for the shingle beaches that fringe the shoreline. The beaches vary considerably in both width and stability and the net drift here, although not large, is to the north.

By contrast the more sheltered western shore of Southampton Water is mostly low lying and fringed with large areas of saltings or otherwise reclaimed for industrial use such as the large oil refinery at Fawley.

West Solent - Calshot to Hurst Castle

Calshot Spit lies at the western entrance to Southampton Water. It consists of a long shingle ridge broadening out at its distal end where a castle built during the reign of Henry VIII still stands. The spit has been formed by wave induced longshore drift from the south-west within the West Solent. The distal end of the spit recurves northwards, partly shaped by less frequent storm action from the south-east.

West along the Solent shore to the Beaulieu River there is erosion of the low cliffs of clays and sands at Lepe and Stanswood Bay. At Lepe this may in part be a result of the eastward deflection of the river mouth causing river scour on the northern bank. In Stanswood Bay the cliffs are exposed to waves from the east as they are channelled along the Eastern Solent.

South of the Beaulieu River the Isle of Wight provides increasing shelter to wave action from the east. The foreshore between the Beaulieu River and Pitts Deep is made up of shingle which is believed to have been pushed onshore from an inter-tidal bank originating from Hurst Spit. Shingle has accumulated in large quantities at Needs Ore Point to the west of the mouth of the River Beaulieu and a further spit has developed to the seaward at Warren Farm. May (Ref 5) has traced the growth of this feature since the mid 1800s by the eastward succession of recurved shingle ridges building up under the net north-easterly littoral drift. A sudden lengthening of the spit as far as Needs Ore Point took place in 1952 following a series of storms. Since this time the western end of the spit has migrated landwards suggesting that the supply of material is limited and insufficient to maintain its position. The gap between Needs Ore Point and Gull Island, a shingle bank at the river mouth, has recently been closed by the placement of 13000 tonnes of shingle from further west. Within the river estuary the spit provides suitable sheltered conditions for the growth of spartina marsh.

West of Pitts Deep (Fig 3) the foreshore changes to mudflats and saltings in the Lymington River estuary and on the Keyhaven Marshes where Hurst Spit to the south provides shelter from south-westerly waves. These salt marshes are in recession as the result of die back of spartina growth and there is a serious risk of flooding should a permanent breach occur in Hurst Spit.

Hurst Spit lies at the western entrance to the West Solent and at the eastern end of Christchurch Bay. It projects for some 2km across the Solent in a south-easterly direction from Milford-on-Sea. This shingle bank lies on a bench of clay which is an extension of the marsh clays to the north-east of the spit. The crest of the bank is only 6m wide and has a maximum height of 5.5m ODN (MHWS is 0.9m ODN). Much of the coarse shingle comprising the spit is derived from erosion of the cliffs further west and also from glacial deposits which originally covered the floor of the English Channel. These were subsequently moved to the littoral fringe by wave action under rising sea levels.

Hurst Spit is sheltered against south-easterly waves by the Isle of Wight. The fetch to the south-west is fully exposed to the Atlantic but wave action is reduced by the shallow sea bed and banks offshore such as Dolphin Bank, The Shingles and North Head. The spit has developed a plan shape approximately in equilibrium with this wave environment. The central part of the spit is aligned normal to the predominant south-westerly wave approach. Thus there is a net north-west to south-east movement of shingle but the transport rate is modest. Strong tidal currents occur during the rising tide off Hurst Spit beach and flow south-eastwards in the same direction as the littoral drift. These currents are likely to reinforce the movement of sand and may influence the movement of shingle, particularly when accompanied by wave action. Beyond Hurst Castle itself the successive growth of the spit eastwards can be deduced from the earlier 'fossil' recurved ridges on the landward side. Active accretion is taking place at the recurved section of the spit. Strong tidal currents in the Hurst Narrows transport some shingle and sand southwards offshore onto the Shingles Bank to be redistributed onto the North Head and Dolphin Banks (Ref 6). Other investigations have shown that some shingle may find its way back onshore under suitable wave conditions. Occasionally shingle is transported north-eastwards up the Solent during storms coupled with strong tidal currents to be deposited on the inter-tidal foreshore between Lymington and Calshot although judging by the narrowness of the beaches in this area any such movement is likely to be small. Surveys have shown the bed of the Solent to be covered by gravel bars, such as the Solent Bank, whose shape and sediment distribution indicate a net transport eastwards from Hurst Spit (Ref 7).

The recession of Hurst Spit in a north-easterly direction has been recognised for some time. Cartographic evidence (Ref 8) shows that the sea has advanced some 100m since 1898 in the vicinity of Sturt Pond at the proximal end of the spit. Two processes appear to be contributing to the recession of the spit. Firstly the shingle ridge is 'rolling back' landwards towards Keyhaven. This process is also occurring to other similar features and is related to the continuing slow rise in post-glacial sea level (of the order of 2mm/year along the south coast). During severe storms shingle is carried over the crest of the ridge to be deposited behind the beach exposing the underlying strata of the beach to wave action and erosion. As the crest height is lowered so the risk of wave overtopping is increased particularly during storm surges which may raise water levels by 1m. The bank deteriorates rapidly as soon as overtopping occurs. The crest is progressively lowered and at the same time the landward slope is scoured away ultimately leading to a breach. The first recorded breaching of the spit was in 1962 when it was quickly rebuilt. Since this time there has been a persistent risk of breaching during severe storms and temporary breaches have occurred with increasing frequency.

The deterioration of the spit is also intimately connected with changes along the coastline of Christchurch Bay to the west. The spit is a continuation of the shingle foreshore at Milford-on-Sea and has in the past been maintained by an easterly drift of sediment along this frontage from the erosion of the cliffs in Christchurch Bay. In the past the gradual movement of the spit inland has been in sympathy with the recession of the shoreline of Christchurch Bay but efforts to halt this erosion particularly at Milford have interrupted the supply of material to the spit and exacerbated the recession at the proximal end.

To increase the height of the bank and reduce overtopping the ridge has been reshaped and nourished with stone at various times, most recently in the past year with shingle from the Owers Bank. Armouring of the seaward slope at the landward end may have reduced the rate of recession of the spit but it is no coincidence that all the recent breaches have occurred near the junction of the armouring with the mobile shingle bank.

The movement of the beach shingle and present day changes in the character of Hurst Spit have been analysed in some detail by Nicholls (Ref 9). He records that the maximum rate of recession has increased from 1.5m per year (1867-1968) to 3.5m per year (1968-1982). The continued existence of the spit is vital for the protection of the low lying marshland on the west bank of the Solent. Nicholls suggests that without shingle nourishment on a significant scale the rate of recession of Hurst Beach is likely to increase up to a possible 6m/year. A permanent breach would appear possible in the long term and would represent a very major change in the coastal processes affecting Christchurch Bay and the West Solent, turning Hurst Castle into an island and probably destroying the saltmarshes at Keyhaven.

Christchurch Bay

Christchurch Bay is backed by a continuous cliffline formed in Tertiary clays and sands of the Barton and Bracklesham Beds and capped by Plateau Gravels. The cliffs range in height from about 30m at Highcliffe to 10m at Milford. The soft heterogenous strata are very vulnerable to erosion by wave action, mass movement and sub-aerial weathering. The coarser material, sands and gravels, contribute to the beach sediment while the finer clay fractions tend to move offshore. The rate of cliff recession is most rapid to the west of Barton, approximating 1m/year, as a result of deep seated rotational slips and mudflows in the clay. The problems of cliff slippage, beach erosion and associated coastal defences have been the subject of a number of engineering reports (Refs 10, 11 and 12). Erosion of the cliffs is now largely constrained by coastal defences but these have failed to prevent the occurrence of some slides. Hordle Cliff is the only area of general accretion along this section of the coastline. (A wide shingle beach at Hordle protects the cliffs from wave attack.) West of Chewton Bunny along the Highcliffe frontage the cliffs have been stablised and the beach nourished, preventing washouts and landslides, caused by ground water draining from the cliff face. Prior to nourishment this beach consisted of sand, but now is of shingle.

Christchurch Bay is open to wave action from the south-west through to the south-east. South-westerly waves are not only most frequent but are also higher and therefore there is a net west to east alongshore movement of beach material along the frontage of Christchurch Bay. The curvature and orientation of the bay reflects the greater exposure to south-westerly waves towards the east. However the wave climate in this part of the bay is modified by the presence of offshore banks such as the Dolphin Bank, the Shingles and North Head. These banks have been fashioned by tidal currents and wave action at the mouth of the Solent. A comparison of charts over the past 200 years shows these banks to be accreting. Under certain conditions refraction of waves over these shoaling areas may divert and concentrate wave energy to certain stretches of the coastline. Tidal currents within the bay are relatively weak except at the entrance to the Solent and in Christchurch Harbour entrance. Maximum tidal currents in the narrows off Hurst Castle can be as high as 2m/s and are capable of transporting shingle into the West Solent on the flood tide and discharging it a long distance south-westwards on the ebb.

The circulation of water within Christchurch Bay is not at all clearly defined and has been the subject of various investigations in order to establish the pattern of seabed material movement and possible sources of beach material. Sea bed drifters have been used to determine the net movement of near bed flow. The recovery of drifters released on the northern end of the Shingles and in the North Channel in the eastern part of Christchurch Bay suggested the presence of a strong onshore transport of near bed water flow and a general east to west drift inshore towards Hurst Beach and Milford. In the offshore zone the transport is west to Mudeford which may be complemented by a return movement eastwards within the littoral zone under the influence of longshore drift (Ref 13). Sea bed drifter experiments (Ref 14) showed an easterly movement in the eastern part of Poole Bay and also a similar drift in Christchurch Bay with a transfer between the two in the offshore zone suggesting that material may be able to migrate eastwards over the Christchurch Ledge off Hengistbury Head. Some movement took place westwards in Poole Bay when the drifters came under the influence of tidal flow at the entrance to Poole Harbour. From both of these experiments the pattern of water movement has been inferred although the degree to which the movement of drifters reflects the transport of shingle has not been established in the absence of any tracing experiments. A closed water circulation and the possibility of shingle recirculation within Christchurch Bay has been postulated by Clark and Small (1969). While the clockwise movement within the littoral zone along the margins of the bay is confirmed by Tyhurst and the transport of material by tidal currents onto the Shingles is undisputed, there does not appear at present to be any mechanism by which material could be transported north-west from the Shingles and back to the shore.

Christchurch Harbour is formed by the drowned lower courses of the combined Avon and Stour rivers and is almost completely enclosed by two spits, one trending south-south-west from the sandy cliffs near Mudeford and the other running northward from Hengistbury Head. The southern spit is largely formed of sand dunes which rise to about 6m and extensive sand bars lie offshore. Of the two spits it is the longer and broader southern one which has been subject to the greatest change over the past 200 years, showing a cycle of growth and decay, while the northern, Haven House peninsula has remained relatively stable. During the 19th century the mining of the ironstone found in the cliffs at Hengistbury Head contributed large quantities of gravel material to the littoral zone which was moved east and north alongshore to the spit. Between 1840 and 1896 cliff recession at Hengistbury Head was rapid, at a rate of 3.5m/year (Ref 15). On several occasions the southern spit extended north-eastwards as far as Highcliffe Castle, but was then broken through by south-easterly gales. According to Robinson (Ref 16) the rapid growth suggests that littoral drift has not been the sole process involved in its development. Large quantities of sand may also be moved in the near-shore zone from the west over the Christchurch Ledge to move onshore during spring tides as south-westerly waves are refracted around Hengistbury Head. Such an onshore movement would be more effective in deflecting the river mouth where the discharge from the harbour is strong, up to 9 knots. There is no evidence of counter drifting having been responsible for the formation of the Haven House Spit and Robinson favours the hypothesis that the original spit was breached in much the same way as in the recent history of the southern spit.

The growth of the southern spit suddenly ceased after the construction of the large groyne off Hengistbury Head during the mid 1930s. The reduction in the supply of beach sediment from the west has led to severe coastal erosion problems. The southern spit has been groyned in an attempt to halt its recession and the beach levels have been built up to prevent the sea breaking through into Christchurch Harbour. It has also been necessary to build defensive walls on the northern spit and along Friars Cliff which was formerly protected by a shingle beach and by the extension of the southern spit.

The effect of the construction of the long groyne on the rate of cliff erosion at Hengistbury Head has been determined by a study of maps and surveys (Ref 15). The groyne has interrupted the easterly drift and a wide beach has accumulated to the west which protects the cliffs from direct wave attack. The cliffs are now retreating at a relatively slow rate of 0.2m/year due almost entirely to sub-aerial weathering. The rate of erosion increases westwards to 0.75m/year as the effect of the groyne is reduced. Just east of Double Dykes the rate rises locally to 1.1m/year. Cliff erosion to the east of Hengistbury Head is of the order of 0.4 -0.8m/year.

Poole Bay

The former recession of cliffs of Tertiary sands in Bournemouth Bay has largely been halted by the construction of sea walls and by the grading of cliffs liable to slipping. Since 1974 the beaches have been extended by a replenishment scheme using sand from offshore (Ref 17). However after initial large losses the beach width declined slowly as the sand was moved eastwards by littoral drift. Analysis of beach data shows that by November 1982 only 12% of the introduced volume remained, mostly in the section to the west of Bournemouth Pier (Ref 18).

Poole Harbour, also the estuary of the present River Frome, is a large natural tidal lagoon formed by the submergence of low-lying land by post glacial sea level rise. Areas of higher ground now form islands such as Green Island, Furzey Island and Brownsea Island. The harbour is sheltered from the sea by twin spit features and thus large areas of Spartina saltings have developed along the complex system of interdigitating inlets and channels particularly on the south side. Parts of the northern shore in the vicinity of Poole itself have been reclaimed for urban and industrial development.

The spits appear to differ both in morphology and development. The North Haven or Sandbanks is simple in form with a single ridge of sand dunes reaching a maximum height of about 16m. The spit is exposed to storm wave action from the south-east and has undergone recession over the past few hundred years probably in line with the erosion of the cliffs further east in Bournemouth Bay. The position of the spit has been fixed since 1890 by the construction of sea walls and the beach has been built up by a system of groynes. The South Haven peninsula has built up considerably and is stepped forward about 1km relative to the North Haven or Sandbanks which as mentioned above has gradually moved inland. It is separated from the continuous shoreline of Bournemouth Bay by the Harbour entrance and has therefore been unaffected by changes in the coastline to the east. The relative shelter of Studland Bay to storm waves from the south and south-east by the headland at Handfast Point has led to the accumulation of sand. The spit appears to be of recent origin and comprises a series of dune ridges separated by saltings and fronted by a wide sandy forshore. Map comparisons (Ref 16) show the development of the spit since the 1600s.

The long-term littoral drift regime in the western half of Poole Bay has been studied both by Robinson (1955) and by Steers (1946) with different conclusions being reached. Both are agreed that between Studland and the entrance to Poole Harbour the drift direction is north-eastwards. Since the construction of the training wall on the south-western side of the navigation channel, however this beach fronting the South Haven Peninsula has changed its orientation with very little drift now occuring.

Along the Sandbanks peninsula, on the other side of the harbour entrance, the situation is less clear. Robinson argues the drift is still north-eastward based on the evidence of beach accumulations against groynes along that stretch of coast. The source of this transport towards Bournemouth he believed, was an onshore movement of sand from the shallow sea bed.

Steers, however, believed the drift along the Sandbanks peninsula was south-westward, supplied by the cliffs at Bournemouth. It is this latter argument which is the more convincing, with tidal currents as well as waves having a role to play especially close to Poole Harbour entrance.

At the southern end of Studland Bay, older Cretaceous rocks are exposed. Resistant chalk forms vertical cliffs between the headlands of Handfast Point and Ballard Down. The average rate of cliff top retreat is relatively slow (0.23m/year, Ref 5). This stretch of coast provides many good examples of all stages in the marine erosion of chalk cliffs to form caves, arches and stacks such as the Pinnacles and Old Harry. On the south side of Ballard Down the Lower Chalk and

Upper Greensand overlie Gault Clay and some slumping and gullying has occurred in spite of the protection given to the toe by a shingle bank. Erosion is most severe during periods of heavy rain and when the strata are saturated by ground water. The sea is only important in removing the material from the cliff base.

Swanage Bay

The shoreline of Swanage Bay has been formed by the erosion of the relatively soft Wealden Beds (sands and clays) and lies between the more resistant headlands of Ballard Down to the north (chalk) and Peveril Point (limestone) to the south. The bay is well protected from the prevailing south-westerly storms and experiences a relatively mild wave regime. The Hampshire coast and the Isle of Wight shelter the bay from the north and east such that the coastline is exposed to greatest fetches from a relatively narrow sector from the south-east. The main focus for wave attack is therefore the northern end of the bay. The beach material is well sorted consisting mainly of sand with some flint pebbles and an increasing accumulation of shingle to the north where wave action is greatest. The net direction of littoral drift appears to be northwards although the rate is slow. Map studies suggest that the position of the shoreline is stable and the foreshore has generally accreted over the past 100 years (Ref 19). The coastline appears to have a plan-shape approaching equilibrium with its hydraulic environment, little material is being lost from the bay and possibly a small quantity being gained from offshore. The application of wave hindcasting and refraction models suggest that present drift rates do not exceed 5000m^3/yr and can be variable in direction (Ref 20).

The Isle of Purbeck to the Isle of Portland

The changes in the rocky cliffed coast of the Isle of Purbeck and the Dorset coast west to White Nothe have generally been slight over the past century. The south-east part of the Isle of Purbeck south of Swanage Bay is formed chiefly in resistant Jurassic limestones of the Purbeck and Portland Beds. The differential erosion of softer clays where these are exposed at the coastline has given rise to the shallow embayment of Durlston Bay between the limestone headlands of Peveril Point to the north and Durlston Head to the south. From Durlston Head west to St Albans Head the horizontally bedded Portland Stone is capped by Purbeck Beds to form vertical incised cliffs rising to a plateau 140m high. Recession of the cliff top is negligible and erosion is limited to joint planes which have been exploited by wave action to form caves.

West of St Albans Head (fig 4) the cliffs gradually fall in height as the Kimmeridge Clay rises from beneath sea level. Landslips have occurred where the seaward dipping limestone beds have slipped over the impermeable clays. Limestone bands within the clays form platforms at sea level known as the Kimmeridge Ledges. The clay cliffs have been eroded fairly rapidly at Kimmeridge Bay at a rate of 0.4m/year (Ref 5).

From Kimmeridge Bay to Durdle Door the coastline follows the trend of a narrow outcrop of Portland limestone. The beds dip steeply to the north and form overhanging cliffs where the softer clays have been removed by wave action at their base. At Worbarrow Bay and Lulworth Cove the sea has breached the limestone barrier to excavate the softer Wealden clays behind, while the northward extension of the bays has been limited by the exposure of more resistant chalk. The early stages in this process are seen at Stair Hole immediately west of Lulworth Cove. At Durdle Door, Portland stone forms a cliffed projection which is cut through by wave action to form a natural arch.

From Hambury Tout to White Nothe chalk forms impressive cliffs rising to 170m. May has estimated these cliffs to be retreating at an average rate of 0.2m/year. West of White Nothe to Weymouth the rate of coastal recession generally increases to 0.4m/year where cliffs of clay are subject to slides and slips particularly at Ringstead Bay (Kimmeridge Clay) and Furzey Cliff (Oxford Clay).

Weymouth Bay is generally sheltered from the prevailing south-westerly wave action by the Isle of Portland but coastal recession of the unresistant Jurassic clays has been rapid. At Lodmoor there has been a landward movement of the shingle bank which protects low-lying land behind from flooding. This recession has largely been halted by the construction of sea walls and the additional shelter provided by the jetties and breakwaters of Portland Harbour.

The Isle of Portland forms a major projection along the coastline of southern England dividing Weymouth Bay on the east from Lyme Bay on the west. At one time during the post glacial period it was probably detached from the mainland by rising sea levels but has since become rejoined by the longshore drifting of beach material which now forms Chesil Beach.
The coastline of the Isle of Portland has changed little over the past century although quarrying has drastically altered the nature of some of the cliffs. The beds of Purbeck and Portland limestone dip southwards and form steep cliffs. The

underlying clay is exposed in the north where past falls of limestone have formed wide undercliffs both on the east and west coast. At Portland Bill there are raised beach deposits indicative of higher sea levels during the post glacial period but the precise age is not certain.

The Isle of Wight

The stages in the separation of the Isle of Wight from the mainland have been discussed earlier in this section. The Island as a whole plays an important role in the modification of the wave climate and tidal regime of the adjacent Hampshire coast. However, changes along the coastline of the Island are unlikely to affect those coastal processes operating along the mainland coast. Thus the Island is considered here as a separate coastal unit.

The nature and configuration of the shoreline of the Isle of Wight is directly related to its varied lithology. The chalk ridge running west - east from the Needles to Culver Cliff essentially divides the shoreline into two contrasting sections. The coastline to the north is generally low and is formed in soft Tertiary strata which are a continuation of those exposed on the mainland coast. To the south the Cretaceaous formations have produced higher cliffs reaching a maximum height of 168 m at Blackgang. The landslips and cliff erosion on the south coast of the Isle of Wight have been the subject of a number of geological studies by Hutchinson (Refs 21 to 23).

South Coast

From The Needles eastwards to Sandown the line of cliffs is continuous, broken only by the post glacial valleys of the Rivers Yar at Freshwater in the west and Yaverland in the east and by several small deeply incised valleys or 'chines'. The rate and pattern of coastal recession is determined by lithological variation and geological structure and by the degree of exposure to prevailing and dominant waves. The chalk is relatively resistant to wave attack as is shown by the development of stacks at the Needles and the Grand Arch in Scratchells Bay. The chalk is intensely folded and dips steeply landwards which increases its resistance to erosion. Thus erosion is very slow along the vertical cliffs of Tennysons Down and Compton Down (about 0.01m/year, Ref 5) although there are some occasional rockfalls. The small embayment at Freshwater is associated with the more rapid erosion of gravel deposits which infilled the valley of the River Yar where it cut through the chalk ridge. These deposits have contributed to a shingle beach within the bay. A sea wall has been constructed to reduce the danger of the sea breaking through to the north coast.

Between Compton Bay and St. Catherines Point the shoreline crosses the upfold of the Cretaceous strata and truncates successively the Upper Greensand, Gault Clay, Lower Greensand and Wealden Beds. The general rate of erosion is rapid from Compton Bay to Blackgang where the shoreline directly faces the south-westerly gales and Atlantic storm waves. Between Hanover Point and Atherfield Point the low cliffs are unstable. The clays, marls and shales are subject to frequent multiple rotational slips and mud flows as a result of the continuing steepening of the cliff by wave action at the toe and the weakening effect of ground water. May (Ref 5) estimated the annual rate of recession on the Wealden Beds in Brightstone Bay to be approximately 0.5m/year. More resistant layers of sandstones form wide platforms at Atherfield Point and from Hanover Point to Chilton Chine. The sandstones exposed in Chale Bay form steeper cliffs. Erosion here has proceeded mainly by the action of waves in undermining the cliff and causing its collapse. Littoral drift along this coast is from west to east.

East of Blankgang Chine and around St. Catherine's Point the rate of erosion reduces as the coast is formed by more resistent sandstones and chalk. There is clear evidence of past slip activity forming that section of the coast known as the Undercliff from Binnel Bay eastwards to Ventnor. The natural dip of the rocks brings the Gault Clay down almost to sea level. Rotational slips in the clays have been triggered by variations in ground water level and caused the collapse of the overlying Upper Greensand and chalk. The mass of rock debris which now forms the Undercliff protects the toe of the cliff and provides sufficient basal support to prevent active slippage. Recent cliff falls have occurred east of Ventnor, at Dunnose. These falls are promoted by wave action at the base of sandstone cliffs which are interbedded with clays to produce a profile of steep faces separated by ledges. Drift along this coast is intermittent and is from west to east.

North of Dunnose the wide embayment of Sandown Bay stretches north-east to Culver Cliff. The town frontages of Shanklin and Sandown are protected by sea wall and groynes. The cliffs gradually become lower until they reach sea level at Sandown where the sea cuts across the former valley of the eastern Yar. Between Yaverland and Culver Cliff all the strata of the succession from the Wealden to the chalk are exposed leading to a varied coastline of slips in the clays separated by vertical cliffs of sandstone and chalk. Chalk forms the headland at Culver Down and erosion is greater in the less resistant rocks to the south in Sandown Bay and in the Tertiary sands and clay exposed to the north in Whitecliff Bay. Although Whitecliff Bay is relatively well sheltered from wave action and is fronted by a wide sandy beach, the cliffs are subject to slumping and gullying. The eastern extremity of the island, The Foreland, is formed by an outcrop of hard Bembridge limestone which forms a wide wave cut platform. Drift is slow and in a south-west to north-east direction.

North Coast

The north coast of the Isle of Wight from Alum Bay in the west to Whitecliff Bay in the east is formed in soft Tertiary strata consisting mainly of marls and clays with some sands, shales and limestone. The coastline from Alum Bay to Sconce Point to the west of Yarmouth is exposed to the west but is to some extent protected from severe wave action by the Shingles Bank. In Alum Bay the near vertical strata of sands and clays are eroded at their base by the sea and also by sub-aerial weathering forming gullies and fans particularly in the weaker clays. At Headon Warren the cliff has a stepped profile due to the slumping of clays between limestone beds. To the east of Totland Bay the clay cliffs show numerous forms of slips, some simple and others rotational even though the cliff foot is protected from the sea in places by dunes. To the east of Yarmouth again there is another area of major landslips known as the Bouldnor and Hamstead Cliffs. The top of Bouldnor Cliff is reported to have receded at a average rate of 3m/year between 1922 and 1962 although Bird and May (Ref 5) quote an average rate of 0.6m/year over the previous century. The entrance to the inlet of the Newton River is protected by two recurved spits consisting of pebbles and sand derived from cliff erosion to the west and built up into the form of small storm beaches by wave action.

The spits are being slowly driven landwards exposing the underlying clay to erosion.

In Thorness Bay there is active slipping on a fairly large scale caused by ground water seepage in the marl cliffs producing an average cliff top retreat of 0.35m/year. The foreshore is rocky and limestone rises above sealevel to form a wide ledge at Gurnard Point. To the east of Gurnard Point the cliffs are more stable. Earlier slumps are now grass covered and the limestone exposed at the base of the cliff has slowed the rate of erosion in comparison with the cliffs to the west. From Gurnard Bay to Cowes the cliffline is protected by sea walls at their base although this does not prevent occasional falls of plateau gravels. To the east of Cowes the cliffs are generally lower and have experienced little change over time as a result of the increased shelter from wave action and the basal protection given to the cliffs by outcrops of limestone. The area is largely undeveloped and evidence of coastline change only manifests itself in partly urban areas. Thus there is some evidence of erosion in Wootton Creek and some downdrift scour west of Ryde. Erosion in these areas is largely the result of the boulder clay cliffs having a low level of protection. Minor shingle spits along this frontage indicate a weak east to west littoral drift. The coastline from Ryde to Bembridge Harbour is mostly artifically protected by sea walls. However in certain areas the sea defences are abandoned and erosion of the boulder clay cliffs is taking place, notably in Priory Bay, north of Bembridge.

4 WINDS, WAVES AND TIDES

Tides

The behaviour of tides in the English Channel in general, and from Portland to Selsey Bill in particular, is very complex. There has been a considerable amount of research describing tidal propagation especially in the Solent and adjacent waters. For a description of the processes involved, the reader is recommended to first consult Reference 24. Further, more recent references on mathematical modelling (25 to 29) illustrate the great difficulties involved in fully describing the tidal processes in this area.

From the viewpoint of the coastal engineer, the expected (ie astronomical) tidal levels are particularly important. The range is greatest at Selsey Bill, decreasing as one travels into the Solent. Minimum values of range, not only for this coast but the whole UK, are found in the Poole/Christchurch Bay areas. From Swanage westward, the range starts to increase again. Even at Portland, however, the tidal range is still small compared to the corresponding value at Selsey. The following table gives the spring and neap tide ranges at a variety of sites along this stretch of coast.

TABLE 4.1 Mean Tidal Ranges - Selsey to Portland

Location	Spring Range (m)	Neap Range (m)
Selsey Bill	4.7	2.6
Portsmouth	4.1	2.0
Ryde	3.8	1.9
Southampton	4.0	1.9
Hurst Point	2.2	1.0
Christchurch Harbour	1.4	0.8
Bournemouth	1.7	0.6
Swanage	1.7	0.5
Portland	1.9	0.7

Despite the small tidal range, however, tidal currents are strong in many areas along this coast. An extreme example is provided by the tidal 'race' off Portland Bill. This area of strong currents and turbulence is a result of eddies in the lee of the Bill, the position of the race depending on the state of the tide. Currents of up to 5m/s have been reported in the vicinity of this race.

Elsewhere along the coast, strong currents or tidal overfalls are common off pronounced headlands, such as St Alban's Head, Peveril and Handfast Points, Hengistbury Head, St Catherines Point and Selsey Bill. In the main bays along the western part of the area, ie Weymouth, Poole and Christchurch Bays, currents are weak especially in shallow water.

Further east, the major tidal inlets of Southampton Water, together with Portsmouth, Langstone and Chichester Harbours, together with the Solent, produce a very different coastline. In the narrow channels, for example at the harbour entrances, tidal currents can be very strong, but in the shallow areas of saltmarshes and mudflats are much weaker.

Apart from the range and currents, another feature of the tides in this area of particular interest is the distortion in the shape of the tidal curves. This distortion is caused by shallow water effects together with relatively small amplitudes of the main tidal components. As a consequence, spring tides have a marked "double low water" in the area of Portland Harbour east to Lulworth Cove. Whilst important from a navigational viewpoint, this feature causes no great problems to the coastal engineer.

From Swanage to Southampton double high waters occur. On the open coast, in Poole and Christchurch Bays, this distortion results in a long "stand" of the tide at or very close to the high water level. Since the crucial combination of events, from a coastal engineering viewpoint, is severe wave action coupled with a high water level, the prolongation of this level is unwelcome.

Surges

Recent analysis carried out at the Institute of Oceanographic Sciences by R A Flather (Ref 29) suggests that the expected maximum surge level occurring once in 50 years ranges from about 1.10m at Portland to 1.25m near Selsey. The expected maximum surge - induced currents are expected to reach 60cm/s, once in 50 years.

In comparison to the magnitude of storm surges experienced along the east coast of England, these effects may appear rather insignificant. However, it must be remembered that in comparison to the small expected tidal ranges, especially in Poole and Christchurch Bays, even a 50cm surge can be significant. In addition, given the long tidal "stand" at or near high water the probability of a surge occurring at such a time is increased. A recent article by J Graff (Ref 30) gives information on extreme water levels at a variety of sites between Selsey Bill and Portland Bill; both astronomical tides and surges are included in this analysis.

Unfortunately little information is available on extreme water levels on the open coasts between Weymouth and Hurst Spit, nor along the coast of the Isle of Wight from the Needles past St Catherines Point to Foreland.

Finally, it should be noted that storm surges along this coast appear to be strongly correlated with onshore wave action either from the south-west or south-east. The resulting combination of surge, wave action and high tide levels severely tests the integrity of coastal defences. A description of one particular event is given by Henderson and Webber (Ref 31) whilst a recent report by Webber (Ref 32) describes surges in the area.

Waves

The coast between Selsey Bill and Portland has a very variable exposure to wave action. Within the major tidal harbours and inlets, such as Poole Harbour, only locally generated waves need to be considered. In contrast, both swell and severe storm waves cause major problems on the open coasts. It is convenient to first discuss swell.

Swell waves

Because of the long fetches stretching out south-westward into the Atlantic Ocean, it is not surprising that swell waves from this direction are a significant feature of the hydraulic regime of the area. The effects of swell are most keenly felt on those parts of the coast facing the Atlantic, ie Bracklesham Bay, the Isle of Wight between St Catherine's Point and the Needles, the eastern portion of Poole and Christchurch Bays, and the Isle of Purbeck from Peveril Point westwards.

However, because of the long period of swell waves, apparently sheltered areas can also be affected. Along the seafront at Hayling Island, for example, swell can cause high values of run-up; before the recent beach nourishment, such events caused flooding of the coastal strip. The penetration of swell into this area is a result of both wave diffraction around the Foreland peninsula on the Isle of Wight, and subsequent refraction over the sea bed between there and Hayling Island. Similar processes enable swell to penetrate into other sheltered areas such as Studland Bay.

The quantitative estimation of swell wave heights is complex, at least partly because the definition of swell is somewhat subjective. The arrival of large swell waves from the Atlantic which bear no connection to local winds is a fairly rare event. Swell waves of low amplitude, however, are of regular occurrence, and help restore beach levels drawn down by storm events. The only satisfactory way to assess swell waves at a particular site, however, is either by direct measurement over a reasonable period or by using a sophisticated mathematical model which can include wave generation not only locally but also in the North Atlantic. Such a model is routinely operated by the Meteorological Office at Bracknell, and provides real-time forecasts as well as stored predictions from previous years, at points 25km apart over the whole English Channel. For existing wave data the reader is referred to Table 4.2 presented below, after discussion of locally generated waves.

Storm Waves

In order to discuss locally generated storm waves along this part of the English Channel it is convenient to divide the coast into two main zones. Firstly the open coast can be defined as Bracklesham Bay, the south-eastern and south-western coasts of the Isle of Wight, Poole and Christchurch Bays, the Isle of Purbeck, and from there west past Weymouth Bay to Portland.

The sheltered parts of the coast lie within Chichester, Langstone and Portsmouth Harbours, Southampton Water and along most of the Solent. There is a transition zone along the outer part of the East Solent, between West Wittering and Southsea.

Everywhere on the open coast, substantial wave activity is likely to occur. The most violent waves arrive from the south-west, because of the combination of long fetches and regular, strong winds from this sector. Hence the coasts most strongly affected by swell are also subject to the largest storm waves.

However, fetch lengths across the Channel towards the coast of France, to both the south and south-east, are substantial. As a consequence, storms from these directions can also be severe. As a result even generally sheltered areas, such as Weymouth Bay can be subject to significant waves when the wind is in a critical direction. As pointed out earlier, large onshore waves can often accompany tidal surges, producing testing conditions for both beaches and coastal defences alike.

The open coast between Selsey Bill and Portland Bill is reasonably well served with wave data; some adjustment may be needed for particular sites to account for the local orientation of the shoreline, or the nearshore sea bed contours. For example, the wave climate at the western end of Christchurch Bay is significantly different both from conditions near the landward end of Hurst Spit, or just west of Hengistbury Head. This is not just because of the different exposures to south-westerly and south-easterly waves, but also because the sea bed shelves more steeply in Poole Bay.

In relatively deep water offshore, the 50 year return period maximum wave height is estimated as 13-16m, with an associated wave period of about 16-17 seconds

(Ref 33). The largest waves are likely to be encountered off Portland Bill, where the dominant south-westerly waves have been least strongly affected by refraction and diffraction. Table 4.2 below lists other potentially useful sources of wave data, including the location of the recorder and the type of instrument used.

Turning to the more sheltered parts of the coast, estimation of the wave climate is best carried out using wind information (eg from Calshot or Thorney Island) together with mathematical models of wave generation over restricted fetches. In some areas, such calculations also need to take into account the limited water depth, and the changes in fetch lengths as the tide level covers or uncovers parts of the inter-tidal foreshore.

Clearly, waves in these rather sheltered areas are very much smaller than on the open coast. Nevertheless, because of the less resilient nature of the 'beaches' in such areas, which are often fragile saltmarshes, wave action can still pose problems.

Very little wave data is available from such areas, but calculations or direct measurements would need to be carried out for any specific site, because of the varying exposure throughout the area. Similar considerations also apply to the difficult transition zone between open and sheltered conditions in the East Solent.

TABLE 4.2 Wave recording summary

Station Name	Recorder Type	Dates of Records	MIAS Ref No.
Littlehampton	WRB	Mar 1985-April 1986	1511
Owers	SWR	Jan 1968-Mar 1971	177
West Winner	WRB	Jan 1972-Jan 1973	132
Milford-on-Sea	WRB	April 1987	1555
Christchurch Bay	WRB	Sept-Oct 1976	130
Southbourne, Poole Bay	WRB	Jan 1974-Mar 1979	131
Bournemouth	WRB	Part 1976	129
Portland	PG & FLWR	1964-1966	133,134
Portland Harbour (inside)	WRB	Sept 1985-Feb 1986	1550
Shambles L V	SWR	Mar 1967-Mar 1970	180

WRB - Waverider Buoy
PG - Pressure gauge
FLWR - Float level wave recorder
SWR - Shipbourne Wave recorder

The above data was obtained from MIAS, IOS Wormley (reference numbers are from the MIAS wave data catalogue-Ref 34).

5 REVIEW OF COASTAL DEFENCES

5.1 Selsey Bill to Chichester Harbour

The promontory of Selsey Bill forms a divide with to the littoral movement of beach material. The nett drift is north-eastwards and north-westwards away from the Bill. West of the Bill the drift is strongly unidirectional, because of the sheltering effect of the Isle of Wight against the south-westerly waves which are predominant in the English Channel.

These waves are diffracted around the Island and then refracted closer inshore so that they impinge on the coastline between Selsey and Chichester Harbour at a very small angle. This gives rise to a dominance of wave action from the south-east. However the south-westerly waves are important in coastal and sea defence works, since they strike sea walls and similar structures almost "head on" and can cause overtopping and flooding of low lying parts of the coastline.

At the Bill about 750m of frontage consists of a shingle beach backed by eroding clay cliffs. The backshore is partly protected by a dilapidated concrete wall at Bill House, some gabion work further west and a short length of deteriorating timber breastwork at the eastern end. Erosion of the cliffed backshore is severe in places to the west of Bill House. The timber breastwork is frequently overtopped at high water and the backshore has to be maintained by frequent backfilling with shingle at the rear of the breastwork. This frontage probably gets very little feed from the west but is perhaps fed from the offshore shingle banks of the Owers, and possibly also by pebbles "rafted" by kelp and brought ashore in storms. To the west of the breastwork about 1km of frontage is protected with a vertical concrete wall with a stepped toe. The area once had a shingle beach but this has largely disappeared and the sand cover over the clay substratum is now quite thin. Wave overtopping takes place at high water even under low wave conditions. Prior to the construction in the 1950's of the present system of defences (which are now deteriorating) this area had the reputation of being one of the most rapidly eroding parts of the UK coast (Ref 2). The sand beach along this frontage is groyned. Work was recently carried out at Selsey West Beach at the western end of this wall. This included the stepped encasement of 300m length of sloping apron to the existing wall. A number of the timber groynes were completely renewed and a number of concrete buttresses constructed to the roots of the groynes. The wall has also been extended westwards, following the set back due to the recession of the adjoining unprotected length of cliff. The area protected by the concrete wall is believed to be a point of drift divergence and any supply from offshore appears to be insufficient to make up the deficit caused by the material being transported both eastwards and westwards out of the area.

There is a short stretch of natural cliff west of the coastguard station and this cliff is fronted by a wide shingle beach. Further westwards the cliffline drops and the shingle ridge extends continuously over a frontage of 4½km maintained by Southern Water, and protecting low lying land. Maintenance consists of groyne repair, addition of gravel from inland sources and regrading of the beach profile (ie. heightening) so as to prevent wave overtopping and breaching.

Between Selsey Bill and Chichester Harbour the frontage is maintained by Chichester District Council and Southern Water and protection consists of concrete sea walls (at Bracklesham) and vertical timber breastworks (at East Wittering). The shingle beach overlying the flat sand foreshore is not substantial due to a reduced shingle supply from the east, where the cliff, at Selsey Bill have been protected by sea walls. Along the Medmerry frontage the shingle ridge is maintained by Southern Water who recharge the beach regularly. Nevertheless breakthroughs occur at high tides even under relatively small wave heights, these having to be repaired by mechanical regrading of the shingle ridge.

Further westwards to East Head Spit the shingle ridge is protected at strategic places by vertical timber breastworks and gabion revetments and at the "knuckle" of the Spit, by breastworks and a gabion wall. The beach is groyned in order to retain the dwindling supply of shingle from the east. The volume of drift in recent years has declined and the now appears to be little input of material to Chichester Bar. East Head Spit has varied in size over the years but has gradually recurred northwards into the harbour since about 1898. There are now local fears that the neck of the spit ("The Hinge") may become breached under sufficiently adverse wave and tidal conditions.

Littoral drift along this frontage has declined (Harlow, Ref 4) from about 75,000m³ per year in the latter half of the nineteenth century to about 9,000m³ per year at present. The reduction is due to a number of causes, not least of which being the construction of major coastal defences at the Bill in the 1950's. However the drift had already begun to decline earlier than this and the groyning of the Medmerry frontage over many years has probably had an equally important effect in slowing down the littoral transport rate. A study by HR examined the feasibility of feeding the beach from offshore by dumping shingle from barges at the low water line. Extensive fluorescent tracer tests showed that the onshore movement was slow and that this was not an effective method of nourishment (Ref 35). The beach ridge is presently being nourished by mechanical means from inland sources. At Medmerry the beach is backed by sea walls and a timber revetment. In contrast East Wittering has less 'hard' coast protection fronting the sand dunes, consisting of gabions and breastworks near the harbour entrance. The beach itself is groyned and is mainly shingle with some clay exposures giving way to sand close to the harbour entrance. At present some 7,000m³ per year of material is transported by waves into the harbour entrance while wind blown sand finds its way onto The Hinge. There now appears to be little direct supply of material from Medmerry to Hayling, which now relies on the reservoir of material still existing on the Chichester Bar.

5.2 Hayling Island

Hayling Island, which separates Chichester and Langstone Harbours, has a south facing shoreline with a seaward frontage of about 6km. At each end of the frontage there are large intertidal sand and shingle spits, West Pole Sands to the east and the East Winner to the west (confusingly!).

Littoral drift is generally from east to west along most of the frontage because the Island is largely protected against waves from the west and south west by the Isle of Wight.

At the western end the beach has until very recently been accreting as a result of the nett drift, with a succession of curving beach ridges at the cuspate foreland of Gunner Point. At the eastern end there is a drift divide, with some of the beach material being carried westward along the island's frontage and a considerable portion also being transported eastwards and then northwards around Sandy Point into Chichester Harbour entrance. The tidal current flow on the west side of the entrance is rapid, and undoubtedly some of the material is swept seawards onto Chichester Bar. From the Bar some material is driven back onshore. The drift of shingle has resulted in long term beach lowering at the eastern end of Hayling Island to the extent that serious wave overtopping was taking place in recent years. Conditions of erosion were so severe that the Havant Borough Council recently carried out a major re-nourishment.

Prior to the beach nourishment, the eastern section was protected by sea walls and groynes. Due to the falling beach levels, the sea walls were exposed to wave action for a large part of the tide and thus had to be refaced and aprons added. Beach levels continued to fall and this led to overtopping and flooding at increased frequency. It was decided that the most cost effective way to protect the area was by means of a beach replenishment scheme. Thus, in 1985, some 520,000m³ of shingle dredged from Owers Bank were delivered to the beach by barge and distributed over some 2km of frontage at the east end of the island. Since that date 30 new groynes have been constructed to hold as much of the replenished beach in place as possible and a recycling exercise carried out using material from the recent accretion at Eastoke. The nourished beach provides a high degree of protection but suffers from the problem of high mobility. Also there are difficulties in maintaining an optimum groyne profile since the beach has still not reached an equilibrium state.

Coast protection is not necessary at the centre of the Hayling Island frontage but serious downdrift erosion is now taking place to the west of Beachcot. The coastal defence works west of Beachcot consist of a timber revetment and groynes which now hold very little shingle. Lowering of the beach levels on the downdrift (west) side of the groyne faces has been so severe that a number of the groynes have been overturned and have had to be reconstructed.

The problem of beach movement from the nourished area is still a cause for concern. Havant Borough Council are monitoring the situation and are regularly surveying and analysing beach profiles. Measurement of the nearshore wave climate has also been carried out during 1988/89 with the assistance of Hydraulics Research. Various strategies for retaining the beach fill where it is most needed (and balancing this against the need for protecting adjoining areas) are being examined.

5.3 Portsea Island

From Langstone Harbour to Portsmouth Harbour the coastal strip of Portsea Island is predominantly urban and is therefore heavily protected.

The beaches fronting Portsea Island are shingle and there is a weak nett west to east littoral drift. Beach movement is dominated by waves generated over the small wind fetch across the Solent. Since the waves are small, the littoral drift is low. Harlow (Ref 4) has studied the long term volumetric changes in this area and has found the rates of drift to be insignificant, probably less than 2,000m³ per year of nett movement. Because the beaches neither gain or lose much in the way of material, there is a high degree of stability (except in isolated promontories such as at Southsea Castle, which are more exposed to wave action).

Portsmouth City Council are the coast protection authority for the frontage between the two harbours, while within the harbours the responsibility for coastal defence is shared with British Rail, the Ministry of Defence, Southern Water and various private land owners.

At the eastern end of Portsea Island, within the Langstone Harbour entrance, coast protecion consists of stone and concrete aprons, gabions, steel pile groynes (constructed in zig zag style on the beach) and timber groynes. The defences here are, in places, somewhat in disrepair.

From Langstone Harbour west to South Parade Pier there is accretion with the wide shingle beach backed by a low sea wall (virtually a coping for the promenade). The nett drift is low but it is likely that a small quantity of material comes from the east via the

Langstone Harbour Bar during exceptionally strong easterly gales.

West to Southsea Castle the coast protection consists of a concrete sea wall and groynes. The shingle beach fronting this protection is fairly stable.

At the western end from the Castle to Portsmouth Harbour, the coast is protected by 'hard defences' ensuring that erosion affects only the foreshore. This results in fluctuating beach levels but no loss (recession) of land. The protection consists of old walls, concrete revetments of varying condition and some groynes.

Within Portsmouth Harbour and at its entrance there are no serious coastal defence problems. The responsibility for the various wharves and sea walls here is shared between the Ministry of Defence, British Rail and Portsmouth City Council.

5.4 The East Solent

This area covers the coastline from Portsmouth Harbour along the east shore of Southampton Water to the Schedule 4 boundary just south of the River Hamble.

From Portsmouth Harbour southeastwards to Gilkicker Point, coast protection is the responsibility of the Ministry of Defence. The protection consists of concrete sea walls and groynes. Beach levels on this frontage have fallen to such a degree that there is little material to be moved. The volume transported in a nett west to east direction from Gilkicker Point to Portsmouth Harbour is so small as to pose few problems with respect to harbour siltation. The drift is of the order of 1,000 - 2,000m^3 per year, some of this possibly accumulating on the Hamilton and Spit

Banks off the harbour entrance. Gilkicker Point is a major shingle headland and an area of historical accretion which is now undergoing recession, being deprived of material from the west.

In Stokes Bay west of the point the shingle beach narrows towards Privett where a concrete sea wall and groynes, built in 1974, protect the coast road. Downdrift erosion is evident to the east of this wall and the volume of shingle transported towards Gilkicker Point is now decreasing with time. At the western end of Stokes Bay, the beach is wider with no protection at the eastern end of the Ministry of Defence property at Browndown. At the western end of Browndown the situation is serious and erosion southeast (downdrift) of Lee on Solent is encroaching onto the western end of the Browndown frontage. Erosion is also evident at the south eastern end of the Lee on Solent concrete sea wall and promenade. Hard defences front the town and comprise a vertical concrete sea wall (1955 - 1972) which although at present appears adequate, may need to be monitored in the near future. The shingle beach fronting the wall is steep and the foreshore is becoming narrower with time. With deeper water encroaching landwards wave activity inshore is progressively increasing. Beach erosion problems are therefore likely to worsen in the future.

The beach north west of Lee on Solent becomes flatter, with a wider inter tidal area. Hillhead is situated on the clifftop, the toe of which is protected by intermittent low walls and groynes. The cliffs drop sharply to Hillhead Harbour which is at the mouth of the River Meon. The Harbour is protected on its eastern side by a concrete capped sheet steel piled wall and to the west by a concrete sea wall and groyne system. Beach nourishment material placed on the west side of the harbour mouth has been transported eastwards across the entrance in the direction of the nett littoral drift. The low lying marsh hinterland is known as Titchfield Haven and the area is protected by Southern Water.

A shingle ridge stretches northwest below eroding and unprotected cliffs as far as the Solent Breezes (a holiday site). Here the cliffs are lower and the holiday site is protected by stone filled gabions and a rubble revetment. This area is a point of littoral drift divergence. To the southeast of Solent Breezes, waves travelling up the West Solent transport material towards Hillhead Harbour. North west of Solent Breezes the effect of Calshot Spit (on the other side of the estuary) is to give shelter against south-westerly waves so that southerly waves become predominant. Thus the nett littoral drift is to the north west and continues in that direction beyond the schedule 4 boundary at Hook Park.

5.5 The West Solent

The frontage considered here is the coastal fringe from the schedule 4 boundary, (just south of the oil refinery) extending round Calshot Spit, and then west to Hurst Spit.

On the west bank of Southampton Water, saltings form the first line of defence against the sea and man-made defences are rudimentary. This is a sheltered area with regard to wave activity and the power station at Fawley, built on reclaimed land, is situated well above the highest tides and does not require hard defences. South of the power station partly reclaimed land backs the saltings and requires little protection. Minor bank erosion takes place at the high tide mark and at one stream outlet the bank is protected by a small sand/cement bag revetment.

Calshot Spit is a long shingle ridge extending eastwards into Southampton Water. The coastal defences around the Spit consist of a few timber groynes, some low concrete walls and stone revetments. These are old but probably adequate in view of the lack of serious erosion. The Spit is relatively stable with only minor changes at the high water line. Large fluctuations of the low water line are probably related to the activity of the tidal currents but these changes are unlikely to affect the stability of the Spit. There are local problem areas. For example, the foreshore on the inside of the Spit, fronting a low vertical sea wall, is lower than the beach on either side.

Between the Spit and the village of Calshot to the west, a long shingle ridge is the responsibility of the New Forest District Council. Old groynes now largely fallen into disrepair are spaced along this shingle beach.

The shoreline between Calshot and the Lymington River is largely in private ownership. Coast protection is low cost and uses locally cut pine posts or palings, inserted vertically into the beach to form either breastworks or groynes.

West of Calshot the eroding cliffs of sand and gravel are exposed to south easterly storms. The most serious erosion appears to be just north of Cadland House. Timber groynes and breastworks have been placed at the foot of the cliffs to try to reduce cliff recession. The shingle ridge is at its narrowest at Bourne Gap and overtopping of the ridge takes place occasionally though the resulting flooding is not thought to be a serious problem.

The intertidal zone in this area consists of mud and low shingle banks and has greatly reduced in width over the last century (Ref 36). This situation is somewhat typical of the whole stretch of the coast from Calshot to Keyhaven.

From here to the Lepe Country Park the shingle ridge, behind which is low lying land, is groyned in places and further held by a disused wartime concrete and brick jetty. The coastal defences are derelict but there are no serious coastal erosion problems.

The Lepe Country Park is leased to the Hampshire County Council. It includes Stone Point, a cliffed promontory subject to erosion. Here locally cut timber forms breastworks and groynes protect the soft sandstone cliffs and the shingle foreshore. To the west of Stone Point the road runs close to the shore and is protected by a concrete block revetment and a recently constructed concrete seawall. The defences from here to the Beaulieu River are largely in disrepair. The intertidal zone is reducing in width due to the rapid landward movement of the low water line. Thus erosion of the backshore is likely to worsen in the future due to increased wave exposure. In the Beaulieu river mouth, saltings (sheltered by Needs Ore Point) form the primary protection against the sea. Inside the entrance the river banks are raised to reduce the likelihood of flooding, but in places these have now deteriorated. The frontage is in private ownership.

At Needs Ore Point on the west bank of the Beaulieu River a spit which has been extending eastwards over the last century has been joined to Gull Island by a man-made shingle ridge. The infilling of the gap substantially increases the effective length of the spit. The shingle infilling in 1986 has not as yet affected the river's regime. There is a possibility that the deflection of the river flow in an easterly direction will cause erosion of the east bank, of the Beaulieu River.

From here to the Lymington River the low lying ground is in private ownership. Due to the shelter afforded by Hurst Spit to the west and the Isle of Wight to the south, this coast is rarely troubled by severe storms. The shoreline, which has a narrow shingle beach, is protected with low cost, piecemeal protection. There are also stretches of earth bank fronted by eroding saltings, protecting low lying land. There have only been slight changes in the position of the high water line historically but now the shoreline is eroding. The most significant changes, from a coast protection point of view, is the large reduction in the intertidal zone. At Pylewell the low water mark has receded some 370m in the last century (Ref 37). The saltings are now in poor condition along much of this frontage and the clay substratum is eroding in places (Ref 36).

On the east bank of the Lymington River some recession of the saltings is evident. On the west bank, the Lymington Harbour Commissioners maintain quays, sea walls and moorings. On this bank also, saltings erosion is evident, especially at the river mouth.

In the shelter of Hurst Spit, Pennington Marsh and the Keyhaven frontage has concrete faced clay embankments which stretch from the Yacht Haven at Lymington to Keyhaven. The defences are maintained by Southern Water. The walls and earth banks are old and in a poor condition and there is a proposal in hand to renew them. The foreshore was well protected by saltings from some three kilometres east of the Lymington River to Keyhaven. The saltings are eroding however, and a recent report (Ref 37) shows that over the last century the low water line has moved landward by as much as 500m. Further loss of saltings and lowering of the level of the intertidal flats as the mud is washed away will have serious consequences, increasing the risk of flooding to the hinterland. The problem would be even more acute if Hurst Spit were to become breached (see 5.6). The full reasons for the reducing width of the foreshore are not known, though the long term rise in mean sea level is a contributary factor.

The thin strip of shingle and sand at the landward end of the intertidal zone is also in decline. Dyer (Ref 7), in 1971, indicated that the small feed from offshore to this frontage is largely shingle, much of which could have originated from the old Solent River which once ran parallel to the present coast. It is possible that drift from the west once carried shingle from the eroding cliffs in Christchurch Bay, eastwards, via Hurst Spit. A decline of the Spit has been brought about by a reduced littoral supply from the west, (due largely to coastal defence works). It is therefore likely that the supply to the West Solent has also now been reduced.

5.6 Christchurch Bay

Christchurch Bay stretching from Hurst Spit to Hengistbury Head is a long, indented, southward facing bay with a varying wave exposure. This exposure is greatest at the eastern end. Littoral drift is in a nett west to east direction all around the bay. Studies by Southampton University (Ref 38) indicate that the rate is very variable along this frontage and despite long term recession the bay has not achieved an equilibrium plan shape. The central part between Barton and Highcliffe is particularly unstable. At present the amount of material "released" by cliff recession is substantial. Despite much of this being fines some shingle accretion has occurred at Hordle Cliff. This accretion is local and further eastwards erosion again persists. The protection of one soft area by defences generally leads to increased erosion downdrift. It is evident that despite the coastal defence measures being currently undertaken, erosion in parts of the bay will persist in the long term.

At the south-east end of Christchurch Bay the 2km long shingle ridge of Hurst Spit ends at Hurst Castle. Responsibility for protection of the distal end lies with the Department of the Environment and the coast defences consist of groynes and timber bulkheads. The end of the shingle spit has traditionally been relatively stable. However the general landward recession of the spit onto the Keyhaven marshes is now causing a drop in shingle level on the seaward face of the Castle frontage. The present defences cannot be considered as a permanent solution to the problem. As recession continues so the Castle will become more 'isolated' seaward of the natural line of the shingle spit. The middle section of the Spit is unprotected although it is maintained, periodically re-profiled and has recently been artificially replenished. This too is a problem area.

The shingle beach along Hurst Spit is now a thin veneer over a clay substratum. The shingle is pushed up by waves to form a relatively narrow storm ridge. With the reduced supply of shingle from the west this veneer will be further reduced and the clay substratum will undergo accelerated erosion. The shingle crest will then be subjected to larger waves as the depth of water at the toe of the spit is increased. Unless major works are carried out recession will increase in the future as will the threat of breaching. A report by C H Dobbie and Partners (Ref 8) studied the history of the spit. It was noted that since 1954 the landward end of the spit had been breached on numerous occasions. Despite the increasing amount of maintenance and capital works during the last decade, the spit continues to be vulnerable to wave attack. During the winter of 1983/84 breaching took place on no less than nine occasions. A partial breach also took place in 1987 after the construction of the most recent remedial works.

The western end of the spit is protected by randomly placed rock on a 1 in 3 slope. There is also a rock strongpoint which, while helping to stabilise the landward end of the Spit, shifts the problem of erosion to the central part. Coastal defences at the Milford end of the Spit are the responsibility of the New Forest District Council.

The frontage at Milford has a shingle beach. At the eastern end is a stepped wave wall and three rock groynes. Towards the western end of the town the land rises to form a cliffed shoreline and this continues west as far as the county boundary at Chewton Bunny. The wave climate at Milford is currently being studied by Hydraulics Research for the New Forest District Concil, using a wave rider buoy.

With the exception of the naturally accreting shingle beach at Hordle the coastline is generally eroding. Even where beach erosion is not serious, cliff recession which is accelerated by aerial weathering, continues to take place. The rate of the erosion is highly variable, this being due to the nature of the cliff deposits and the varying degree of wave exposure in different parts of the bay. Thus erosion of the sandy cliffs at Hordle is slow due to the presence of the wide shingle beach. One reason why the beach accretes at Hordle may be due to a local reduction in the transporting capacity of waves in this area. Although many studies have been carried out in Christchurch Bay, none have been sufficiently dailed to explain such "local" changes in beach behaviour.

At Barton on Sea coastal defences together with cliff drainage protect the beach from further erosion and the cliff face from slippage. This includes several rock groynes and a rock revetment. Shingle nourishment has been carried out on a modest scale and it is proposed to add a T-head extension to the four downdrift rock groynes in an attempt to contain the re-nourished beach more effectively. East of the Barton coastal defences there has been rapid erosion, with the cliffs receding at the rate of nearly 1m per year (Ref 37) over the last century.

From Barton to Chewton Bunny, the coastline is receding. This is because soft cliffs of sand and gravel overlying clay are unprotected and because coast protection works further to the west are cutting off some of the littoral drift. The beach consists of a mixture of sand and shingle with numerous mudflows at the cliff toe. The historic recession rate of 1m per year is probably now being exceeded, with the increasing effectiveness of coastal defences updrift.

The coast protection authority for Christchurch Bay up to Chewton Bunny is New Forest District Council. West of the stream outfall at Chewton Bunny, the coast protection authority is Christchurch Borough Council.

At Highcliffe, shingle beach replenishment, improvements to the existing groynes and revetment and the construction of rock groynes have taken place along the Chewton Bunny to Avon Beach frontage in recent years. The cliff toe has been protected by an artificial shingle beach built in 1984 and extending over one kilometre west of Chewton Bunny. Its performance is being monitored by the Council. The large rock groynes associated with this scheme have stabilised the "artificial" foreshore and to date little of the nourishment material has been lost.

From Highcliffe Castle to Friars Cliff a short frontage is now the responsibility of Christchurch Borough Council, having been taken over from the Ministry of Defence. It is protected by concrete sea walls and groynes. From Friars Cliff to the entrance to Christchurch Harbour the coast protection authority is again Christchurch Borough Council. The cliffs which were continuous from Milford, lose height west of Friars Cliff giving way to low ground at Mudeford. The sand beach which fronts these cliffs is generally stable and is held by timber groynes and backed by concrete and sheet steel walls. Erosion was once a problem on the north side of the harbour entrance but since the recent reconstruction of rock groynes accretion of sand and shingle has taken place. The stability of this frontage is due to the plentiful supply of sand from the southwest but also depends on the configuration of the entrance channel through which there is a rapid tidal flow. In historic terms the spits at the entrance have seen large changes (Ref 16) and predicting the future erosion/accretion pattern is difficult.

The south side of Chichester Harbour is protected by Mudeford Spit. This sand bank once grew so rapidly that it forced the entrance channel, known as the 'Run', to follow the coastline as far east as Highcliffe Castle. After the cessation of ironstone mining on Hengistbury Head and the construction of the long groyne, the supply of material from west of the Head has dwindled. Mudeford Spit has now reduced in size and is no longer as volatile as it was during the last century.

The north end of Mudeford Spit is leased to Christchurch Borough Council from the Borough of Bournemouth. It is protected against breaching by a rock revetment, a short length of sheet steel wall and a number of rock groynes. The rock groynes were first constructed in 1981 in response to a downdrift problem which had developed at the northern end of the seawall. This scheme was successful and the distal end of the spit increased substantially following groyne construction. The rock groynes became the forerunners of similar "low cost" schemes within the Borough (Ref 40).

Bournemouth Borough Council have recently completed a large scale coastal defence scheme over the frontage from the southern end of the Mudeford Spit around Hengistbury Head to Southbourne. A number of rock groynes were constructed, in 1987 (Ref 15), from Mudeford Spit west to the long groyne at Hengistbury Head. This work was carried out in conjunction with a concrete seawall extending west to the long groyne. The purpose of the rock groynes is to build up a beach and stabilise the foreshore in this area of former downdrift scour. The seawall is intended to stabilise the toe of the eroding sand/clay cliffs east of the long groyne.

5.7 Poole Bay

This large bay extends from Hengistbury Head to the Isle of Purbeck; like Christchurch Bay it is strongly indented and experience a wide variation in exposure to wave activity.

From Hengistbury Head to Southbourne the foreshore is sand intermixed with shingle, with the backshore largely unprotected. The high cliffs of Hengistbury Head drop away quite sharply just east of Double Dykes and then rise again at Southbourne. These sand and gravel cliffs are backed by amenity land.

A 214m long groyne, constructed in 1938, protrudes seaward from Hengistbury Head and traps some of the eastward littoral drift, creating a wide sand beach on its western flank. This beach protects the cliffs on the south extremity of Hengistbury Head. At Double Dykes a recently constructed gabion revetment protects the seaward end of an ancient Iron Age fortification from erosion. The low cliffs in this area are about 4½m above sea level and have been eroding on average at a rate of 1m per annum. To the landward north of Double Dykes there is a small valley and the land generally falls to the Christchurch Harbour. There is a danger that a breach could form here, and with it the formation of a new channel through to the Harbour. Protection in the form of long timber and rock groynes has recently been completed from Double Dykes west to Southbourne. Rapid erosion used to take place when the tidal level was sufficiently high to allow waves to reach the cliff toe. During severe storms the beach is dragged down and the cliff face cut back, resulting in a vertical scarp. Subsequently, aerial weathering gives further, slower erosion of the loosely bound sand and shingle cliff face. The construction of the system of long groynes together with artificial nourishment is designed to widen the beach and hence reduce the frequency of waves reaching the cliff toe.

From Southbourne to Sandbanks the resorts of Southbourne, Boscombe, Bournemouth, and Poole form an almost unbroken strip of urban development. Along this frontage the sandy beach is backed by concrete or masonry sea walls fronting a promenade, with cliffs rising steeply behind. The walls, built in stages from around 1807, are in fair condition. The cliffs of sand and gravel with lenses of clay, have often been a source of trouble, but in recent times drainage and regrading has reduced cliff slippage. Most of the frontage is already groyned but a major programme of groyne reconstruction is scheduled for the 1990's. A replenishment operation was carried out here in 1974-75 when approximately 650,000 cubic metres of sand, dredged from offshore source was pumped onto the beach. The replenished beach covers approximately 5km of frontage from Southbourne to Bournemouth Pier. The scheme has been successful and has very significantly reduced seawall maintenance.

West of Bournemouth, Poole Borough Council are responsible for continuous concrete sea walls and groynes (except for an unprotected gap of some 250m, at Canford Cliffs). The coastal defences built in stages from 1920 to 1981 are mostly in fair condition. At the southwestern end, at Sandbanks, intermittent sea walls with some groynes are mainly in private ownership. This area is sheltered from westerly and southwesterly waves by the Isle of Purbeck and has been more stable historically than the eastern part of Poole Bay. There is a reversal of the general drift direction here and material is transported from east to west towards the harbour entrance and Sandbanks. Any sand that moves westwards during south easterly gales tends to remain in the area. This has a significant effect on the growth of sand bars near the harbour entrance.

Poole Harbour is situated at the western end of the Bay. It is sheltered by Sandbanks, a long narrow spit to the north of the entrance and by the South Haven Peninsula to the south. Within the harbour, cliff recession has exceeded 40m in places over the past century (Ref 41) but in some areas there is also a large spread of Spartina saltmarsh. These marshes are undergoing considerable change (Ref 42), with recession being the dominant process. On the north side of the harbour there has been major reclamation and the northern perimeter of the Bay now consists of walls, quays, and stone revetments. The effects of reclamation have not been serious although the industrial use of the area has increased the level of pollution within the harbour. Coast protection is the responsibility of Poole Borough Council which it shares with Dorset County Council, Poole Harbour Commissioners, British Rail and various private land owners. There are no serious coastal defence problems in the harbour, except in Brownsea Island.

5.8 The Bays of Studland and Swanage

South of Poole Harbour the South Haven peninsula is owned by the National Trust. The coastal fringe is low lying with marram covered dunes backing a sand beach. It is well protected from all but strong south-east waves and the tidal range in Studland Bay is very low. The sand spits extending northwards from Studland enclose large areas of saltmarsh and heathland. This area is largely unprotected and apart from some dune erosion has not suffered greatly. At the southern end of Studland Bay the sand beach is backed by cliffs of the Bagshot Beds. Here there is local cliff recession and some derelict coastal defences can be found in the intertidal zone. There is no housing development at risk and the cliff recession is not causing any serious problems. South of Studland Bay there are chalk cliffs which extend from Handfast Point to Ballard Point. The area is part of the Purbeck Heritage Coast and is unprotected.

To the south of Ballard Point is Swanage Bay, which is cut into the soft clays of the low lying eastern edge of the Isle of Purbeck. The Bay can be divided conveniently into three stretches; Ballard Beach to the north, the Grand Hotel cliffs, and the town beach. Ballard Beach consists of a pebble ridge overlying a chalk rock foreshore and has no coast protection works. In the centre of the Bay the Grand Hotel cliffs are fronted by a concrete sea wall and promenade. Timber groynes retain a beach of fine sand. To the south, the coarse sand beach that fronts the town centre is well sheltered from the predominant south-westerly storms and the concrete and stone sea walls and timber groynes here require little maintenance.

The frontage of Swanage Bay has several owners including the Swanage Town Council, the Swanage Pier Company and part is also in private ownership. Purbeck District Council, the coast protection authority, maintain the walls fronting the town. South of the pier around Peveril Point, the frontage is privately owned and has intermittent sea walls built on a rocky foreshore.

The Bay is largely self contained and while there is some alongshore 'movement' there is no evidence of any nett change in volume. The chalk headland of Ballard Point to the north and the limestone headland of Peveril Point to the south both act as large groynes and there is little if any loss of beach material.

5.9 Swanage Bay to Weymouth Bay

High cliffs occur along most of this stretch of coastline. Except for some cliff top development in Durlston Bay the area is largely unspoilt and has little need for coastal defence works. Holiday development in Ringstead Bay is protected by unintrusive low cost defences. Larger scale coastal defence works only begin in Weymouth Bay.

In Durlston Bay the limestone cliffs are unstable, putting cliff top development at risk. The rocky foreshore at the foot of these cliffs is unprotected. The area is privately owned and lies within Purbeck District.

From Durlston Head to St Aldhelm's Head there is a limestone plateau which is resistant to erosion. At sea level the cliffs are steep and in places overhang as a result of wave undercutting. There are also many caves formed as the result of jointing faults in the rock strata. The Portland limestone beds were quarried there are and remains of 'quays' hewn out of the rock. There are virtually no beaches along this stretch and no coastal problems. The area is privately owned and is in Purbeck District.

West of St Aldhelm's Head the limestone plateau gives way to a clay/shale plateau (e.g. Kimmeridge Clay) which extends almost to Worbarrow Bay. The near vertical cliffs are eroding quite rapidly and in many places limestone bands form ledges (the Kimmeridge Ledges) which jut out to sea.

Differential erosion has created a number of deeply incised bays. These include Chapman's Pool, Egremont Bight, Kimmeridge Bay and Brandy Bay. There are thin, discontinuous sand and pebble beaches along this frontage and the littoral drift, which is in a nett west to east direction, is low and intermittent. From St Aldhelm's Head to Kimmeridge Bay the area is privately owned and within Purbeck District. From Kimmeridge Bay to Worbarrow Bay the coastline is owned by the Ministry of Defence. There is no coastal development in this area.

Between Worbarrow Bay and White Nothe there is a variety of geological strata ranging from soft Wealden clays to chalk and limestone beds, with varying degrees of resistance to wave action. The topography is varied, including deeply incised bays such as Lulworth Cove, offshore stacks as at Durdle Door and great landslips as at White Nothe. The beaches are predominantly shingle in the bays. The nett direction of the littoral drift is from west to east but the movement is low. There are no man-made coastal defences in the area. Between Worbarrow Bay and Lulworth Cove the land is owned by the Ministry of Defence. From Lulworth Cove to White Nothe the coast is within Purbeck District.

West of White Nothe there is a large area undercliff consisting of slipped Gault, Greensand and Chalk. Further westwards the cliffs drop to a plateau of Kimmeridge Clay which extends to Ringstead. In Ringstead Bay a holiday site has a rudimentary timber breastwork and rock armouring which do not intrude into the intertidal zone. Beyond Ringstead there are clays, shales and grits. This area has many cliff slips extending as far west as Bowleaze. For example at Osmington Mills there are extremely unstable cliffs of shale and mudstone and here early in the twentieth century the biggest recorded mudflow in Britain took place. The foreshore consists of shingle and large pebbles overlying rock, and the beach is fairly continuous over the frontage (although the frequently occurring mudflows do intrude onto the top part of the beach). While there is a potential nett west to east littoral drift there is little evidence of much material being transported along the coast. The promontories and rock ledges tend to reduce littoral

littoral drift to a minimum. The numerous offshore ledges also dissipate much of the wave energy particularly at low tidal states.

Bowleaze Cove is in private ownership, with a holiday complex at the coastline. The backshore here is protected by a short length of concrete seawall and gabions, these being the responsibility of the owners.

From White Nothe to Redcliff Point the coast lies within West Dorset District. Beyond that the authority is Weymouth and Portland Borough Council. However the coastal defences within this stretch are all privately owned.

5.10 Weymouth Bay

From Redcliff Point to Newton's Cove (south of Weymouth Harbour entrance), the coast is within Weymouth and Portland Borough.

The high ground of Furzey Cliffs west of Bowleaze consists of Oxford clay and the unstable seaward slopes have recently been regraded. A new sea wall and groynes at Overcombe replace limestone rock and gabion protection. Immediately west of this a concrete sea wall protecting low lying land at Lodmoor continues to Weymouth. The stretch of wall fronting Lodmoor has been overtopped and the coastal defences here generally require some upgrading. There is a long stretch of shingle beach extending from Lodmoor to Weymouth. The pebbles decrease in size from Lodmoor south-westwards due to reduced wave exposure and give way to a wide sand beach between Weymouth pier and the entrance to the Harbour. There is some evidence of erosion of the shingle beach at Lodmoor, and it would appear that the wide sandy beach to the east of the harbour has taken a slightly different alignment following the extension to the north pier about 10 years ago. Further back in time the construction of the breakwaters of Portland Harbours also caused changes in this frontage.

The promontory called the Nothe, on the south side of the harbour entrance is amenity land and was protected by stone and concrete seawalls and some gabions. Landslips occurred on the south face of the Nothe during the winter of 1987/88 as a result of heavy and prolonged rainfall. The retaining wall on the south side of the Nothe was destroyed and has now been replaced by a more substantial structure.

The south part of Newton Cove, situated between the Nothe and the northern breakwater of Portland Harbour, is protected by a low masonry wall and rock armouring. This and a short stretch of wall south of the breakwater is the responsibility of the Ministry of Defence.

Further south the cliffs within Portland Harbour are also subject to slippage and part of Sandsfoot Castle has been lost to the sea. Here the cliffs are Sandsfoot and Nothe clays capped with limestone. Erosion has released material for the development of sand beaches. No cliff top development is at risk and there are no coastal defences along this frontage, apart from a short stretch of stone wall north of the entrance to the Fleet and some gabions east of Sandsfoot. This coastal area comes under the jurisdiction of the Weymouth and Portland Borough Council.

A shingle beach extends from the mouth of the Fleet southeastwards to Portland. This beach is within Portland Harbour (and is dissimilar and quite distinct from Chesil Beach). Since the construction of the Harbour breakwaters, the beach is no longer supplied with shingle from the north face of Portland Island but is relatively stable. Responsibility for coastal defences between the Fleet and Portland lies with the Crown Commissioners, British Gas and the Ministry of Defence. Here rock and gabions protect a gas main. There are also some recently constructed drains which empty through this beach into Portland Harbour. These have been constructed to cope with flood water in the eventuality of Chesil Beach being overtopped (Ref 43). The drains and associated works are the joint responsibility of Wessex Water and the Weymouth and Portland Borough Council.

The Isle of Portland is composed mainly of Portland and Purbeck stone, with Kimmeridge Clays on its northwestern and northeastern sides and high, resistant limestone cliffs to the south. No serious erosion is taking place here, although quarrying has led to the accumulation of limestone waste at the shoreline. The northern part of the Isle of Portland is owned by the Ministry of Defence. The harbour area and the coast, as far south as Balaclava Bay, is protected by various sea walls and rock armouring. The coast protection authority for the rest of Portland is the Weymouth and Portland District Council. They have no coastal defences on the east coast.

The Bill of Portland forms the southernmost tip of the Island. Because it is situated in deep water with a rapid tidal flow off the Bill, it is extremely unlikely that any beach material is transported to Weymouth Bay from the west face of the Isle of Portland and vice versa. Indeed the Island is very rugged and has very little in the way of beaches. The Bill is thus an effective zero transport boundary and forms a natural divide between the coastline in

Weymouth Bay to the northeast and Chesil Beach to the northwest.

5.11 The Isle of Wight

The Island has a wide variety of geological strata running as a series of bands in an east - west direction. It is approximately trapezoidal in shape, with the main axis of chalk running from the Needles to Culver Cliff. To the north of the main axis there are sands, silts, clays and gravels which are easily erodible. There are also occasional areas of limestone giving more 'permanent' features such as the rock ledges around Bembridge. On the northeast facing coast from Bembridge to Cowes good shelter against wave activity has led to the development of fairly wide sandy beaches. On the northwest facing coast there are clay cliffs which are prone to slippage and this occurs intermittently from Cowes to Alum Bay, just north of the Needles. The beaches here are generally narrow and eroding, probably being swept clear by tidal flows.

In the south the strata is mainly Lower Greensand, with Wealden Beds occurring to the south-west in Brixton Bay and also at Sandown in the south-east. (The Bays of Shanklin and Brightstone are formed where the soft underlying beds of clay and ferruginous sands have been eroded by wave action). On the southwest facing coast the cliffs of sand and clay are eroding rapidly. There is massive cliff slippage at Blackgang Chine where the beds are underlain by Gault Clay. On the southeast facing coast saturated sand cliffs continue to erode, despite the construction of coastal defences.

Further southwards still, the chalk downs are again encountered between St Catherine's Point and Dunnose

Head. There are clay bands at the base of the chalk and this has led to slippage and extensive undercliffs stretching from Niton to Bonchurch. The erosion of the chalk has led to the development of pocket beaches of shingle and some stretches of sand. The picture over the Island's coasts is thus one of general beach erosion and cliff retreat. There are many stretches of coast designated as sites of special scientific interest and there are also a number of Nature Reserves and National Trust areas.

5.11.1 Culver Cliff to East Cowes

The Culver Cliff headland is the boundary between the northeast and the southeast facing coasts of the Isle of Wight. It extends seawards in the form of extensive rock ledges thus separating the beaches in Sandown Bay to the south from those in Whitecliff Bay to the north.

North of Culver Cliff the deeply indented Whitecliff Bay is eroding there being little supply from the south. Beach deposits are fairly sparse. The beds of coloured sands in the cliffs of the Bay are a source of beach material for the coast to the north. At the northern end of the Bay the Bembridge limestone runs out to sea in the form of extensive, nearly horizontal ledges. These ledges are found as far northwards as Bembridge. Despite the protection afforded to the backshore by these ledges, waves attack the soft cliffs of shales, brickearths and clays which extend northwards to Bembridge Harbour. The rate of cliff recession is about ½ metre per annum at Foreland reducing to less then half this amount just east of Bembridge Harbour. Sand and gravel derived from the erosion of these cliffs is transported towards Bembridge Harbour in the nett direction of littoral drift. This drift gives rise to the large accumulation of sand on the intertidal flats and a limited amount of shingle on the spit on the eastern side of the entrance channel to the harbour. There are derelict coastal defences around Foreland, indicating that the process of erosion in this area is not easily controlled and that it has been going on for many decades. There are short lengths of seawall, probably in private ownership to the north of Foreland. These also are generally in a poor condition.

The coast protection authority south of Bembridge Harbour is South Wight Borough Council. Within the harbour the seawalls and quays are owned by the Bembridge Harbour Improvement Company, with short stretches being in private ownership. Some of these walls are old and dilapidated but this does not pose serious problems since the harbour is well sheltered from wave activity. North of the harbour the coast protection authority is Medina Borough Council whose jurisdiction stretches around the north coast to Thorness Bay.

From Bembridge harbour mouth north towards Nodes Point there is some 800m of frontage protected by sheet steel piled walls, old masonry walls and short groynes, all of which are generally in a poor condition. The coastal defences are owned partly by Medina B.C, partly by the National Trust and also by private landowners. The foreshore here is wide and sandy but water depths at the sea wall (called the Duver) are low and there is little or no beach at high tide. Wave action along this wall can be quite strong. This may be partly due to the fact that the low water channel to the harbour runs close to the wall. At low water the inter tidal zone extends several hundred metres seaward on the other side of the channel. The nett rate of littoral drift across the sand flats fronting the harbour entrance has been estimated to be of the order of 80,000 m3 per year and is from south to north (Ref 44). The low water channel seawards of the harbour entrance is so shallow as to be ineffective in preventing the bypassing of sand. North of the harbour the intertidal zone gradually narrows up to Seaview and then widens again rapidly towards Ryde.

The coastline from Node's Point northwards, is backed by weak cliffs, and in Priory Bay in particular there is rapid erosion. There were coastal defences within this Bay but these are now derelict. Erosion here is partly due to cliff slippage and partly because of cliff toe scour. Horestone Point at the north end of Priory Bay has a rocky foreshore backed by slipping clay cliffs. The sea wall fronting these cliffs has partly collapsed and the sections which are still intact are in a poor condition. North of Horestone Point, the sand beach is groyned and backed by a poorly maintained low sea wall, which is overtopped even in relatively calm conditions. The groynes here are very flimsy. Further north, this embayment which extends to Nettlestone Point, has a sand and shingle beach. The coastline at Nettlestone Point is quite rocky and boulder strewn and the coastal defences are in a poor condition.

Further west the defences (extending to Puckpool Point) consist of a variety of concrete or stone sea walls, most of which are also old and in a poor condition. Part of the frontage is privately owned. The road runs along a shingle ridge across the mouth of a small inlet. The crest of the ridge is not very high and the road is probably flooded during the highest tides. The shingle beach overlying the rocky foreshore has some dilapidated groynes. The nett littoral drift is in a southeast to northwest direction. Shingle movement on the upper foreshore is restricted by the presence of headlands such as Nettlestone and Puckpool Points. However the intertidal zone widens markedly northwestwards from Nettlestone Point and there is probably a significant movement of sand on the lower foreshore, towards Ryde East Sands.

From Puckpool Point towards Ryde Pier, the coastal defences become more substantial and appear to be adequately maintained. The foreshore is sandy and beach levels at the toe of the seawall improve in a northwesterly direction. There are a number of crescent shaped concrete groynes towards Ryde Pier. Their strong curvature allows sand to be retained on their downdrift (west) sides. The beaches appear to be generally healthy although there is a slight local deterioration in beach levels at the base of the high vertical seawall near Ryde Pier.

To the west of the town centre the coastal defences have a large 'setback', indicating that the coastline to the west has been allowed to recede for many years. The coastal defences are not homogeneous, with short stretches of private walls being separated by stretches of massive seawalls (the latter presumably the responsibility of Medina B C). The level of the sand foreshore in this area appears to be somewhat lower than that to the east of Ryde Pier and is not particularly healthy. The coastal defences proper finish at Pelhamfield.

The coastline west of Pelhamfield is in private ownership and there is no easy access to the foreshore. The sands to the east are replaced by a muddy foreshore to the west of Binstead Hard. Binstead was once a source of building stone (limestone) and the fragmentary remains of Quarr Abbey are of this material. West of the Abbey frontage is Wootton Creek, which has a car ferry terminal for the Portsmouth to Fishbourne crossing. There are some old concrete seawalls and an old timber revetment on the east side of the creek entrance (seawards of the terminal). Low clay cliffs, particularly west of the entrance, have been eroding for many years. Local residents believe that erosion on both sides of the river mouth has become more serious in recent years. The wind fetch across the East Solent is limited and the nett east to west littoral drift is small. From Wootton to Old Castle Point, East Cowes the low coastline is formed of red and green clays and is eroding.

At East Cowes there is an old concrete seawall and old concrete groynes which stretch from Old Castle Point to the harbour entrance. Accretion of shingle on the east side of the breakwater at the mouth of the River Medina indicates a nett east to west littoral drift. Masonry wharves and jetties line both banks of Cowes Harbour. These are mainly the responsibility of the Cowes Harbour Commissioners though some stretches are in private ownership.

5.11.2 West Cowes to the Needles

From West Cowes to Gurnard Bay, the coast road runs at the foot of low cliffs and is protected by a seawall. Some of the coastal defences in this area were built as far back as 1894. The cliffs are subject to slippage, being made up of Bembridge limestone and marls on the higher ground with the clay Osborne Beds outcropping at sea level. The foreshore here consists of a very thin strip of shingle and is eroding.

In Gurnard Bay the beach is rocky and strewn with stones and shingle. It is backed in places by a low dilapidated seawall. Rapid erosion has been reported at Gurnard since at least 1957, with the soft clays of the cliffs and foreshore being almost continually exposed to wave attack. There is also aerial weathering and cliff slippage in this area. Landowners in Gurnard Bay have built their own seawalls and revetments, which in a lot of cases are breaking up or becoming undermined by wave action. In some areas the defences have been engulfed by earth movements. Beach surveys by Hydraulics Research indicate that there has been a significant lowering of foreshore levels in this area (Ref 45). There is also evidence of nearshore sea bed lowering. Thus the situation here, with regards to coast erosion, is quite serious.

West of Gurnard Point there are high cliffs of Bembridge marl which extend into Thorness Bay. There is active slippage on a large scale, as well as a tendency for mudflows. The foreshore is rocky, the underlying Bembridge limestone rising above sea level at Gurnard Ledge. The boundary of Medina Borough is located in Thorness Bay. The west end of the Bay and the coast beyond lies within South Wight Borough.

In the southern half of Thorness Bay high cliffs give way to low lying land at the mouth of two small streams at Little Thorness. Further south there are again cliffs of Bembridge marls with limestone at their base and these are subject to slippage.

Ground levels fall westwards towards the mouth of the Newtown River which is bounded by two inward recurving spits of sand and shingle. These spits rest on a platform of alluvium associated with former marshes. Recession has been taking place here for many years, despite the efforts of Southern Water and the National Trust who have tried to maintain timber groynes and breastworks on the seaward faces of the spits.

Littoral drift is into the mouth of the river but the magnitude is small and insufficient to prevent spit recession. A seawall surrounding the Newtown Nature Reserve (inside the river mouth) was breached in the late 1950's/early 1960's and the reclaimed land is now flooded at every high tide.

To the west of the Newtown River, the land rises to form the Hamstead and Bouldnor Cliffs which are seriously affected by major landslips and mudflows. The toe of the cliffs has little protection as the foreshore is muddy with exposures of clay, thus allowing erosion to take place even under relatively mild wave conditions. Thus along most of the Thorness to Yarmouth frontage beach deposits are sparse. The shingle is angular and appears to have originated from local cliff erosion (Ref 46).

The coast road between Bouldnor and Yarmouth is protected by a seawall which has been extended eastwards recently. The wall begins with a massive buttress/groyne at the eastern (updrift) end of this frontage and the clay cliffs backing the wall have been regraded by the Isle of Wight County Council. The foreshore is groyned but beach consists largely of boulders, with little sand or shingle.

On the west bank of the River Yar there is a sand and shingle spit (Norton Spit) to which the harbour breakwater is attached. The sheet steel piled breakwater is capped by timber planking. Large quantities of rock have been placed along its seaward face to protect it from wave action. The spit itself is groyned and backed by a simple timber breastwork. There is erosion at the western end of the Spit, near Norton.

At Norton a concrete seawall protects the road to Fort Victoria. At its western end it is extended in the form of a Maccaferri gabion revetment whose seaward face is grouted with bitumen. The beach in front of these defences appears to be virtually non-existent although there is a fairly good shingle beach further west near Fort Victoria. The 'set back' west of the gabion revetment is a good indication of the degree of landward recession taking place. The beach is groyned as far west as the pier, and the accumulation in this area and along the Fort Victoria to Yarmouth frontage in general has been supplemented by shingle from offshore sources. A large part of the frontage has been protected since the last century, but recession has continued, however, at about 1/3 metre per year (Ref 46).

Fort Victoria, situated at Sconce Point, is fronted by a small shingle promontory. An old concrete wall extends around the seaward face of the Fort and in places it is being undermined as a result of falling beach levels. The condition of this old seawall is generally poor although some maintenance has been carried out i.e part of the wall is now backed by concrete decking to prevent scour by overtopping waves. This amenity area is owned and maintained by the County Council.

Between Fort Victoria and Fort Albert the coastline is unprotected and shoreline recession has been taking place at the rate of about half a metre per year. The beach is sandy with small quantities of locally derived angular shingle. The gently sloping clay cliffs backing it are unstable and prone to both slippage and toe erosion. Old, partly collapsed seawalls extend around Fort Albert (which is now converted into flats). This area is fairly well sheltered from wave action but there are high tidal currents close inshore which remove a lot of the finer material derived from cliff erosion. The headland on which Fort Albert stands prevents any major transfer of material between the beaches on either side of it.

Colwell Bay to the south of Fort Albert is more exposed to wave action, being outside the shelter of the West Solent. The steep cliffs consist of Headon Beds of sands and clays and recession in the centre of the Bay has been taking place at the rate of about half a metre per year. The beach is of sand and shingle and some of this material is transported northwards. Two timber groynes trap beach material in the central part of Colwell Bay but do not offer much protection to the eroding reddish sand/clay cliffs. Further south the foreshore is groyned and backed by a timber breastwork which prevents direct wave attack to the foot of the cliff. The cliffs are nevertheless unstable, showing signs of slippage. Further southwards still the sandy foreshore is groyned and backed by a concrete seawall which extends continuously to the south end of Totland Bay. Here the cliffs are partly vegetated and consist of Headon Beds (sands and clay) and Osborne Beds (predominantly clays). Cliff instability continues to be a problem over most of this frontage and a number of landslips have occurred in recent years. In 1960/61, several houses were threatened but the cliffs have since been stabilised. The problems are now largely due to aerial weathering, the cliff toe being protected from wave attack (except in severe storms when wave overtopping takes place). The headland at Warden Point at the north end of Totland Bay also tends to reduce northward drift though probably to a lesser extent than the headland at Fort Albert. Shingle in Colwell and Totland Bays is angular and is derived from local erosion.

The Headon Cliffs which begin at the unprotected south end of Totland Bay and extend south to Hatherwood Point, are also affected by the slipping of the various layers of Oligocene strata which include sands, clays, limestones and a capping of plateau gravel. There is also some mudflow activity in this area.

Alum Bay is unprotected and backed by nearly vertical sandy clay cliffs. These range from Barton Sands in the east to Reading Beds in the west. The cliffs are unstable and mudflows occur in this area also.

The northwest facing part of the Isle of Wight coastline finishes at the Needles, which are the west end of the chalk spine which extends across the Island to Culver Cliff. The cliffs are subject to some aerial weathering and there are occasional cliff falls but recession is slow. The strata extend a considerable distance seawards in the form of pinnacles of rock. These are the remnants of a ridge which once extended westwards to the Isle of Purbeck. They form a natural zero-transport boundary with regard to littoral drift.

5.11.3 The Needles to St Catherine's Point

Chalk cliffs extend along the southwest facing shoreline up to Compton Bay. While cliff top recession is intermittent and is the result of cliff falls, toe erosion takes place due to wave action rather than weathering and proceeds at a slow but steady rate. Erosion releases flint pebbles which are transported eastwards in the direction of the nett littoral drift. The deeply incised embayment at Freshwater Gate tends to collect much of this material. Within the embayment there is a healthy pebble beach backed by a concrete seawall. This wall protects a narrow strip of low lying land, this being the former course of the River Yar which once exited through Freshwater Gate. The almost continuous movement of the pebbles leads to abrasion and the seawall and groynes have had to be reconstructed or repaired on a number of occasions. The existing groyne system is designed to restrict the movement of the pebbles which tend to be transported eastwards by wave action. Such movement can expose the foundations of the coastal defences around the hotel at the western end of the bay. Chalk cliffs continue eastwards to Compton Bay. The long term rate of recession of the chalk cliffs in this area is about 0.2 metres per year (Ref 46). From this bay west to Blackgang Chine, Wealden Beds of sands, clays and shales are exposed to the English Channel storms and Atlantic swell. Coastal recession is rapid and the materials released have led to the formation of wide sandy beaches. The rate of cliff top recession has been estimated as being of the order of half a metre per year. The coastline is undeveloped and erosion and land instability does not pose coastal defence problems. Subsidence however is posing a threat to the 'Military Road' fringing Compton Bay and the situation is being monitored by the County Council. The Wealden Beds end at Blackgang Chine and here the near vertical cliffs of black shale are overlain by harder sandstone beds which form a cliff terrace. Muds flow over this terrace and then run out onto the foreshore. Erosion in this area has resulted in the loss of the original coast road and a number of houses. It continues to pose a problem for the remaining cliff top development.

5.11.4 St Catherine's Point to Dunnose Head

The south coast of the Isle of Wight is typified by terraced cliffs slopes which extend from St

Catherine's Point east to Dunnose. The so called Undercliff has been formed as a result of deep seated rotational slips of Chalk and Upper Greensand over the Gault Clay, the latter being known as the 'blue slipper'. Coast protection works along the developed parts of this frontage have thus been necessary to protect the toe of the coastal slopes and to reduce the inherent instability of the Undercliff.

The coastline from St Catherine's Point to Ventnor is largely undeveloped. The foreshore is composed of easily erodible clay or sandstone, overlain by debris from former landslides. The volume of beach material transported eastwards is low and there are only isolated pockets of sand and shingle. There are short stretches of seawall at the west end of Reeth Bay and at the west end of Puckaster Cove. There are also remnants of a seawall near Binnel Point at the site of a former harbour. These walls were in private ownership as are the more extensive walls in Castle Cove near Ventnor. Beach material in Castle Cove is sparse and consists mainly of rounded shingle. Two rock-filled crib groynes installed here attract very little beach material. To the east of Castle Cove a timber breast work backfilled with rock gives partial protection to a slumping clay cliff.

The whole of the frontage from Ventnor to Bonchurch is now protected by concrete and masonry walls of various ages. The sloping timber revetment between Ventnor and Bonchurch has recently been replaced by a stepped concrete seawall. This area was once supplied with shingle from the local erosion of Chert Beds. With the construction of the coastal defences the supply of pea shingle has dwindled. The beaches in this area are likely to deteriorate in the future, unless the supply is artificially reinstated. Coastal defences continue through Bonchurch and end at the massive landslip at Dunnose. This whole frontage is exposed to strong wave action. At the western end of the new wall a vertical seawall of earlier construction extends round a small promontory. Wave action here is particularly severe and the seawall toe has to be protected by concrete armour units. Armour units are also used to form a small offshore breakwater to dissipate wave energy at a point where there is a marked change in seawall orientation. With the exception of a substantial beach of pea shingle west of the pier at Ventnor, the intertidal zone in this area has sparse beach deposits. This fine shingle is derived from gravel beds to the west of St Catherine's Point but is transported to the east around this headland in small quantities. The potential drift is in a nett west to east direction but the volume transported is low and only takes place intermittently.

5.11.5 Dunnose Head to Culver Cliff

From Dunnose north to Shanklin the cliffs are unprotected and there is a wide range of geological strata, varying from chalks and clays to sandstones. Erosion of these cliffs releases sand which is transported northwards into Sandown Bay. There is also a supply of pea shingle from past erosion of Chert Beds at Bonchurch though, as mentioned above, this supply is intermittent and dwindling. Coastal defences begin again just to the north of Horse Ledge, where a vertical timber breastwork and groynes extend northward to Shanklin Chine. The sand/clay cliffs are unstable along the southern part of this frontage and landslips and mudflows have caused localised damage to the breastwork. Completed in 1979, this breastwork is regularly overtopped by waves and the backfill has been partly washed out.

North of Shanklin Chine there are concrete seawalls which now extend over the whole frontage in Sandown Bay, finishing at Yaverland. The walls at Shanklin and Sandown are quite old. Those in Shanklin are believed to be as old as 90 years while the old walls in Sandown have required extensive reconstruction due to extensive undermining resulting from foreshore erosion. The formerly unprotected frontage between them at Littlestairs now has a stepped concrete seawall and long low groynes.

At Shanklin the wide sand and shingle beach is intersected by long concrete groynes which appear to be functioning effectively. The old concrete/masonry wall shows signs of wear and tear. There are two massive groynes at the northern end of Shanklin, which over the years have led to large scale sand accretion to the south and lee side scour to the north. The stepped concrete seawall at Littlestairs was completed in 1971 and is fronted by long low groynes which spread out the beach deposits more evenly than on the adjacent frontages and have prevented seawall toe scour from taking place on the north sides of the groynes.

The gap in the coastal defences at the northern end of Shanklin was closed in 1973. Nevertheless the cliffs of ferruginous sandstone in Sandown Bay are still liable to sudden falls after periods of heavy rain. These cliffs are often saturated and are then liable to shear off in 'vertical slices'. They are especially prone to slippage south of Littlestairs.

At Sandown the existing seawall had become undermined as a result of progressive foreshore lowering and was reconstructed between 1977 and 1979. A number of long, low groynes were also built, similar to those at Littlestairs. Here too these have caused a more even distribution of the beach deposits along this frontage and the sand beach is generally healthy. In the northern part of Sandown Bay however, to the north of the war memorial, there are some large concrete groynes whose footings have had to be protected by sheet steel piling and the beach here is less evenly distributed. Large tidal gullies sometimes form on the foreshore. These gullies extend northwards onto the frontage protected by Southern Water who maintain about 500m of seawall which protects low lying land near Yaverland. Here the groynes are rather high in proportion to the general beach level. Tidal scour sometimes exposes the underlying chalk. To the east of this frontage the South Wight B C administers a further 300m length of concrete seawall. Beyond that, towards Culver Cliff the sand and shingle beach is unprotected, with the exception of some rather dilapidated timber groynes. To the north of the wall there is some erosion of the sand/clay cliffs.

Beach material tends to be transported to the north end of Sandown Bay and accretes on the south side of Culver Cliff. This large promontory is of fairly durable chalk and acts as a 'zero-transport' boundary with respect to littoral drift. Hence there is very little transfer of material to the frontage in White Cliff Bay to the north.

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FIGURES.

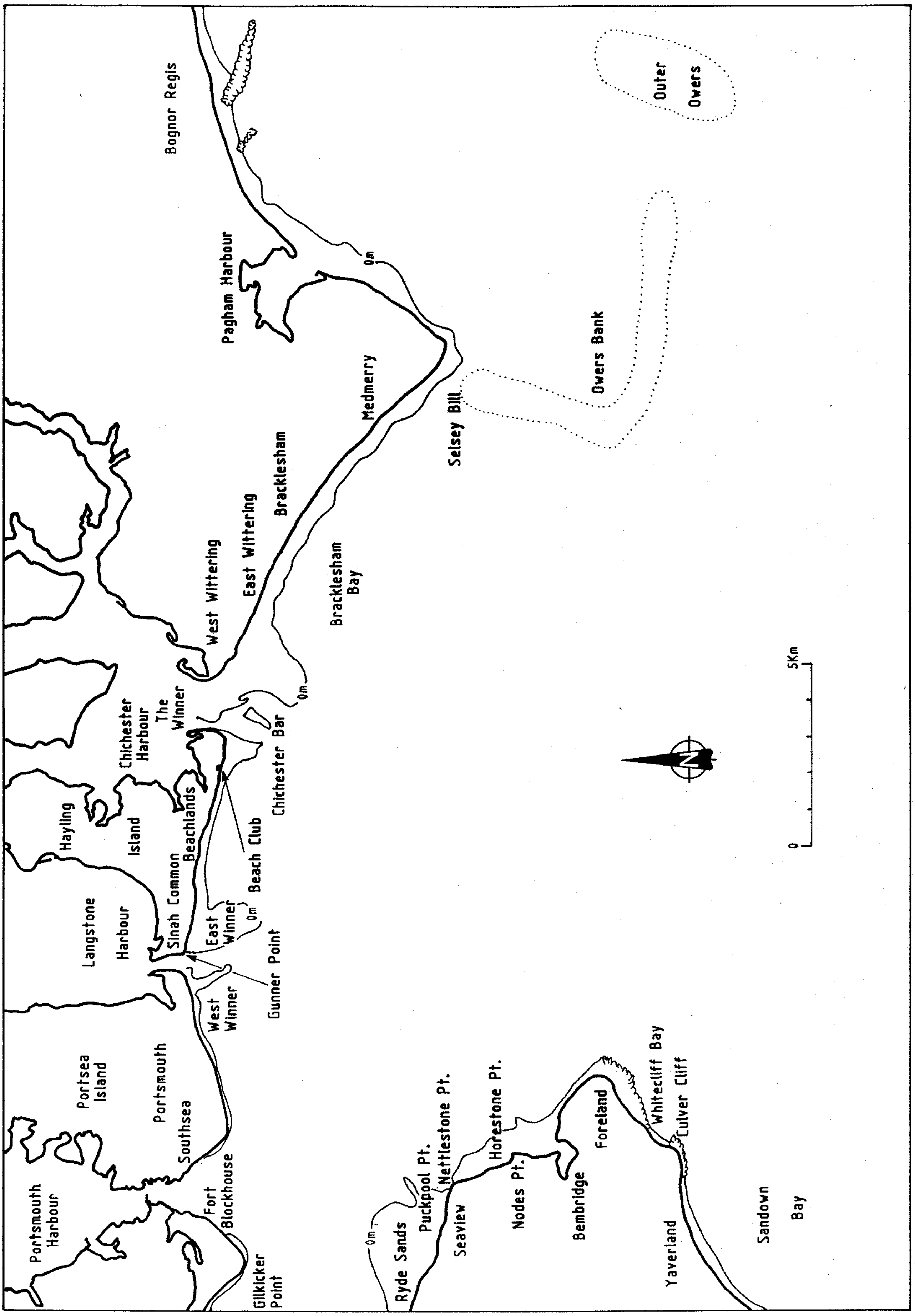

Fig 1 Selsey Bill to Isle of Wight

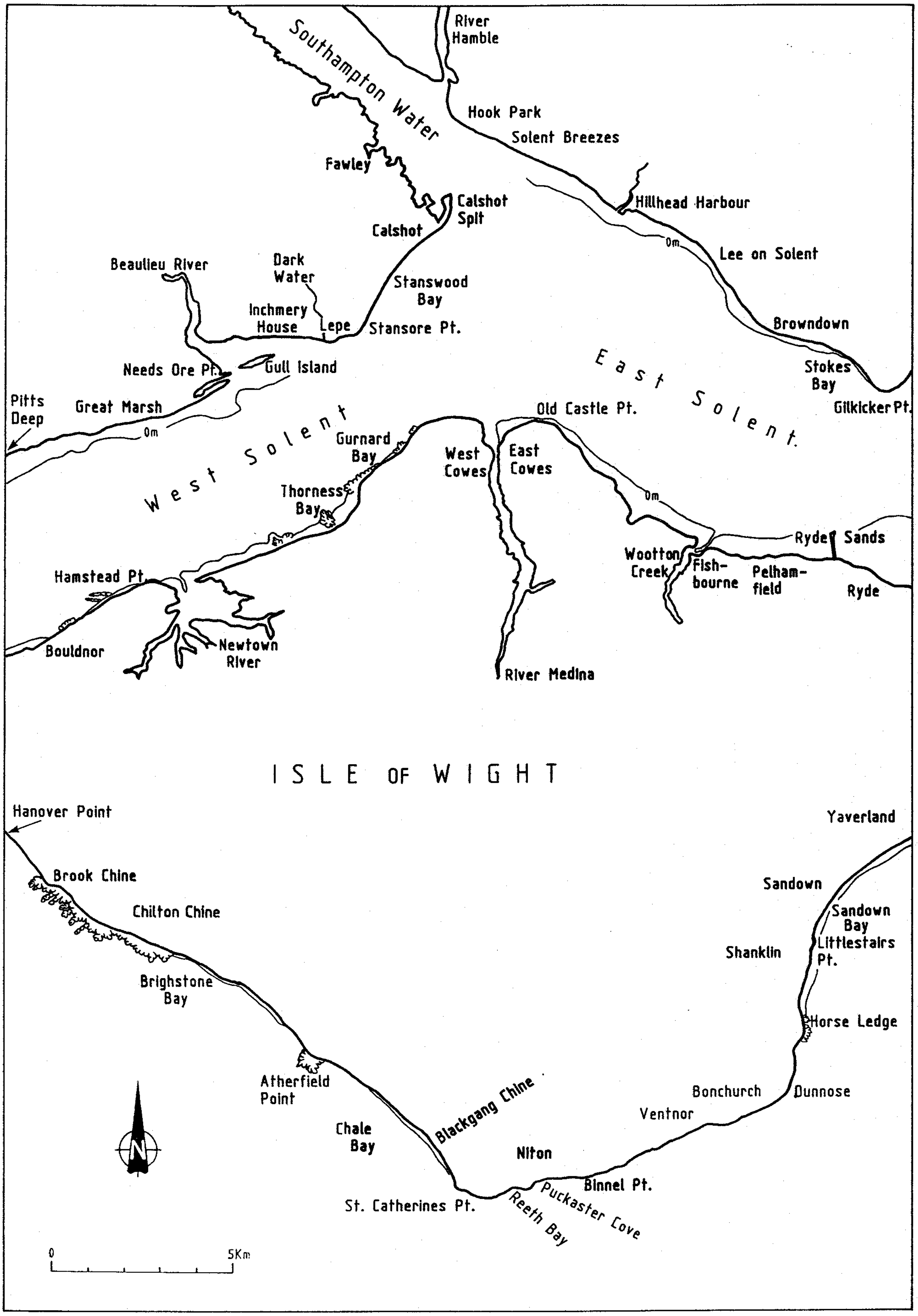

Fig 2 The Solent and Isle of Wight

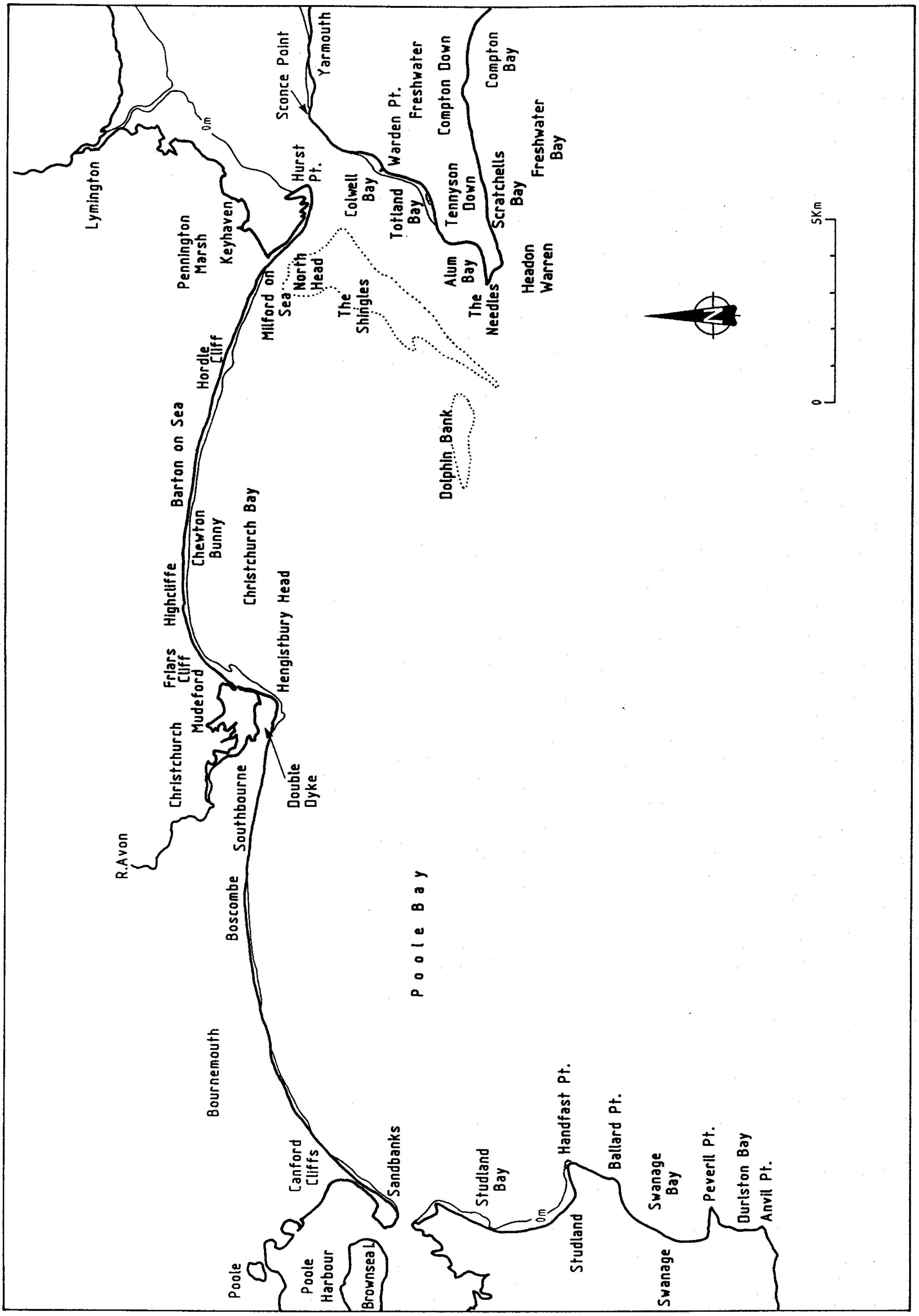

Fig 3 Isle of Wight to Swanage Bay

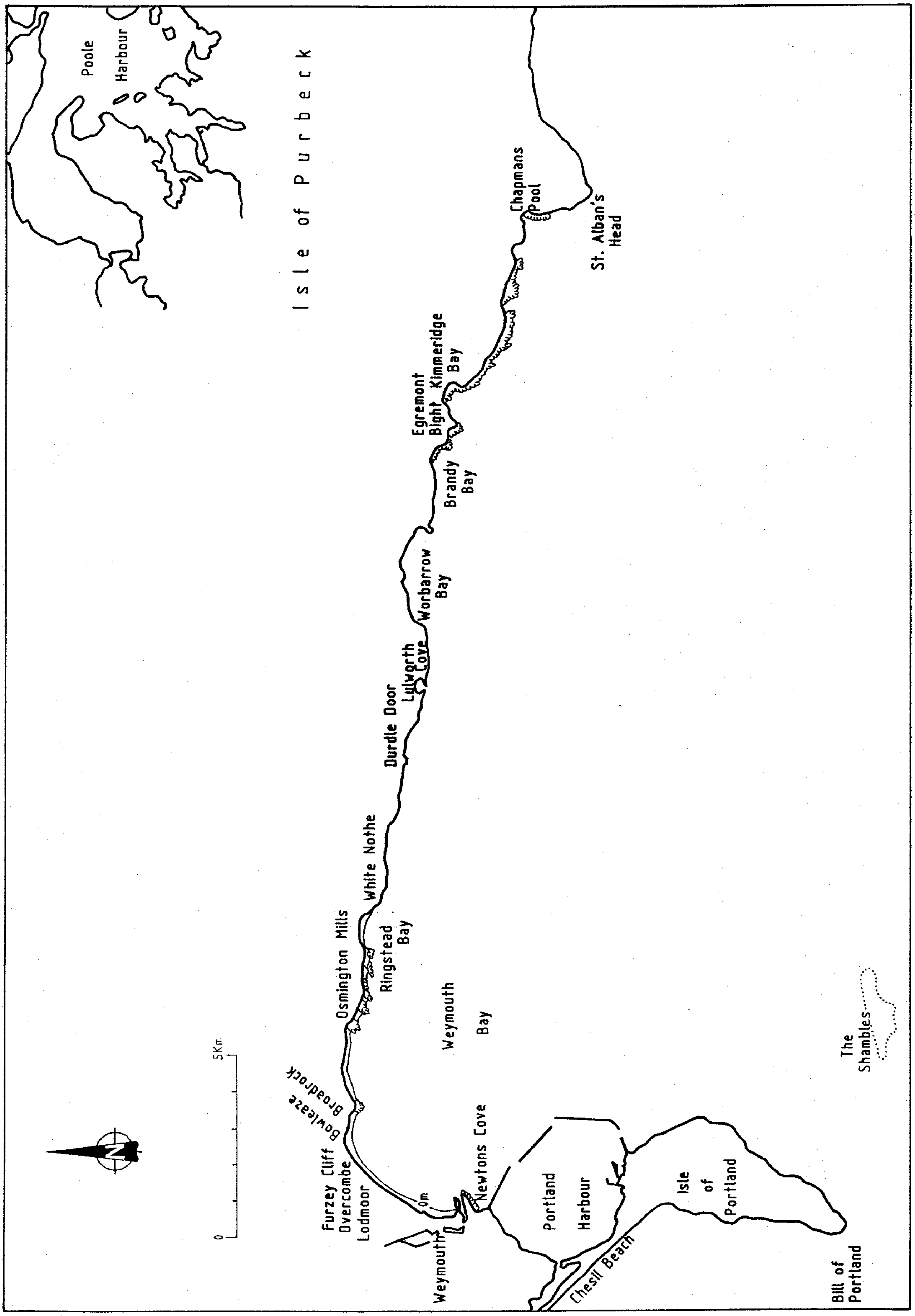

Fig 4 Isle of Purbeck to Isle of Portland