Hydraulics Research
Wallingford

A MACRO REVIEW OF THE COASTLINE OF ENGLAND AND WALES

Volume 6. The South West Coast. Portland Bill to Avonmouth

J Welsby and J M Motyka

Report SR 192
February 1989

Registered Office: Hydraulics Research Limited, Wallingford, Oxfordshire OX10 8BA.
Telephone: 0491 35381. Telex: 848552

ABSTRACT

This report reviews the coastline between Portland Bill and Avonmouth on the south-west 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 of semi-dependent cells are also identified.

This is the sixth 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.

Welsby J and Motyka J M. A Macro review of the coastline of England and Wales. Volume 6. The South West Coast. Portland Bill to Avonmouth. Hydraulics Research Ltd, Report SR 192, February 1989.

CONTENTS

CONTENTS (CONT'D)

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 6 of the series, and covers the south-western region of the British coastline, from Portland Bill to Avonmouth.

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. Identification of littoral cells is intended to help planners to 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 the Water Authorities. Both Acts now come under the jurisdiction of the Ministry of Agriculture, Fisheries and Food.

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

Much of the coastline of South-West England is composed of rocks which are resistant to both wave action and weathering. Shoreline change in most areas is therefore slow. The areas which are most prone to erosion are within Lyme Bay on the English Channel coast and from Minehead eastwards within the Bristol Channel.

Much of the present day beach sediments is derived from glacial deposits which have been reworked by wave

action over a long time span. Sands and gravels which were moved onshore with the rising sea level are now cut off from their source of supply. Thus the major shingle beaches, Chesil, Slapton and Westward Ho! are eroding. Major sand spits at the mouths of estuaries are also eroding either due to lack of contemporary supplies of beach material or the interruption of drift by coastal defences. Examples are the eroding sand spits at the mouth of the Exe on the south coast and of the Taw-Torridge estuary on the north coast.

For the most part, however, the rocky, strongly indented coastline of the South-West has sand beaches which are "fixed" in position by promontories and these beaches are relatively stable. Coastal defences are few and far between and thus the natural coastal regime has not been greatly affected by urban development. Even in highly developed stretches like the Cornish Riviera (Torbay) the problems associated with coastal change are on a relatively minor scale as compared for example with the coastal problems on the south-east coast of England.

The prevailing south-westerly wave action leads to a predominance of littoral movement in an eastward direction both on the English Channel coast and along the north coast of Cornwall and Devon. Though the coastline is subjected to strong wave activity the strongly segmented shoreline has a low rate of littoral drift and the type of problems found elsewhere in the country ie updrift accretion and downdrift erosion are uncommon. Because the coastline is strongly compartmented the concept of coastal cells is perhaps not particularly apt since almost every bay bound by headland falls into this category. There are however certain stretches of coastline which can naturally be compartmented, these being:

Lyme Bay

The coastline from Portland Bill to Exmouth is composed of relatively soft rock strata and is largely unprotected by coastal defences. Although the coastline is indented and the foreshore in many places is intersected by debris from cliff falls and slides, there is a drift of material through this frontage though it is slow, intermittent and variable in direction. The whole stretch could be treated as one coastal cell. The shingle ridge of Chesil Beach terminates at Bridgeport Harbour. However shingle does bypass the harbour mouth and feeds the coast to the west with small quantities of pea sized shingle. Thus the beach should be treated as a part of the cell since it "feeds" the coast to the west although itself it is largely unaffected by that coast.

Exmouth

The beaches adjacent to the Exe estuary and the sand bars within and outside the estuary itself are intimately linked by being reworked continuously by the action of waves and tidal currents. Thus, material from the erosion of Dawlish Warren spit eventually feeds the beaches of Exmouth on the other side of the Exe estuary. The stretch of coastline from Otter Cove to the north to Langstone Rock to the south, should be treated as a coastal unit.

Exmouth to Torbay

Relatively soft sandstones predominate along this stretch of coastline. The cliffs are partly protected, particularly from Exmouth to Teignmouth. It would appear that the amount of material derived from their erosion is now not significant. The Teign estuary and adjacent beaches are virtually a self

contained system with sand circulating clockwise via a system of sand banks at the mouth. This estuary can therefore be considered as a largely independent sub-cell within the larger unit. South of Teignmouth the red sandstone cliffs are indented with may coves and sand beaches of varying size which are contained between heads and act largely independently of each other.

Torbay

Within Torbay there are headlands of more resistant limestone whereas the beaches of the bay are backed by softer red sandstone. The relatively stable beaches of Torquay, Paignton and Goodrington are separated by headlands and should be considered as smaller practically independent cells within the larger unit of Torbay.

Berry Head, to Start Point

The strongly indented coastline south of Torbay is of resistant shales, slates and grits which are fronted by thin boulder strewn beaches. These form the dominant cliffs south to Start point. However the shoreline of Slapton sands in Start Bay, from Strete to Torcross, is low lying and fronted by a continuous shingle barrier beach impounding lagoons partly infilled with alluvium. There is much alongshore movement in response to varying angles of wave approach but the beach itself is a closed system. The coastline from Berry Head to Start Point should be treated as a coastal unit although any man made works to the north or to the south of Slapton Sands would have very little effect on the barrier beach itself.

Start Point to the Lizard

South of Start Point hard rocks (predominantly slates) extend to Bolt Tail. To the west of Bolt Tail there are slates, grits and conglomerates which extend south to beyond Falmouth forming a bay and head land coast which is intersected by a number of drowned river valleys. Thus the interchange of material between adjacent stretches of coast is very small. The beaches are localised but with extensive sands at Bigbury-on-sea. There is also a continuous stretch of sand in Whitesand Bay with intermittent deposits extending west to Millendreath Beach. Thus the whole of Whitesand Bay from Rame Head to Hannafore Point can be considered as a large independent "sub-cell" along this frontage. The strongly indented coast extends west to the Lizard and beach deposits along this stretch are sparse. At the Lizard ancient, resistant schits with igneous intrusions form an intricate coast of coves, stacks and caves and here also littoral drift is negligible.

The Lizard to Land's End

Between the Lizard and Land's End is Mount's Bay, which is bordered by cliffs of less resistant slates covered by head. There are major stretches of sand and shingle beach. At the eastern end of the Bay a sand and shingle spit, known as Loe Bar has formed across the entrance to the river Corber, thereby creating a freshwater lake known as the Loe. There are large stretches of sand beach at the central and western end of the bay particularly in the lee of St Michael's

Land's End to St Ives

Granite cliffs form the peninsula and extend north to St Ives. The coastline is very rocky with a number of

small coves. One cannot foresee any coastal problems in the area, apart from maintenance of existing sea walls and harbour quays.

St Ives Bay

The wide sand beaches within the bay are backed by slate cliffs. These cliffs are partly covered with wind blown sand, particularly east of the Hayle estuary. There is very little influx or outflow of material from the bay. However there are likely to be short term movements of sand within the bay and the whole stretch from St Ives to Godrevy Point is essentially a single coastal unit.

St Ives to Hartland Point

The rugged Atlantic facing coast from St Ives to Hartland Point has many wide sand beaches backed by dunes and separated from each other by rocky, sediment free stretches of cliffline. The nett northward drift is low and the predominant movement of sand is in an onshore/offshore direction in response to climatic changes ie from swell to storm wave action. There is very little interaction of one stretch of this coast to the next, with regard to littoral movement.

Devonian slates are predominant from St Ives to Boscastle while from there to Hartland Point the cliffs are of shales and sandstones. The one major estuary is the Camel and this contains vast quantities of shifting sand. The whole of the estuary should be treated as one sub-cell; otherwise other stretches of sand,when they are separated by rock headlands,largely unaffect each other.

Barnstaple Bay

From Hartland Point to the mouth of the Taw-Torridge estuary there are shale and sandstone cliffs fronted by a rocky foreshore, partly covered by pebbles. Cliff erosion produces beach building material which is transported eastwards towards the Taw-Torridge estuary. From Westward Ho! to Saunton the estuary margin consists of recent superficial deposits. The pebble ridge at Westward Ho! protects an area of sand dunes and saltings which would otherwise be liable to flooding. Within the estuary itself there are large expanses of sand with sand banks extending upstream almost to Barnstaple. Braunton Burrows on the north side of the estuary is a massive sand dune system which also protects reclaimed marshland (Braunton Marsh). The sand and shingle spit at the south end of Braunton Burrows is eroding and it is clear that movements within the estuarial system and the flanking shingle and sand spits are interlinked. Thus the whole stretch from Hartland Point to Saunton Down should ideally be considered as a coastal cell.

Saunton to Foreland Point

Devonian rocks of sandstones, shales and slates extend from Saunton Down northwards to Morte Point. These form strongly indented headlands within which are contained wide sand beaches which face westwards into the Atlantic. These beaches can be considered as separate from the sand beaches in Barnstaple Bay to the south.

From Morte Point the same type of rocks extend to Minehead, forming a north facing coastline which is strongly indented as far east as Foreland Point and then take up a more regular line further eastwards to Minehead. The beaches are very compartmented from

Morte Point to Foreland Point and there is little drift although the nett direction is from west to east.

Foreland Point to Minehead

From Foreland Point to Minehead the sandstones, shales and slates make up a fairly regular cliff line and there is a predominant west to east littoral drift. This drift results in a large accumulation of shingle in Porlock Bay. This frontage should be considered as a coastal cell although it is likely that some material is transported eastwards in small quantities into Minehead Bay.

Minehead to Burnham

The cliffs of interbedded clays, shales and limestones east of Minehead are very soft and there are serious erosion problems along this frontage, for example in Blue Anchor Bay. Much of the coastline is fringed by shingle banks and there is a weak west to east nett littoral drift. Eastwards into the Severn Estuary the lower foreshore which is of sand and silt at Minehead has increasing quantities of mud at the low tide mark. The crumbling cliffs, especially from East Quantoxhead eastwards produce beach building material in the form of pebbles. The clay and shale fraction however tends to disintegrate rapidly and is transported offshore in suspension. With active erosion taking place and a strongly directional drift the whole frontage from Minehead to Burnham needs to be considered as a coastal cell.

Burnham to Avonmouth

Much of the backshore consists of alluvial deposits and there are wide sand beaches backing low lying

marshland from Burnham to Sand Point. These beaches are separated by limestone headlands which prevent transfer of sand between adjoining bays. At low water there are extensive mudflats which effectively act as a seaward boundary to the sand beaches. Much of the low lying shoreline is susceptible to flooding and is protected by embankments. From Clevedon eastwards there are areas of higher ground formed of Marls which are easily erodible. Wave activity this far up estuary decreases rapidly and sediment movements become increasingly influenced by the strong tidal currents within the estuary. The currents are strong enough to transport sand in suspension. There is no significant drift along this stretch of coastline. However coastal problems are similar, namely erosion of the soft cliffs and potential flooding of low lying land.

3 COASTAL GEOLOGY AND TOPOGRAPHY

3.1 Geological Background

The coastline of the South-West peninsula from Portland Bill to the Severn Estuary is mainly composed of rocks ranging in age from the Pre-Cambrian to the Jurassic eras (ending 135m years ago). The whole area is a great compound syncline or downfold aligned generally along an east-west axis with smaller folds to the north and south. The oldest Pre-Cambrian rocks are found in the Lizard peninsula of South Cornwall and in the Bolt Head and Start Point regions of South Devon. These rocks consist of hard metamorphic schists which are generally resistant to marine erosion.

Much of the coastline of South Devon and Cornwall from Torbay to Boscastle is formed of Devonian rocks mainly

slates and sandstones which are also exposed along the coast of North Devon between Croyde Bay and Minehead. Between Boscastle and Barnstaple younger Carboniferous rocks are exposed. These are known as the Culm Measures and consist of well folded shales, slates and sandstones. During the period of folding and faulting that followed the formation of this rock sequence large igneous masses were intruded into the layers of sedimentary rocks. These were later exposed at the surface as the large granite domes that form Dartmoor, Bodmin Moor and Land's End. The associated minor intrusive activity formed dykes, sills and smaller bosses. For the most part these older rocks form a stable coastline that is rugged and crenulated with many small bays and coves between headlands.

East of Minehead on the North Devon coast and Paignton on the South Devon coast the Devonian and Carboniferous rocks are overlain by younger Triassic and Jurassic formations, mainly consisting of various sandstones and marls. Surrounding Lyme Bay these formations are capped by Cretaceous greensands and chalk.

The present configuration of the coastline of the South-West peninsula was formed during the mid Tertiary era (about 30m years ago), when the whole area was uplifted. This resulted in the flat-topped cliffs and plateaux characteristic of North Cornwall and which represent a number of former sea floor levels. During the Pleistocene Ice Ages the area was not covered by ice even at the glacial maximum but extreme peri-glacial (arctic) conditions accelerated sub-aerial weathering of the surface rocks to form coverings of unconsolidated gravels known as 'head'. These deposits typically consist of a mixture of coarse rock fragments embedded in a sandy-clay matrix. Where the head caps the bedrock at the coastline it

may be readily eroded if accessible by wave action thus supplying sediment to the beach. In places the gravels may be vulnerable to mass movement (such as the cliffs to the east of Lyme Regis).

Sea level changes during and after the Ice Age have played an important role in the coastal development of the South-West, particularly in Barnstaple Bay, Start Bay and Lyme Bay. During the cold glacial phases global lowering of the sea level caused the periodic exposure of extensive parts of the sea floor, subsequently submerged by rising sea levels as the ice sheets melted during the interglacial periods. Raised beach deposits, now exposed well above the level of current wave action, for example at Rock Nose west of Westward Ho!, are evidence of higher sea level than present and the 'old' cliffline that runs inland to Appledore and Braunton represents the extent of such marine inundation.

Evidence of lower sea levels is provided by submerged estuarine and lacustrine clays, peats and forest deposits which are occasionally now exposed on the foreshore, for example in Barnstaple and Bridgwater Bays. Valleys which were deepened to lower base levels have now been drowned to form branching, tidal inlets and estuaries which penetrate far inland, for example at Kingsbridge, Plymouth Sound and at Carrick Roads, Falmouth. Similarly vast low lying areas of Somerset were inundated by the sea and later infilled by estuarine clays and peat to form the Somerset Levels.

3.2 Coastal Processes

Shoreline change is effected by processes involving coastal erosion and the supply of beach sediments, their movement and distribution alongshore by wave action and their subsequent deposition under suitable conditions. The rate of erosion and the supply of

beach sediments depend both on the geological composition of the rocks and the wave climate. Much of the cliffline of the South West is made up of old, hard Devonian and Carboniferous rocks which are resistant to the effects of wave action and weathering In many cases the cliffs themselves are relic features and current marine erosion is very limited. Thus present shoreline change is slow or negligible. The coastal outline however reflects variations in the local geological structure by the formation of numerous headlands and bays. Current inputs of suitable beach material are limited to exposures of superficial deposits such as 'head' or raised beaches where these overlie the bedrock. Much of the sediments that form the large sandy beaches that are to be found enclosed in embayments along the coast of Cornwall are therefore probably derived from nearshore glacial deposits reworked by wave action over a long period of time. In contrast The rate of erosion of the softer sedimentary rocks exposed along the coastline in Lyme Bay is more rapid. The cliffs are very vulnerable to slumping in part promoted by wave action at their toe. Here the cliffs actively provide suitable sediments to the foreshore below.

It is thought that much of the shingle found at the present coastline, particularly the large accumulations such as at Chesil, Slapton and Westward Ho!, originated prior to the final post glacial rise in sea level. Beach sediments supplied by cliff erosion were mixed with glacial outwash materials and were transported more freely along a shoreline seaward of the present line. It is envisaged that large pebble banks formed bay-bar features in Lyme Bay and Barnstaple Bay. As sea level rose to its present position these sediments were moved onshore by wave action such that the shingle ridges eventually became isolated from their souce of supply. Movement of the

shingle is presently mostly restricted to redistribution within individual embayments. In the absence of adequate contemporary inputs of material and with the continuing slow rise in sea level these features are undergoing long term recession.

There are few accretionary features along the South-West coast and these are associated with the major river estuaries for example the River Exe and Taw-Torridge estuary. In each case the spits are currently under erosion because of the lack or interruption of beach supplies thus posing problems for coastal protection. Some accretion in St Austell Bay is associated with mining waste while wide inter-tidal mud flats and salt marshes have developed in the more sheltered areas of Bridgwater Bay and the Severn Estuary.

The prevailing direction of wave approach along the coast of the South-West Peninsula coincides with winds from the south-west sector and which also have a maximum fetch from the Atlantic. This leads to a general expected pattern of littoral drift eastwards along the coast of the English Channel and also along the north coast towards the Severn Estuary. However the presence of many headlands creates a crenulated coastline with changing orientation and degree of exposure to wave action. Easterly waves along the south coast induce reversals of drift direction while westerly and north-westerly waves have a similar effect along the north coast. The headlands themselves modify the direction of wave approach and littoral drift by refraction and diffraction. Thus the net rate of littoral transport may vary considerably locally in magnitude and direction and gross movements in beach sediments often involving a transfer onshore and offshore are an important factor

in the explanation of temporal changes in beach behaviour and morphology.

Portland Bill and the Severn estuary form the natural boundaries with respect to the transport of sediment in the littoral zone around the coast of the South-West Peninsula. Portland Bill forms a major projection along the coastline of Southern England dividing Lyme Bay on the west from Weymouth Bay on the east. The wave climate and orientation of Lyme Bay is such that it is unlikely that material is transferred eastwards from Chesil. The upper Bristol Channel and Severn Estuary act as a vast sink for sediment derived both from glacial deposits and shoreline erosion. Fine sediments are deposited on the wide inter-tidal mudflats in Bridgwater Bay and further upstream where wave activity is reduced. However, large quantities of sediment are maintained in suspension and are constantly being reworked and redistributed by the strong tidal currents. Within the long stretch of coastline from Portland Bill to the Severn estuary a large number of semi-dependent and independent cells can be identified. The rocky headlands effectively restrict the littoral drift of sediment alongshore and it is therefore redistributed and reworked within individual embayments or 'cells'. These may vary in scale from the larger bays such as Lyme Bay and Start Bay to the much smaller coves and pocket beaches in Cornwall and Devon. The coastal processes and shoreline changes of each section of the coastline are discussed in more detail below.

Portland Bill to Start Point

Chesil beach is a unique shingle feature about 29 km in length extending from Portland Bill in the south-east to West Bay (Bridport) Harbour in the north-west. From Chesilton to Abbotsbury, for some

13 km, the shingle bank is separated from the mainland by the shallow tidal lagoon called the Fleet. Further westwards it adjoins the backshore.

The beach material is fairly homogeneous, 98% being made up of flint and chert, possibly derived from rock formations found to the west (Ref 1). It is regarded as a 'fossil' feature since fresh beach material is limited almost entirely to supply from eroding cliffs. This supply is extremely small, the cliff between West Bay and Burton Bradstock being made up of a weak sandstone providing only small amounts of beach forming material. The supply of shingle from offshore is insignificant (Ref 2).

The beach crest is continuous over most of the length of Chesil and decreases in height from east to west, with a maximum height of 14.7m OD near Chesilton. Pebble size and beach gradient also decrease in an westward direction (Ref 3). At the eastern end of the beach, the mean long diameter of the shingle at the high water line is 55mm but decreases to 20mm by Langton Herring. Further westwards, the pebble size at West Bay is 10mm. This pronounced lateral sorting is a function of the varying wave regime along Chesil Beach. The alignment of the beach is such that wave approach is close to normal and therefore much of the longshore movement of pebbles is merely the short term response to varying wave conditions. The eastern end is exposed to the greatest wave activity associated with south-westerly gales with a maximum fetch from the Atlantic. Wave over-topping and flooding have caused particular problems here. However there is a gradual reduction in wave activity towards the western end of the beach. Carr (Ref 4) has produced evidence of an easterly drift of pebbles at the eastern end of Chesil while the accumulation east of the harbour piers at Bridport and the equally large 'set- back' to

the west testify to a westerly drift there. Numerical modelling of littoral drift along the western part of Chesil shows a fairly low net annual rate of transport of 8000m³ from east to west (Ref 5). However, gross movements are much greater, producing large fluctuations in beach levels from year to year. This drift pattern would seem to conflict with evidence that the source of the material is from the Cretaceous deposits to the west. However, the present Chesil Beach is likely to be the remains of a much larger bay-bar feature formed at lower sea levels during the Pleistocene and which may have extended around Golden Cap and as far westwards as Seaton. The lagoonal clays and peats which underlie the present beach suggest that the shoreline was then seaward of its present position and that the pebble bank has moved landwards as sea level rose during the post glacial period.

Landward recession of Chesil Bank continues, albeit slowly. A comparison of cartographical evidence has provided information about changes in crest height and alignment over the past century (Refs 6 and 7). The most significant changes have taken place at the eastern end where the ridge is exposed to the direction of dominant wave attack. Gravel extraction, mostly at the western end, has led to a growing concern about the long term consequences of the removal of gravel from a finite storage volume. This practice has now ceased following a number of public inquiries into the matter.

The cliffs forming the coastline between West Bay and Axmouth are generally soft and unstable and are characterised by complex landslip and landslide features. They are formed of erodible clays, marls, sands and limestones which are overlain unconformably by younger Cretaceous greensand and Gault clay. From

Lyme Regis westwards there is also a capping of chalk. Varying groundwater conditions are responsible for the failure of the chalk and greensand over the impervious Gault clays and mudstones causing large scale deep seated slides. Smaller translational slides involve unconsolidated superficial deposits, mainly head, which are highly permeable and unstable. No major slips have occurred in this area for about 150 years but minor changes still take place in the form of mudslides and slumps. Between West Bay and Lyme Regis there are major landslip features at Golden Cap, Fairy Dell and Black Ven. It is estimated that the retreat of the cliffs at Fairy Dell between 1887 and 1969 was 35m (Ref 8). The debris fans associated with the slides result in localised advance of the high water mark and temporarily limit the lateral movement of beach material until the debris has been removed by wave action. From Lyme Regis to Axmouth undercliffs form a coastal strip nearly 9km long and 500m in width including the Ware, Pinhay, Whitlands, Dowlands and Bindon Cliffs. Pinnacles and masses of displaced rock occur in the undercliffs and at Dowlands and Bindon a deep gorge separates an isolated ridge from the main cliff. These movements probably date from the late Pleistocene period and very large scale movements are now infrequent. This particular area has been intensively studied and described in detail by Arber (Refs 9,10 and 11).

West of Axmouth there are chalk cliffs which are particularly prominent at Beer Head and mark the western margin of Seaton Bay. At Hooken Cliff between Beer Head and Branscombe there have been many falls including a massive slip in 1790. These are related to the plane of weakness between the sandy Cretaceous beds and the underlying clays which occurs at sea level. The Cretaceous strata dip to the east and are replaced near Sidmouth by cliffs of sands and marls

belonging to the New Red Sandstone gradually decreasing in height towards the Exe estuary. The cliffs are generally soft and eroding providing beach material for the foreshore of coarse sand and shingle below. The pebble beds in the eroding sandstone cliffs at Budleigh Salterton provide a ready local supply of quartzitic material to the beach below. The movement of this material is confined by the headlands at both ends of the frontage with Otterton Ledge to the east and Straight Point to the west. However, the general direction of net littoral drift in this part of Lyme Bay is to the east and accumulations of shingle have deflected the mouths of both the rivers Otter and Axe to the east.

At the mouth of the River Exe there are spits on both sides of the estuary, Dawlish Warren to the south and Exmouth Point to the north. The changes in the configuration of these spits appear unrelated. The distal end of Dawlish Warren is subject to periodic breaching and destruction followed by recovery and growth while the outline of Exmouth Point and the position of the river channel appear relatively stable (Ref 12). Erosion of the southernmost spit has been progressive. The sand dunes of the Outer Warren have disappeared exposing the higher dunes of the Inner Warren to wave attack and breaches have occurred with increasing frequency. In the mid 18th century the spit projected northwards from the base of Langstone Cliff. The proximal end is now set back some 400m and present supply to the Warren from the west is effectively prevented by Langstone Rock. The rate of erosion of the spit appears to be accelerating. Cartographic evidence has shown a long term average annual recession for the period 1787 - 1949 of 1m (Ref 12). However, measurements between 1949 and 1962 suggest an annual loss in excess of 2m (Ref 13). In addition the spit has become realigned to the

north-west aided by the 'fixing' of the western end by a rock revetment in 1917. The distal end of the Warren has a history of periodic fluctuation. Erosion of the seaward dune face has provided material for its extension north-eastwards towards Exmouth followed by breaching usually in periods of south easterly gales. The increased rate of recession and reduction in width of the spit has resulted from a reduction in the supply of material from the west. It has been suggested that the construction of the railway along the coast to the south in 1849 has been a contributary factor although erosion was clearly apparent prior to this time. Attempts have been made to stablise the dunes on the Warren by brushwood and tree planting and the construction of gabion work and groynes. However, measures to prevent toe scour of the dunes due to wave attack have not been entirely successful and it is likely that the spit will continue to diminish.

High sandstone cliffs continue on the southern side of the Exe estuary and run around the headland known as The Parson and the Clerk towards Teignmouth. Most of this frontage is protected by walls. Thus with no further supply of material from local cliff erosion and only a weak net south to north littoral drift the foreshore of coarse sand is generally unstable. A progressive deterioration and fall in beach levels has been reported in recent years (Ref 14).

The condition of the beaches at the mouth of the Teign estuary is related to a cyclical pattern of changes in the configuration of near shore banks. The area appears to form a largely self-contained unit with almost constant sediment storage which is continuously redistributed by wave action and tidal currents. Little sediment is added from beyond the Ness headland to the south or from the north where the coast is protected by a sea wall and groynes. The tidal flows

in the estuary mouth are dominated by a flood residual with runs close to Denn Beach on the north side of the estuary. There is an ebb residual near the Ness Head shore on the south side. This situation creates an anti-clockwise water circulation within the estuary approaches which influences the movement of sediment. This has been confirmed by experiments using fluorescent tracers by Hydraulics Research Ltd (Ref 15). Sediment accumulating in the vicinity of Ness Head extends in a north-easterly direction to form a bar known as the Ness Pole lying to the south of the harbour entrance. This bar eventually becomes detached and then migrates northwards across the entrance to from the banks of the Inner and Outer Pole. When the banks move onshore they contribute beach sediment to the north shore which is then moved southwards towards the mouth by the processes of normal beach drifting. Littoral drift at Teignmouth is generally from north to south but periods of northerly drift may occur during prolonged south-westerly storms (Ref 14). The condition of the Teignmouth beach is therefore closely related to the supply of material from nearshore banks and results in fluctuating beach levels particularly on the North Shore (Ref 16).

To the south of Teignmouth the unprotected sandstone cliffs are indented, forming numerous small coves. The red sandstone cliffs give way to older limestones and slates further south. The deep indentation of Torbay is enclosed by two large promontories, Hopes Nose to the north and Berry Head to the south. Both headlands are composed of hard resistant limestones whereas the bay is cut in less resistant red Sandstones. The bay faces east and is thus protected from prevailing south-westerly winds. Erosion is limited by the shallowness of the bay and its orientation normal to maximum wave activity during

easterly storms. Thus the wide sandy beaches of Torbay and Paignton show overall stability, the net south to north littoral drift being low and sediment being contained within the bay by the headlands. At the southern end of the bay and on the north side of Berry Head there are several small sheltered coves. However, on the more exposed southern side of Berry Head, at St Mary's Bay, landslips have occurred in cliffs of shale between the limestone headlands of Durl Head and Sharkham Point. Detailed mapping of the area suggests that over steepening of the cliff face by wave action causes large shallow slides promoted by heavy rain, heavy easterly seas and high tides (Ref 17).

High cliffs (over 130m) of resistant Devonian shales, slates and grits and fronted by thin boulder strewn beaches form the coast to the south interrupted by the large estuary of the River Dart. These rock formations continue to form the coastal plateau to Start Point but south of Strete, the shoreline of Start Bay is fringed by shingle (over a length of approximately 9km) which makes up a series of detached barrier beaches with Slapton Sands in the north and Beesands and Hallsands to the south. The barriers impound freshwater drainage from the west creating lagoons or 'leys' which have been partially infilled with alluvium. The barriers are separated by cliffed headlands, the double headland of Torcross Point and Limpet Rocks separating Slapton Sands to the north and Beesands to the south. Tinsey Head lying between Beesands and Hallsands to the south. The foreshore at the foot of these headlands consists of slate reefs covered only intermittently by shingle.

Longshore movement of beach material is variable in both rate and direction in response to wave climate changes but is effectively contained by the headlands

and their associated reefs. Start Bay faces east and thus prevailing westerly waves are refracted around Start Point to produce a south-easterly wave approach and longshore transport from south to north. Winds and waves from the east and north-east will produce a longshore transport in the opposite direction. An analysis by Carr et al (Ref 18) shows two discrete directions of wave approach. For waves greater than 0.5m, 70% approached from between 40-90° and 27% approached between 120-150°.

The nature of the changes in beach morphology and volume also indicate variable longshore transport. Several studies provide detailed accounts of beach morphology, particle sizes, tracing experiments and attempted correlations with varying wave conditions. Beach surveys undertaken by Gleason, Blackley and Carr (Ref 19) show greatest temporal variation in beach levels at either end of the barriers while the central sites on Slapton Sands showed less change. Beach profiles recorded elevation changes typically of between 1 and 2m and as much as 6m on occasion. However, taking the beach as a whole there was no uniform erosion or accretion nor a progressive variation in beach elevation or volume distribution alongshore from one survey to the next. Beach material is therefore redistributed along the foreshore in both directions, being removed from or accumulating at either end, depending on the wave conditions. Onshore - offshore movement of sediment from the nearshore zone is also a factor accounting for the fluctuation of beach levels. However the seasonal model of winter lowering and summer replacement is not found to be applicable to Start Bay beaches. Much of the total annual variation in levels seems to occur during the winter months alone.

More recent data on Slapton Sands identifies falling beach levels at Torcross at the southern end of Slapton Sands in response to the destructive influence of southerly gales and a corresponding gain in beach height and width at Strete to the north with accretion there occurring during periods when winds are from the east or north- east (Ref 20). Although it is not yet possible to ascertain any significant long term trends, the deterioration of the beach at Torcross combined with severe wave over-topping and flooding that can occur when easterly gales coincide with high tidal levels is already causing severe problems along this frontage.

Shingle size varies on either side of headlands and some longshore sorting is evident but each barrier beach behaves as an isolated system. The size grading of the material on the surface may vary in either a north or south direction and the finer fractions tend to be transported the furthest (Ref 19)

Evidence suggests that Start Bay is a closed system there being no supply of material to the foreshore from outside the area. Studies have found the configuration and position of the Skerries Bank, trending north-eastwards off Start Point, to have changed little in the hundred years between 1850 and 1950. The tidal flows effectively inhibit any transfer of sediment towards the shore which would otherwise be associated with a gradual movement of the bank in that direction (Ref 21). Therefore, in the absence of any contemporary supply of beach material either alongshore or onshore, the beach sediments must have been derived from offshore sources and transported landwards by rising sea levels following the end of the last glacial period. Sea bed sediment sampling and geophysical data within the bay indicate the existence of a submerged barrier-lagoon complex

with associated tidal marshes and infilled river channels dissecting the bedrock shoreward of a buried cliffline (Ref 22). Under such conditions, material could have originated from outside the local area and this could explain the origin of the high proportion (over 75%) of flint pebbles in the beach material which have no local source.

In 1917 the small village of Hallsands situated at the southern end of Start Bay was completely destroyed by the sea. This disaster has been widely attributed to the legacy of dredging shingle from the inter-tidal zone between 1897 and 1902, combined with storm waves, gales and spring tides. It has been estimated that approximately 400000m³ of shingle was removed during this period for use as ship ballast and that the beach level fell by more than 6m. Since that time the beach has not been re-established thus demonstrating the lack of present day supplies of beach material.

Start Point to Lands End

South of Tinsey Head the Devonian sediments are faulted against very old, hard, resistant metamorphic rocks called schists which extend south to Start Point and then eastwards as far as Bolt Tail to the east of the Kingsbridge Estuary. The cliffs are high and rugged and erosion by wave action and weathering is negligible. To the west of Bolt Tail the Devonian slates, grits and conglomerates reappear in Bigbury Bay and continue until south of Falmouth forming a bay and headland coastline. The rocky coast is intersected by the drowned, branching river estuaries of the Kingsbridge, Avon, Erme, Yealm, Tamar, Fowey and Fal each creating a partial barrier to the transfer of sediment alongshore. Within St Austell Bay beach changes have largely been determined by mining activities over the past century (Ref 23). Tin

mining and china clay quarrying have produced large quantities of quartzite and kaolinite waste which are brought downstream from the mining areas and deposited at the coast. Large scale beach accretion and siltation has occurred for example at Par Sands and Carlyon Bay. St Austell Bay is well sheltered from wave action with only a very small net easterly drift and weak tidal currents. Thus there is little transport of material away beyond the margins of the bay (Ref 24).

To the south of Falmouth the Lizard peninsula is composed of ancient, resistant metamorphic rocks (mainly mica and hornblende schists) into which serpentine and igneous materials have been intruded. These structural weaknesses have been exploited by wave action to form an intricate coastline of coves, stacks and caves particularly on the more exposed western face. Between the Lizard and Lands End the large embayment of Mount's Bay is bordered by low cliffs formed in less resistant slates covered by periglacial head. At the eastern end of the bay there is low lying land fronted by a long sand and shingle spit, known as Loe Bar, which has completely dammed the River Corber and now encloses a freshwater lake. At Praa Sands the beach is backed by high sand dunes. Further west St Michael's Mount forms a prominent feature within the bay. The 'island' is essentially a granite intrusion and is now joined to the mainland by a large sand tombolo. South of Penzance granite cliffs form the coastline and continue around the Lands End peninsula.

Lands End to Hartland Point

In contrast to the coast of south Cornwall, the north Cornwall coast is characterised by bold cliffs incised

by steep valleys. The cliffs are generally higher, the highest cliffs reach over 200 m between Boscastle and Widemouth Bay. The general appearance of many lines of the cliffs of north Cornwall and Devon is governed by the fact that they are cut into one or other of several marine erosion platforms (formerly the sea floor) uplifted during the Tertiary period (about 30 m years ago). These platforms govern the height of the cliffs which tend to have a flat top and a sheer drop to sea level. Examples are seen between Navax Point and Portreath, in the St Agnes Head area and at Hartland Quay. Elsewhere there are seaward sloping 'hogs back' type cliffs often displaying several slope elements. It is usually only the base of such cliffs that are presently being actively eroded by the sea. The segments represent periods of cliffing followed by sub-aerial weathering and are related to varying sea levels. Many fine examples can be found along the coast of North Devon, at Baggy Point, Ilfracombe and Foreland Point. The cliffs of North Cornwall and Devon have been described in detail by Arber (Refs 25 to 27). Contemporary rates of erosion of the hard rocks exposed at the coast are extremely slow and where wide shore platforms occur these are likely to be relict features. The geological structure of the rocks clearly influence the local nature of the cliffs. In the Tintagel - Boscastle area thrusting and faulting have produced lines of weakness which have been exploited by the sea to form stacks, gullies and reefs.

The granite cliffs continue around the Lands End peninsula to St Ives. North of St Ives to Boscastle the cliffs are formed in Devonian slate. In general the coastal outline is smoother than that of South Cornwall with large embayments, some containing large stretches of sandy beaches, such as St Ives, Perranporth and Newquay. Where these are exposed to

persistant onshore winds there are considerable areas of windblown sand such as at Hayle, Gwithian, Perranporth, Trevose head, Polzeath and at Bude. The River Camel forms the only major estuary and indentation along this coast and contains large quantities of drifting sand derived from the waste of past tin mining activity.

North of Boscastle to the Taw-Torridge Estuary alternating shales and sandstones of the Upper Carboniferous are exposed to form high, flattopped stable cliffs. From Bude to Hartland Point the coast faces due west. The rock strata are intensely folded and faulted and this is seen in the cliffs and exposed by wave action on the reefs and wave-cut platform.

Hartland Point to Morte Point - Bideford Bay

To the east of Hartland Point the coast faces north and forms the large embayment of Bideford or Barnstable Bay. From Hartland Point to Westward Ho! the coast is of continuous high cliffs fronted by a rocky foreshore sometimes covered by banks of large pebbles at the limit of high tides. Littoral drift is to the east but the net effect is insignificant as any drift is confined within individual bays. However, the accumulation of pebbles has caused some problem at Clovelly where a pebble bank blocks the harbour at low tide. Eastwards towards Westward Ho! the cliffs become wooded and have a hog's back shape. East of Peppercombe there is a well developed wide wave cut platform at the cliff base formed in a band of resistant limestone and strewn with pebbles.

Northwards of Westward Ho! to Saunton coastal cliffs are absent and the coastline is formed in recent superficial deposits. The former coastline can be traced inland to Appledore and Braunton representing a

small embayment formed by the erosion of relatively soft strata within the Mezozoic rocks and now crossed by the twin estuaries of the Rivers Taw and Torridge. The Westward Ho! Pebble Ridge is a shingle spit extending some 3km northwards into the estuary and forms the only natural protection against the incursion of the sea for Northam Burrows, a large area of alluvial flats lying slightly below the high water mark of spring tides. The ridge is the product of wave action and is essentially a storm beach reached only at high tides and fronted by wide intertidal sand flats. It is composed of large smooth pebbles ultimately derived from the North Devon coast but with remarkable consistency of lithology, a fine grained sandstone of varying shades of red, grey and green. At the southern end erosion has reduced its width but north of Sandy Mere, (a pool behind the ridge), active accretion has extended the ridge which shows typical recurve features at its distal end. It is clear that the ridge was once of much greater dimensions than at present. It is estimated that the net loss of pebbles from the ridge averages 1200m^3 per year and this has been reflected in a reduction in height and width of the ridge which has coincided with recession and encroachment onto the Burrows (Ref 28). Between 1861 and 1932 the average annual rate of retreat is estimated to be 1.75m. A presumed reduction in the supply of beach material from the west is believed to have initiated such erosion, enhanced by the northward drift of stones from the ridge itself. Efforts to curb the recession and protect land and property are likely to have contributed to the depletion of the pebble ridge. The sea wall at Westward Ho! was built in the 1920s but wave reflection and scour at the base of the wall merely accelerated erosion at the proximal end of the ridge and the slipway interrupted the alignment of the crest such that movement of the stones onto the ridge was inhibited. Following a

breach of the ridge in 1962 and again after severe storms in 1974, gabions were placed in a effort to build up the ridge. However, these proved ineffective and became badly damaged. Breaching and wave overtopping of the ridge remained a permanent danger especially at its midpoint. Since 1974 several beach replenishment exercises have been undertaken whereby material from the area of accretion at the north-eastern end of the spit was placed near the slipway and in 1982 rip-rap was placed against the sea wall to reduce scour and reflection.

The reason for the decrease in supply is not clearly known. The cliffs from Rock Nose to Hartland Point enclose bays containing large quantities of pebbles to which the cliffs must contribute. However, these pebbles are contained within the headlands of the individual bays and the drift of pebbles appears to be of little significance. It is also thought that theridge material originates from the raised beach deposit at Rock Nose but addition to the beach below must be slow since surface exposures of the pebbles are few. It would appear that the ridge is in fact a relict feature formed during the late Pleistocene period. Prior to the melting of the ice sheets the sea retreated and blue clays and pebble banks were deposited near the shore. Peat and forests occupied the land behind. As sea level rose to its present position so the banks were moved onshore over the clays which are often re-exposed on the foreshore when the overlying beach sands are removed during storms. Deposits of peat and submerged forest are often exposed on the foreshore near the southern end of the ridge. Thus under present conditions the ridge would appear to have become an isolated feature with only a therefore limited supply of stones and erosion is likely to continue.

The coastal sand dune system of Braunton Burrows extends southwards for 5 km into the Taw-Torridge estuary from the cliffs at Saunton Down. The dunes form a belt 2 km wide and rise to 16 m. The lower fore-dunes have suffered erosion in the past and attempts have been made to re-establish them. Erosion at Airey Point and Crow Point has been attributed to the effects of sand and gravel extraction.

The Westward Ho! pebble ridge and Braunton Burrows appear to have been formed independently by the drift of material from opposite directions indicated by the recurved ends of the two spits, Crow Point on the north of the river and Grey Sand Hill to the south (Ref 29). Groynes at Westward Ho! indicate drift on the upper beach to the north while those near Bideford Bar Lighthouse indicate drift in the opposite direction. Stuart and Hookway (Ref 30) show that marked pebbles on the pebble ridge moved north and that pebbles from the ridge do not cross the estuary but accumulate at Grey Sand Hill.

To the north of Braunton Burrows the coastline is once again formed of cliffs of Devonian rocks which outcrop from beneath the Culm Measures and consist mainly of grits, sandstones, conglomerates, slates and shales. Two bays, Croyde Bay in the south and Morte Bay further north, are each enclosed by projecting rocky headlands. Both bays are fully exposed to the prevailing westerlies and thus the sandy beaches are backed by wind blown sand accumulating at the base of the low cliffs.

Morte Point to the Severn Estuary

Between Morte Point and Minehead the coast of Exmoor is characterised by rugged and strongly indented cliffs. Small coves contain sand and shingle beaches

but there is no significant littoral drift. The cliffs are high and of the hog's-back type with steep slopes formed by sub-aerial weathering. The slopes are often wooded as between Lynton and Porlock. The northern aspect of the cliffs provides protection from severe marine erosion and there is little active cliffing at the sea margin. Steep valleys dissect the cliffs, for example at Lynton, where large boulders and stones discharged by the river during the 1952 floods accumulated at the river mouth and pushed the LWM seawards. At Porlock a shingle ridge protects low lying alluvial land between Gore Point and Hurlestone Point and is generally accreting at the eastern end.

The coast of Bridgwater Bay, eastwards from Minehead to Burnham-on-Sea, is formed in relatively soft Lower Lias (Jurassic) and older Triassic rocks (New Red Sandstone) which consist of interbedded clays and marls with some limestone. Between Blue Anchor and Watchet the cliffs reach 75m high but generally decrease in height eastwards. The crumbling cliffs have been subject to long-term wave induced erosion as well as sub-aerial weathering and are fronted by a wide foreshore with some rock exposures. Erosion and falling beach levels have threatened the coast road at Blue Anchor Bay which is now artificially protected. Much of the coastline is fringed with shingle banks which protect the low lying land in the eastern part of the bay from flooding. The foreshore at low water is a mixture of sand and silt but further eastwards there is an increasing proportion of mud and fine sediments as wave action is reduced. Just west of the estuary of the River Parrett occurs a series of unusual accumulations of beach shingle. A storm beach of shingle extends from Lilstock to Stert Point but between Stolford and Wall Common the shingle is piled up in as many as twenty 'fossil' ridges behind the present storm ridge and extends seaward over some

400m. At Wall Common ridges have developed seaward of the County Sea Wall which predates the 1850s. These shingle 'complexes' have been studied in detail by Kidson (Ref 31).

The shingle has accumulated downdrift of Lilstock Point which acts as a natural barrier to the drift of coarse beach material from the west. From Lilstock to Hinkley Point the low cliffs (about 25m) are made up of Lower Lias rocks consisting of thinly bedded limestones, clays and shales and are fronted by a wide rock abrasion platform which clearly shows the variable dip of the strata. This local source is likely to supply the beach material since supply from further west is limited. The clays and shales distintegrate rapidly under marine action and are carried in suspension into the Bristol Channel. The limestone is therefore the most important constituent of the beach shingle. Small cliff falls are frequent and limestone debris is usually present on the platform. At Hinkley Point softer clays and shales outcrop in very low cliffs of 1-2m and are subject to fairly rapid erosion but add little coarse material to the beach. The size of the shingle decreases eastwards reflecting the inability of the Lias limestone to withstand abrasion. Similarly the proportion of limestone found in the shingle gradually decreases eastwards, the remainder being made up of more resistant sandstone pebbles. Tracer experiments have shown the net rate of the easterly longshore movement along this section of the coast to be slow for the following reasons; the initial large size of the material, the wide wave-cut platform allowing waves to dissipate their energy, the relative shelter from severe wave attack and the very high tidal range when the actual period over which waves are able to reach the shingle is limited to storm periods or spring tides (Ref 32).

From north-west of Hinkley Point to Brean Down there is a vast intertidal silt area extending for some 3 or 4 km known as Stert Flats and Berrow Flats. The accumulation of the shingle to the west of Wall Common has led to the starvation of the beaches farther to the east and to severe coastal recession in the past. This is now reduced by the use of spartina grass. Spartina grass was introduced experimentally in Bridgwater Bay in 1928 and now covers about 300 acres eastwards to Stert Point. It has been effective in trapping mud and silt and the level of the foreshore has risen by a mean rate of 5cm/year (Ref 33). This accretion appears to be extending and the spartina has sown itself in several places on the coast along the Bristol Channel.

The mouth of the River Parrett is deflected northwards across the mudflats by the shingle spit at Stert Point, which incorporates Fenning Island. Stert Island was formerly part of a much larger spit feature and was created by a major breach in the 18th century. Subsequently more shingle has accumulated at Stert Point from the west while counter drifting to the south has led to the accumulation of shingle at the southern end of Stert Island (Ref 29).

North of Burnham-on-Sea the coast faces west and is exposed to persistant westerly winds and Atlantic gales which carry sand from the wide intertidal flats inland to form coastal dunes (up to 16m high) extending for about 7km northwards towards Brean Down. Sea buckthorn and marram grass have been planted in order to stablise the dunes which provide protection from flooding of the vast low lying alluvial area of the Somerset Levels behind.

Weston Bay and Sand Bay to the north are each enclosed by limestone headlands. These headlands and

associated nearshore current movements have caused the deposition of extensive sandy beaches but prevent the longshore transfer of materials between the bays. Much of the shoreline of Weston Bay between Brean Down to the south and Worlebury Hill to the north is built-up and is artificially protected by sea walls. In Sand Bay, between Worlebury Hill and Middle Hope, falling beach levels over recent years have been attributed to wave reflection from the sea wall and has led to wave overtopping on some occasions. This situation has been remedied by a sand nourishment scheme.

Bristol Channel and Severn Estuary

Much of the shoreline of the southern side of the estuary as far as Avonmouth is low lying and is artificially protected by a variety of walls and clay embankments. The sand beaches give way to a muddy inter-tidal foreshore fringed by saltings which for the most part are in a fairly healthy condition.

The Bristol Channel and the Severn Estuary together form a wide, shallow estuary with a large tidal range and strong tidal currents. At spring tide the range at Avonmouth exceeds 12m but can occasionally reach a maximum of over 14m due to the funnelling action by the configuration of the estuary and which culminates in the formation of the Severn Bore. The reduction of all fetch lengths excepting those from a narrow sector in the south-west leads to a significant reduction in wave activity. Thus the overall net easterly littoral drift of sediment apparent along sections of the more open coast to the west decreases in magnitude upstream and sediment movement becomes increasingly influenced by strong rectilinear tidal currents (over 1.5m/sec at springs) with a westerly residual flow. Such currents

are capable of maintaining large quantities of sediment up to sand grade in suspension.

The bed of the Bristol Channel and Severn Estuary comprises of a wide range of lithologies. Off the coast of North Devon the sea floor is largely rock with occasional sand and gravel ribbons. In the Inner Bristol Channel there are two east-west trending sand banks, Culver Sand and Holm Sand, with thick (up to 10m) and extensive (30km^2) sub-tidal and inter-tidal muds to the south in Bridgwater Bay. Further upstream superficial deposits cover the rock floor with sands and gravels occupying the central channels and muds covering the more shallow inter-tidal margins. Thick deposits of mud are found within Newport Deep and the tributary estuaries are also muddy.

There appears to be no contemporary source for the sands and gravels, the underlying bedrock being made up of finer grained Jurassic limestones and siltstones. It is therefore more likely that these sediments were derived from glacial material deposited within the estuary during the post-glacial sea level rise and subsequently reworked in this high energy environment. The only contemporary source of sediment appears to be fine-grained material supplied by the rivers and from erosion of local rocks.

Thus the Upper Bristol Channel and the Severn Estuary appear to act as a sediment circulation cell within which there is only a relatively small input of fresh fine sediment and where existing sediments are reworked and redistributed by tidal currents. The sands appear to circulate in a clockwise direction around individual sand banks. The suspended finer fractions are concentrated in a turbid water zone that extends along the English side of the estuary. Estimates of the quantity of suspended sediment within

the estuary naturally vary according to the area under consideration and the method of calculation but are of the order of 10 - 30 million tonnes (Refs 34 and 35). The areas of settled mud within Bridgwater Bay show a complicated pattern of erosion, stability and deposition suggesting that this area acts as both a long term source for fine sediment and as a long term sink to which sediment eventually returns. Newport Deep is also thought to act as a sink as well as the tributary estuaries and salt marshes for example between Hinkley and Stert.

Several schemes have been proposed to utilise the high tidal energy within the Severn Estuary for power generation by the construction of a barrage. This has given rise to a wealth of studies involving data collection and physical and numerical modelling to establish the possible effects on the existing physical, chemical and biological systems. The cessation of tidal flows in the upper estuary would reduce the movement of sediment and promote the settling of large quantities of sediment along its margins and tributaries. Outside the barrage deposition is also likely to predominate although it is possible that localised erosion may be accelerated due to the reduced tidal range and consequent narrowing of the inter-tidal zone.

4 WINDS, WAVES AND TIDAL CURRENTS

4.1 Wind - wave climate

There are a number of systems for obtaining offshore wave data around the British coast. Numerous weather observation stations have measured winds around the coastline of England and Wales and the data measured at the more exposed stations can be converted to

offshore wave data by means of computer simulation (Refs 36 and 37). Offshore wave data is collected by weather ships, light vessels, and visual ship observations. There has been much data gathered in recent years on the inshore wave climate, either by wave rider buoys or pressure sensors, and the areas where this has been carried out are listed below.

The south west corner of England from Portland Bill to Lands End and then east to Ilfracombe is well exposed to the predominant waves from the south west. Department of Energy reports predict that maximum extreme wave heights for a fully developed 1 in 50 year storm may exceed 22m in the area off Lands End (Ref 38). These heights diminish to the east up the English Channel and to the north east into the Bristol Channel. Estimated crest to crest periods associated with these wave heights range from a maximum of 19 seconds off Lands End diminishing to the east and north east. These wave conditions bear little relation to the inshore climate which depends to a large extent on the shelter afforded by the land mass and local promontories and the regularity or otherwise of bed contours in the nearshore zone.

The design of coastal structures should ideally be based on long term wave data observations. Such observations can be carried out in a number of ways, from a wave gauge (a graduated pole placed on the foreshore and observed manually) to pressure gauges (set on the floor of the sea bed and recording pressures on an enclosed tape), to wave rider buoys (which are tethered offshore and send data back to a recorder onshore). It is also possible to obtain the inshore wave climate by converting locally gathered wind data, using a computer program. This is done regularly by such establishments as the Meteorological Office and Hydraulics Research (Refs 36 and 37). In

almost all cases, however, such information requires to take into account such nearshore effects as wave refraction over the seabed bathymetry or diffraction around headlands. These processes have a very major effect in bending waves round so that they are nearly parallel to the nearshore seabed contours and thus reduce littoral drift to a small value despite the fact that the beaches may be very exposed to Atlantic wave activity.

Beside the data recorded regularly by the coastal weather stations, weather ships and light vessels, local wave conditions are sometimes recorded as mentioned above. Listed below are the known records of wave climate for particular areas both offshore and nearshore. These are obtained either from the Institute of Oceanographic Sciences (Ref 39) or from the records of Hydraulics Research.

The offshore coastal recording stations include:

The Seven Stones Light Vessel (off Lands End)	SWR	Jan 1962-Jun 1964
The Seven Stones Light Vessel (off Lands End)	SWR	Aug 1964-Jun 1965
The Seven Stones Light Vessel (off Lands End)	SWR	Aug 1965-Dec 1967
The Seven Stones Light Vessel (off Lands End)	SWR	Jan 1968-Dec 1969
The Seven Stones Light Vessel (off Lands End)	SWR	Jul 1971-Jun 1974
The Seven Stones Light Vessel (off Lands End)	SWR	Apr 1975-Sept 1981*
Channel Light Vessel (English Channel)	SWR	Sept 1979-Mar 1987*
The Boyle Weather Station (in the Celtic Sea)	SWR	May 1974-Jun 1977
The Shambles Light Vessel		

(Portland Bill, Dorset) SWR Mar 1967-Mar 1970

Inshore data has been recorded at the following locations

Portland (Dorset)	FLWR	1964-1966 (18 months)
Chesil Cove (Dorset)	PG	Nov 1979-Mar 1980
West Bexington (Dorset)	PG	May 1973-Sept 1977
West Bexington (Dorset)	WRB	Sept 1985-Mar 1987
Bee Sands (South Devon)	PG	Apr 1972-Jul 1974
Slapton (South Devon)	PG	Dec 1972-Jan 1976
Budleigh Salterton (South Devon)	PG	Apr 1975-Jul 1975
Hall Sands (Devon)	PG	Mar 1974-Sept 1976
Prawle Point (Devon)	WRB	Apr 1975-Jul 1975
Eddystone, off Plymouth (Devon)	WRB	Jul 1973-Sept 1981*
Falmouth (Cornwall)	WRB	Jun 1984-May 1985
Falmouth (Cornwall)	PG	Jun 1984-Mar 1985
Scilly	WRB	Feb 1980-June 1985
Perranporth (Cornwall)	PG	Aug 1945-Jan 1947
Perranporth (Cornwall)	WRB	Nov 1975-Sept 1981*
Off Perranporth (Cornwall)	WRB	Aug 1978-May 1979

Perranporth (Cornwall)	WRB	Sept 1980-Sept 1981*
Off Farley, Culver Cliff (Bristol Channel)	WRB	Dec 1971-May 1972
Hinkely Point (Bristol Channel)	PG	Mar 1959-June 1959
Helwick Light Vessel (Bristol Channel)	SWR	Aug 1960-Jul 1961
Clovelly (Bristol Channel)	PG	Apr 1967-Nov 1967

* indicates that the recording continued beyond that data.

SWR - Shipborne wave recorder
WRB - Wave rider buoy
FLWR - float level wave recorder
PG - pressure gauge or sensor

The above data provide local, short term measurements of wave conditions off a particular stretch of coast. In order to "transfer" the same conditions to the point of interest at the shoreline requires the use of wave refraction models (Ref 40).

4.2 Tides and tidal currents

Tides off the south west corner of England are semi diurnal in character, the flood tide flowing east up the English Channel and north east towards the Severn Estuary. A considerable amount of research and measurement of tidal phenomena has been carried out (Refs 41 to 43) which enables the expected (astronomical) tides and their associated currents to be described at a number of points around the coastline of Britain.

From a coastal engineering viewpoint the magnitude of the tidal range is particularly important. Where the tidal range is large and the level of the high water mark of spring tides is high then there is a likelihood of wave overtopping during severe storms. On the other hand where the tidal range is small then even a small surge can increase the high water considerably and enable waves to reach areas of backshore which are normally out of reach of wave action.

In the English Channel the tidal range decreases eastwards from almost 5m (spring tide) at Penzance to less than 2m (spring tide) at Portland.

On the west facing coast of Cornwall and Devon the spring range increases by about 3m between Cape Cornwall and Ilfracombe, as a result of the funnelling action in the approaches to the Bristol Channel. Within the confines of the Bristol Channel and the Severn estuary this increases from about 8.5m at Ilfracombe to over 12m at Avonmouth. Details about the predicted tides can be found in Admiralty Tide Tables.

Mean Spring Tidal Ranges

The English Channel

Penzance	4.8m
Falmouth	4.7m
Plymouth	4.7m
Salcombe	4.6m
Torquay	4.2m
Exmouth	4.0m
Lyme Regis	3.7m
Bridport	3.5m
Portland	1.9m

Approaches to the Bristol Channel

Cape Cornwall	5.4m
St Ives	5.9m
Newquay	6.4m
Padstow	6.5m
Clovelly	7.4m
Ilfracombe	8.5m

The Bristol Channel and Severn Estuary

Minehead	9.7m
Watchet	10.3m
Weston Super Mare	11.3m
Avonmouth	12.3m

Tidal currents are strongly dependent upon the seabed and on the local inshore topography. General information on the strength, direction and duration of tidal streams can be found on the relevant Admiralty Charts and tidal stream atlases. However such information is usually very sparse and to obtain detailed information on tidal current activity in a local area requires the use of numerical models (Refs 42 to 43). Some of these models are also able to predict the movement of sediment in suspension, dispersion of sediment or effluent from its source of origin and are able to predict rates of siltation or erosion.

Tidal current activity is complex around the south west coast because of the many headlands and promontories which divert or deflect tidal streams. An extreme example is the tidal race off Portland Bill where, despite the small tidal range, currents of up to 5m/s can occur. Strong tidal currents are also common off pronounced headlands such as Start Point (1m/s on spring tides), or the Lizard Peninsula (1.2m/s on springs).

In the bays off the south-west coast tidal currents are much weaker and have very little effect on the

movement of beach material. In Torbay, for example the maximum currents on spring tides are of the order of 0.5m/s. In Perran Bay tidal current speeds are less than 0.5m/s on springs and are only slightly higher than this in Padstow Bay. Within Bristol Channel, tidal current speeds are very much higher with the rapidly increasing tidal range. Off Hartland Point tidal currents of 1½m/s are experienced. Currents of this order of magnitude are generally experienced up to the mouth of the Severn. In the Bristol Deep, within the Severn Estuary these increase to 2m/s. With the complex system of banks and channels in the Severn Estuary measured values of tidal current speed at individual positions give little indication of the general pattern of tidal movement. Detailed information can be obtained from computational models which for example were used as part of the Severn Tidal Barrage Study (Refs 44 and 45).

Surges

Wind induced surges can play an important part in raising water levels above that predicted by "astosnomic" tide tables. Recent studies by the Institute of Oceanographic Sciences give predictions on maximum sea levels that can be expected for various return periods (Ref 46). In these predictions both astronomical tides and surges are included in the analysis. For the coastal engineer often it is the joint probability of occurrence of wave overtopping by both waves and tidal levels that is necessary for design purposes. A number of such analytical techniques have been developed at Hydraulics Research and have been used in the design of major flood defence schemes in Britain (Refs 47 and 48).

5 REVIEW OF COASTAL DEFENCES

5.1 Portland Bill to Start Point

The coastline from Portland Bill to Start Point consists of three distinct stretches. To the east there is the 29Km long shingle ridge of Chesil Beach. Next there are soft, eroding chalk and sandstone cliffs with a sand and shingle foreshore. To the south west there are more durable slate and limestone cliffs, forming a deeply indented coast, with sandy coves and inlets.

5.1.1 Portland to Lyme Regis

Chesil Beach is a gently curving, continuous ridge of shingle which stretches from the Isle of Portland to Bridport Harbour. The shingle size and the height of the bank reduces westwards, the crest height at Chiswell being about 13.5m A.O.D, 7m at Abbotsbury and 6m at Bridport. The size sorting and bank size is a function of the wave exposure, see Chapter 3. The rate of littoral drift along the Chesil Beach is low and generally in a north-westward direction. Near Bridport the nett drift is about 8000m^3 per year.

There is no significant feed to Chesil Beach either from alongshore or offshore. Although the volume of pebbles forming the beach is large (estimated at between 24 and 100 million tonnes) the quantity of material that has been extracted from the beach for industrial purposes is believed to be between 1 and 2 per cent of the present volume (Ref 2). Extraction has now ceased but losses continue as a result of the nett transfer of shingle from east to west across the entrance to Bridport Harbour. Already coastal defence problems are being felt at both the east and west ends

of the beach. At the east end where the beach joins the sea wall at Chesilton, there is an area of potential weakness. The natural reaction of any shingle ridge is to migrate landwards as beach pebbles are thrown over the crest by wave action. Thus the eastern end is tending to separate from the sea wall. Overtopping has been reported in this area on about twenty occasions over the last century, with fifteen of these having been recorded during the last fifty years. Measures have now been taken to stabilise the crest of the beach adjacent to the sea wall. The protection consists of a three layered gabion mattress placed over the crest, raising its height by about 1m. The scheme also includes a drainage system behind the beach, so as to reduce the problems of flooding if the crest was overtopped.

The unprotected beach to the west has been moving landwards at a very slow rate. Some stretches have on occasion, been overtopped but not with the serious consequences as the eastern end. At Cogden Beach shingle has been extracted for many years. This has not led to any serious problems locally since the extraction holes fill in rapidly by wave action.

There have been major changes at the western end of the beach where the entrance channel to Bridport Harbour has been cut through the shingle ridge. There was always a river outlet here but since the construction of the harbour arms the beach to the east has built up while that to the west has eroded. The situation began to deteriorate as far back as 1852 when the then open harbour arms were encased. Continued abrasion by pebbles has led to the maintenance costs of keeping both harbour arms intact being very high. A study carried out by H.R.L. (Ref 5) to see if the harbour arms could be shortened to reduce maintenance costs showed that any shortening

of the piers would lead to serious siltation in the harbour entrance. Shingle bars are now a permanent feature in the entrance channel and maintenance dredging is required to regulate water depths. Even so access is limited to the higher stages of the tide.

To the west of Bridport Harbour the shingle beach has largely disappeared. Downdrift erosion is a perennial problem and a number of coastal defence schemes have been carried out in recent years to strengthen the sea wall and minimise overtopping. The newly reconstructed sea wall and rock toe protection are the joint responsibility of the West Dorset District Council and Wessex Water. The importation of large quantities of quarrystone to the base of the west jetty has only slowed the rate of beach deterioration. Two rock bastions have also been constructed on the foreshore between the harbour and the western end of the promenade. These have not eradicated the problem of beach lowering and further measures are needed to protect this frontage from further deterioration.

To the east of the harbour entrance the beach is backed by steep sandstone cliffs but these are out of reach of wave activity. West of the harbour the cliffs are sands and clays which are susceptible to erosion and slippage. They provide little beach building material. The cliffs, of erodible sands and clays, extend west to Lyme Regis.

Eype Mouth has a steeply shelving shingle beach, which on either side of the narrow river valley is backed by cliffs of crumbling sandstone overlying clay. The small village of Lower Eype is well upstream and there are no coastal defences within the embayment.

Between Eype Mouth and Seatown the soft sandstone cliffs are underlain by clays which outcrop at sea level and the sand and shingle foreshore is intersected by the remnants of old slips.

Seatown lies in a valley formed by faulting of the sand/clay cliffs. The foreshore consists of a steeply shelving shingle beach with sand at low water. Erosion has taken place partly as the result of shingle extraction. Cliff falls in the vicinity of Golden Cap to the west act as temporary barriers to the alongshore transport of beach material. Thus the intermittent supply of shingle to Seatown's beach is another reason for the fluctuation in beach levels there. There are however no coast protection problems at present along this frontage.

The first settlement west of Seatown is Charmouth, situated upstream of the mouth of the River Cher. The foreshore consists of a shingle ridge with sand at low water. The Char which is partly trained by a concrete wall, drains seaward through the ridge. Erosion of the Black Ven Marls near Charmouth has added considerably to the beach material. However since the early 1960's a huge mudslide east of Charmouth has effectively separated Charmouth from the beaches towards Lyme Regis. Slips are frequent in this area and their seaward limit is often marked by accumulations of boulders pushed seawards by the slides. Slippage often results in the cliff edge being displaced seawards and downslope, hence the area of land 'lost' is not always easily identifiable. At Fairy Dell for example cliff retreat between 1887 and 1969 has been estimated as 35m (Ref 8). This is an average rate of 0.4m per year. Taking into account those areas of cliff which have 'partially slipped' then the rate of land loss is probably considerably higher.

Between Charmouth and Lyme Regis erosion of the cliffs has added sand to the beaches. The lower foreshore is sheltered by extensive limestone reefs. The sand beaches disappear just east of Lyme Regis. An area of low clay cliffs east of the town is protected by a seawall maintained by West Dorset District Council. The foreshore here is so rocky that wave reflaections from the wall prevent the formation of a beach of any size despite the presence of groynes. Also the groynes along the town frontage prevent material reaching the area. At the eastern end of Lyme Regis the sand and shingle beach is held in position by large groynes. The central part of the frontage is protected by a mass concrete sea wall also fronted by groynes. The beach here is low, due probably to the fact that the Cobb breakwater at the west end of the town traps the majority of the nett west to east littoral drift. However in the shelter of the Cobb there is a wide sand beach which extends into the harbour area. The coastal defences here are maintained by the West Dorset District Council. There are plans to improve the harbour area and to build up the beaches along the town frontage.

5.1.2 Lyme Regis to Exmouth

Devonshire Head, east of Lyme Regis is the county boundary between Dorset and Devon. West of this boundary, the coast protection authority is the East Devon District Council.

From Lyme to Seaton the coastal cliffs are notorious for their instability and there are extensive stretches of undercliff. Slips occur when the junction between the Greensand and the underlying Gault clay occurs above sea level and dips seawards. The release of flints, as a result of erosion and cliff slippage, has led to the build up of a wide

shingle beach to the west of the Cobb, giving this frontage good protection against wave activity. At Dowlands Cliffs the biggest recorded landslip in the U.K. occurred in 1839 when over 8 million tonnes of waterlogged chalk fell into the sea. Another fairly large slip occurred at Pinhay Bay in October 1960, following torrential rain.

Landslips have choked the original port at Axemouth and today the River Axe is deflected to the east by a large shingle bank (due to the west to east alongshore drift), forcing it against the foot of the cliffs. A 500m stretch of concrete wall on the east bank protects the foot of these cliffs against undermining.

To the west of the river mouth the town of Seaton is fronted by a beach of shingle and well rounded pebbles. Built by South West Water after serious flooding in 1980, a 900m long concrete sea wall topped with a parapet protects the low lying urban area against flooding. Immediately to the west, an old 200m long promenade and sea wall protects higher ground and is the responsibility of the East Devon District Council. The coastal defences are generally in good condition and appear to give adequate protection against wave action.

Between Seaton Seaton Hole there are cliffs of friable red marls. West of Seaton Hole the cliffs are of chalk. Erosion of these unprotected cliffs has produced shingle for Seaton's beach.

Beer has a shingle beach backed by eroding chalk cliffs. Protection at Beer consists of a concrete breakwater which retains the substantial shingle beach. South of Beer the high chalk cliffs extend around Beer Head west to Branscombe. There have been

many cliff falls along this coast including a massive slip at Hooken Cliffs in 1790 when some ten acres of land fell into the sea. Cliff instability does not pose any coast protection problems as the cliff top is largely undeveloped.

Branscombe at the mouth of a wide valley overlooks an unprotected beach of flint and chert pebbles. The eastward deflection of Branscombe Mouth indicates a pronounced west to east littoral drift. Branscombe East Cliff is vegetated and its toe is well protected by the beach. Branscombe West Cliff also has a pebble beach at its base. Since about 1946, shingle has been removed from this beach by a private contractor, though it is not known whether this practice continues. Between Branscombe and Sidmouth the cliffs of reddish marl with a capping of chalk, are pitted with caves. Differential erosion has led to the formation of small bays, stacks, arches and rocky foreshore platforms. At their toe there is an extensive shingle beach with material being transported in an eastward direction.

Sidmouth is at the mouth of a river valley flanked by cliffs of red marl. Infilling of the entrance by shingle has made the river unsuitable for navigation. The beach has sand at low water. Coast protection at Sidmouth consists of a seawall with groynes over 1100m of the frontage. The pebble beach is subject to drawdown during severe storms, exposing the sea wall to wave attack.

On the eastern side of Sidmouth, Salcombe Hill Cliff has little or no vegetation cover over the red marl. Both the high and low water marks showed a recession of about 30m between 1890 and 1937 (Ref 14). To the west the red marl cliffs are also prone to falls. From Peak Hill to High Peak the cliffs are of red

sandstone which extend south to Budleigh Salterton. The coastline has many coves with small sand beaches. One such is Ladram Bay which has been eroded out of sandstone between two more resistant headlands. It is skirted by a shingle beach. This coastal section is unprotected. Littoral drift is from west to east but is strongly fragmented. The sandstone is fine grained and is easily transported offshore in suspension by tidal currents. Thus the foreshore platforms in these areas are largely bare.

Budleigh Salterton has a steeply shelving beach of pebbles of quartzite and sandstones derived from the red marl. The beach extends eastwards, beneath high crumbling cliffs known as 'The Floors', and ends at the Otterton Point some 4Kms to the east. The River Otter has been deflected 500m eastwards as a result of the nett west to east drift. However the shingle is effectively constrained by headlands at both ends of the town frontage. At the east end of the town a low gabion wall does not entirely prevent erosion of the backshore. This stretches for some 800m, the eastern section being the responsibility of South West Water. There are no groynes or major defences along the town frontage.

East of Straight Point towards Littleham Cove, red marls with green mottling mix with the sandstone. The headland of Straight Point houses a firing range and is the responsibility of the Ministry of Defence.

Sandy Bay lies to the west of Straight Point, a high rocky headland. It has a wide sandy beach backed by crumbling sandstone cliffs. There is little possibility of beach material being transported around Straight Point.

Exmouth, on the eastern bank of the River Exe, has a long sandy beach extending from the Pier east to Orcombe Point. This beach is believed to be fed with sand from Dawlish Warren Spit. The eastward growth of this spit has forced the low water channel of the River Exe towards the Exmouth frontage. Hence there are dangerous currents off the Exmouth Beach. Masonry and concrete seawalls with some groynes and rock protect the town frontage. These are the responsibility of the East Devon District Council. There are also various stretches of revetment in the dock area upstream of the Pier, and these are the responsibility of the Exmouth Docks Company. Gabions protect the bank of the river adjacent to the Docks car park. Upstream for 4.5Km, masonry and concrete walls and revetments (mostly British Rail) run to the Schedule 4 boundary.

Movement of sand and mud within the estuary is complex and related to the growth or decline of the Dawlish Warren Spit. Erosion of material from the Warren has provided material for extension of the spit towards Exmouth (Ref 12). Since 1938, there has been a period of erosion with the spit migrating landwards into the estuary. The reason for this erosion may be connected with the construction of the railway line on the west bank of the Exe and sea wall protection extending to Dawlish. Protection of the previously eroding sandstone cliffs has greatly reduced the sediment supply.

5.1.3 Babbacombe Bay

On the west bank of the Exe British Rail protect the esturial shoreline to Dawlish Warren. Where the railway line runs close to the shore coast protection consists of stone and concrete sea walls protected by

loose rock in places. There appear to be no serious coastal problems within the estuary.

Dawlish Warren has a history of continuous change. On the north face of the spit, protection consists of privately constructed gabion walling and a low cost timber revetment. The south face is protected by gabions with a concrete seawall and groynes near the root, these defences being the responsibility of South West Water. A 400m rock revetment which is the responsibility of the Teignbridge DC, protects the proximal end of the spit.

From the Warren to Dawlish sandstone cliffs are fronted by a railway embankment. The railway line runs between the town and the beach and the coast protection mainly, the responsibility of British Rail but with short stretches maintained by Teignbridge DC, consists of concrete seawalls and some groynes. There is a continuous beach of shingle and coarse sand from Dawlish Warren to the southern end of Dawlish. The nett south to north littoral drift is low. The beach is generally unstable with alternating periods of erosion and accretion. Sand is sometimes blown onshore (Ref 28). From Dawlish south to Teignmouth old masonry and concrete seawalls with some groynes and timber or stone revetments protect the cliffed coastline. A few short lengths of cliff are unprotected. Responsibility lies mainly with British Rail for most of the coastal and estuarial frontage from Exeter to Newton Abbot. Teignbridge DC are responsible for short lengths of wall at the south end of Dawlish and north of the estuary mouth at Teignmouth. Also South West Water protect about 900m of low lying urban land north of the estuary mouth.

Teignmouth has a beach of highly mobile dark red sand. The condition of this beach is closely related to the

movement of sand bars at the mouth of the Teign, see Chapter 3. Movement of material via the bars is episodic and the north shore has periods of accretion and erosion. Littoral drift is generally from north to south, but also with periods of reverse drift (Ref 14). Teignmouth has a sea wall, and groynes to retain beach levels. In December 1975, easterly gales severely eroded the beach and undermined the sea wall, requiring major reconstruction. Coastal responsibilities on the north side of the harbour rest with the Teignmouth Harbour Comissioners, the Teignmouth Quay Company, South West Water, Crown Commissioners and British Rail. Shaldon on the south bank of the Teign Estuary is partly open to wave activity and the urban frontage is protected by a masonry sea wall which is the responsibility of Teignmouth District Council. The beach is narrow and consists of coarse sand and shingle.

The cliffs on the undeveloped coastline south of Shaldon are unprotected. The Teignmouth District Council boundary is near Herring Cove and to the south of it the authority is Torbay Borough Council. The coastline is strongly indented and there is thus little drift, but with a tendency for material to be transported northwards. The red cliffs of conglomerate to the north give way to limestone in the south. There are rock falls in this area and many of the coves are littered with boulders from cliff weathering. Maidencombe Cove has a sand beach flanked by wave cut rock platforms and backed by sandstone cliffs. In March 1962 rock falls were caused by waves reaching 3 to 4m up the cliff face. Damage was caused to the concrete apron of a cafe and disrupted the water mains. Watcombe Beach is backed by a short length of masonry sea wall. Further south the cliffs are again unprotected. At Oddicombe Beach the sands are backed by cliffs of sandstone and limestone. A

short concrete wall built in the 1940's has been recently renovated by the Torbay District Council.

South of Oddicombe there is much clifftop development. The coastal defences however are discontinuous and cliff erosion is generally not serious. Babbacombe Beach is sandy and is backed by an old wall which has been extended in recent years. The beach is sheltered by a stone breakwater at the south end of the cove. There are no coastal defences as far south as Anstey's Cove.

Redgate Beach lies within Anstey's Cove and is backed by 150m of masonry seawalls. These were built by the District Council in the 1950's and are in a satisfactory condition. The sand beach is backed by a shingle storm ridge which helps protect the cliffs behind.

The promontory of Hope's Nose marks the north end of Torbay. It consists of hard, resistant Devonian rocks and the cliffs are unprotected, despite the heavy urban development, as far south as Meadfoot Beach.

5.1.4 Torbay

Torbay is a large Bay containing a number of semi-enclosed beaches. These are generally stable and are wide and sandy. They are backed in places by old masonry walls. Littoral drift is low because of the strong indentation of the Bay. The nett movement is northward. The promontories of Hope's Nose and Berry Head are formed of fairly resistant Devonian rock (e.g. slates, limestones and grits) but the Bay has softer Permian rocks (e.g. sandstone). Movement of the beaches is largely checked by the shallowness of the bays, allowing waves to break and dissipate their energy offshore. Also most of the beaches are aligned

almost at right angles to the dominant waves, hence reducing littoral drift.

Torbay Borough Council maintain the defences in Tor Bay where most of the sea walls have been in existence for many years. Meadfoot Beach, mostly of sand with some shingle and shale, is backed by an old 800m long stone sea wall. The cliffs in this area are locally less resistant, and cliff falls in the past have damaged the masonry and concrete sea walls and endangered the roadway. There are a number of coves along this frontage with shingle beaches, the material being partly derived from local cliff erosion. These cliffs are unprotected from Meadfoot to Torquay Harbour.

Between the Harbour and Corbyn's Head lie Torquay's main beach, backed by masonry walls. Changes in the position of the low water line in this area is related to the construction of the harbour. There has been a redistribution of beach material with accretion to the east (in the shelter of the harbour arms) and erosion to the west.

Corbyn's Head is undefended, being amenity land and there has been considerable erosion of the red conglomerate at the cliff foot. South west of Corbyns Head lie Livermead Sands. Here the relatively stable sandy beach is contained between headlands. It is backed by about 500m of old masonry walls.

Between the headlands of Livermead and Hollicombe, is Hollicombe Beach. It is backed by masonry stone walls and a rock revetment. Here and at Preston and Goodrington Sands there was commercial removal of sand and shingle. The beaches at present are not undergoing erosion while cliff erosion is not a serious problem.

South of Hollicombe Head Paignton's beaches of reddish sand extend south to the small harbour at Roundham Head. Coast protection consists of low masonry stone walls of varying age. The walls are in good condition but there is, on occasion, local flooding by wave action.

South of the rocky headland of Roundham Head lie Goodrington Sands, bounded by concrete and stone faced sea walls of varying ages. A short stretch at the southern end is the responsibility of Dart Valley Railway Company. Further south are Saltern Cove and Shell Cove. The former has no coastal defences while the latter is backed by a timber breastwork. Some erosion of the backshore is evident in this area.

Between Goodrington and Brixham, there are several small bays and coves, the beaches of which are generally stable. Broad Sands, a sand beach with some locally derived shingle and pebbles, is backed by old sea walls which are generally in a satisfactory condition. Elberry Cove to the southeast is sheltered between two rocky headlands. The unprotected beach is composed of pebbles and is accreting. The resistant limestone cliffs further east to Brixham are unprotected and fronted by a narrow foreshore, with little beach material.

Brixham Harbour faces north and the long breakwater of coursed masonry, affords protection for the town's frontage so there are little formal coastal defences except for a short length of wall on the west shore. The beach is rocky with some sand and shingle within the Inner Harbour.

Breakwater Beach and Shoalstone Beach to the east of the breakwater are of shingle with rock outcrops and some 300m of masonry seawalls.

Berry Head, a high limestone headland, can be considered as an effective barrier to littoral drift, separating the sand beaches in Tor Bay from the thin boulder strewn beaches to the south of the Head.

5.1.5 Start Bay

This deeply indented bay is largely devoid of artificial coastal defences, apart from the low lying land at Slapton Sands and at Beesands.

Situated to the south of Berry Head, St Mary's Bay is enclosed by the limestone headlands of Durl Head and Sharkham Point. It has a sand and shingle beach. Falls and subsidence of the shale and sandstone cliffs (with one house destroyed in 1925) have occurred in the past, but there are no coastal defences in the Bay.

South of Sharkham Point, the coast protection authority is South Hams District Council extending south to the Plymouth City boundary in Jennycliffe Bay, Plymouth Sound.

High steep cliffs of resistent grits and shales extend to the River Dart. The small isolated beaches such as Man Sands and Long Sands are shingle with sand at low water. Beach material has, in the past, been taken from Man Sands for road making purposes.

Kingswear is situated north of the Dart Estuary with Dartmouth on the south bank. Both towns are situated sufficiently far upstream so as to be unaffected by strong wave activity and any deterioration of the defences is largely due to their age. The urban frontage is protected from the sea with masonry sea walls and quays, some of which are in a poor condition.

The cliffs between the Dart Estuary and Strete to the south consist of Dartmouth Slates and there is little erosion of the cliffs or from within the coves. Blackpool Sands, consists of fine gravel and coarse sand. The steeply shelving beach which faces almost due south is backed by high cliffs and enclosed between rocky headlands. The privately owned coast protection consists of about 100m of concrete seawall and rock revetment.

Slapton Sands forms the north end of a continuous shingle beach extending to Torcross. It is essentially a storm ridge with lagoons or "leys" to the landward. At Slapton Ley there is rock protection at the war memorial and car park. A concrete seawall and rock revetment , the responsibility of Devon County Council, protect the road at the back of the ridge, from Strete to Torcross.

The village of Torcross lies on the landward side of the coast road but nevetheless close to the beach. The shingle ridge is backed by a 300m long sea wall built after the severe storms of January 1979 when both Torcross and Beesands were flooded and severely damaged by wave action. The defences at Torcross are the responsibility of South West Water.

Beesands is separated from Slapton Sands by a small promontory called Limpet Rocks. It has a steeply shelving shingle beach while the backshore has large boulders placed to protect the village from storm waves. South West Water share responsibility for some 500m of rock protection here with South Hams District Council.

Hallsands, situated at the top of the sandstone cliffs with just one cottage near their base, has a narrow

shingle beach. In the early 1900's, 650,000 tons of shingle were removed from this beach to build the docks at Devenport. In 1917 storms dragged down what was left of the shingle beach and destroyed all but one of the cottages.

South of Hallsands there are strongly faulted cliffs of Mica and Hornblende Schists which extend to Bolt Tail, east of the Kingsbridge Estuary . The shoreline is rocky and strongly indented so that there is very little littoral drift.

5.2 Start Point to Plymouth

This coastline is composed largely of hard, wave resistant cliffs with numerous embayments cut through by small rivers which compartmentalise the drift. Some of the bigger bays like Bigbury, have major sand beaches.

5.2.1 Start Point to Bolt Tail

The rocky coastline between these two headlands is of hard limestone and metamorphosed schists, which are very resistant to weathering and wave action. There are numerous small coves fringed by wide rock ledges. Littoral drift is insignificant and the sand beaches are boulder strewn and fragmented. There are no coastal defences in this area.

Entry to Salcombe Harbour is partly restricted by a bar. The major beach is of rock, sand and mud and is situated on the east side of the entrance. The town frontage, which is on the west side of the estuary, is protected by stone quay walls. Devon County Council has defences as far south as South Sands and there is also privately owned frontage on the north facing shore at Splatcove Point.

From Bolt Head to Bolt Tail the high cliffs are are of mica schist. The foreshore is very rocky and narrow and practically devoid of beach material.

5.2.2 Bigbury Bay

This bay has cliffs which consist largely of shales and slates. Short lengths of coast protection are concentrated at the eastern end of the bay at Hope Cove and Thurlestone Sands.

The cliffs in Hope Cove are red, shaly friable rock. This eroding, rock flanked sandy cove has a small harbour at its northern end. Coast protection is shared between South Hams District Council and the Devon County Council and comprises of short stretches of stone wall. There is also a small breakwater.

Thurlestone Sands, has a coarse sand beach, on a rock platform. The cliffs of pebbles and grits are friable and sea stacks testify to the differential erosion of the strata. The only structure at risk is the Links Hotel in the north part of the cove. Dunes have developed behind the beach. The privately owned coastal defences consist of short lengths of sea wall, rock armouring and gabions at either end of the beach.

There are several large sand beaches to the west, at the mouths of the Rivers Avon and Erme and these have been subjected to major fluctuations. The area is exposed to south westerly storms and hence there is a good deal of seasonal fluctuation in beach levels. Occasionally peat beds are exposed in Bigbury Bay. The cliffs of shales and slates are subject to weathering and their erosion at Bigbury-on-Sea may eventually threaten property. In Challaborough Bay, beach erosion has taken place and the cliffs have been

subject to slippage and toe erosion. Here too properties may also be at risk at some future date. A number of houses at the head of the bay are protected by privately owned masonry and concrete sea walls. The sand beaches at the mouth of the River Erme have also undergone large changes, mainly as a result of the meandering of the low water channel.

The slate cliffs continue eastwards to Wembury Bay. This stretch of coast is undeveloped. Strata outcropping at sea level have formed extensive reefs. The beaches are very narrow and the nett west to east littoral drift is insignificant.

5.2.3 Wembury Bay to Plymouth Sound

The coastline around Wembury Bay is largely owned by the National Trust and the bay is a marine conservation area. The beach is rocky, has fine shingle, with patches of sand. The cliffs consist of slates which are generally fairly resistant, but from Blackstone Rocks to Wembury Point there is fairly rapid erosion resulting in the loss of good agricultural land.

From Wembury Point the low cliffs continue into Plymouth Sound. Along the eastern edge of the Sound within South Hams district, there are several strongly indented sandy bays of which Bovisand Bay seems the only problem area. A low bluff at the bay-head is protected by a short granite slab revetment which has been subject to storm damage.

Within the Sound Plymouth City Council share responsibility for defences with the Ministry of Defence, the National Trust, the British Transport Docks Board and several private owners. Because the shoreline is rocky the coastal defences are

discontinuous. At Mountbatten Point at the head of the Sound about 900m of stone sea walls are the responsibility of the Ministry of Defence. From Phoenix Wharf to Millbay Docks there are some 500m of stone sea walls, some of which are privately owned and maintained. At Millbay Docks the wharves are owned by the British Transport Docks Board. At Western Kings there are some 200m of stone sea wall. North of Devil's Point there are about 500m of masonry sea wall, the property of the Ministry of Defence. To the north of this is a short stretch of stone sea walls, some of which are private. On Drake's Island there are stone sea walls which are the property of the National Trust.

5.3 Plymouth to Falmouth

5.3.1 Devil's Point to R Fowey

The coastline from Cremyll on the west bank of Plymouth Sound to the River Fowey is under Caradon District Council. Cornwall County Council are responsible for four short stretches where roads or footpaths are threatened and some parts of the coastline are in private ownership. Although only relatively short stretches of coastline are developed, there are erosion problems at Kingsand, Cawsand, Portwrinkle, Plaidy and Downderry.

Cawsand Bay on the west bank of Plymouth Sound is protected from the prevailing south westerly storms by Rame Head. The sand and shingle beach is backed by an old stone seawall. This wall has been repaired and there are further schemes for improving the coastal defences in the area.

Westward around Penlee and Rame Head to Whitsand Bay the coastline is rocky and undeveloped. From Rame

Head to Hannafore Point the sand beach called Longsands, is continuous except for a number of small rocky promontories. To the west of Longsands is Portwrinkle with its small harbour and the sand and shingle beach to the east. The village is fringed by a wide rock platform and is protected by stone seawalls and gabions (looked after mainly by Cornwall CC). The stone walls are generally in good condition though some remedial works are in hand.

Slate cliffs dominate the coastline west to Downderry and they are fronted by narrow sand and shingle beaches. At Downderry a shingle beach gives way to extensive grey sands at low water. The slate cliffs are overlain by a thick covering of head which is easily eroded. A gabion retaining wall was built in 1970 to stabilise the toe of the cliffs. Cornwall County Council have also instigated further remedial works elsewhere in the area.

West of Downderry, mass cliff movements take place. At Seaton Beach the road runs close to the shore and here Cornwall County Council are responsible for a short length concrete seawall west of the river mouth. A similar seawall was built in 1981 on the east side. West to Millendreath, the slate cliffs are unprotected and subject to slippage.

At Millendreath the small rock flanked beach is of fine shingle and sand. Protection here is mostly privately owned and consists of short lengths of concrete seawall. Gabions, placed by the Cornwall County Council, protect the road at the east end of this cove.

East and West Looe are situated on either side of a narrow estuary south of the confluence of the East and West Looe rivers. A sandy beach on the east shore at

the mouth of the estuary is sheltered by a stone jetty. In the estuary itself there are stone or concrete seawalls with gabions protecting the frontage further upriver. The various wharves and sea walls at East and West Looe are maintained by the Looe Harbour Commissioners. On the west shore of the estuary, the concrete seawall extends from West Looe, southwards round Hannafore Point and as far east as Wallace Beach. Further works at Looe Harbour and at Hannafore are envisaged in the medium term. The wall protecting the coast road from West Looe to Hannafore is believed to be the responsibility of the Caradon District Council.

The coastline of Dartmouth Slates continues west to the Lizard. It is dissected by several headlands, bays and estuaries. The small coves are fringed by rocky headlands and wide rock platforms and there is very little drift.

Polperro has a small harbour in a cleft of an otherwise unbroken line of cliffs. The harbour walls here are maintained by the Harbour Commissioners but some stretches of sea wall are also in private ownership and have been damaged on numerous occasions by storms. During bad weather the harbour entrance is usually closed.

Between Polperro and Polruan the coastline of slate cliffs largely owned by the National Trust. There is a fine beach at low tide in Lantic Bay which is just to the west of Polruan.

At Polruan there are various, privately owned stone seawalls within the estuary and thesare thought to be in adequate condition.

5.3.2 Fowey to Dodman Point

The responsibility for this stretch of coastline lies chiefly with Restormel Borough Council. They have no serious coastal problems and, because of the rocky nature of the coastline, little direct involvement in coastal protection. Maintenance of the coastal defences is shared with Cornwall County Council, Charlestown Estate Company, the English China Clay Company and the Mevagissey Harbour Commissioners.

At Fowey, on the western bank of the estuary and at the beaches of Whitehouse and Readymoney there are stone seawalls and quays. These are believed to be in an adequate condition. The coastal defences at Readymoney are in private ownership.

Westward round Gribbin Head, there are high slate cliffs which continue northwards to Polkerris. The beaches are thin and boulder strewn. Polkerris is tucked away in the northeast corner of St Austell Bay and is flanked by rocks and cliffs. A small sand beach is contained within the shelter of a substantial breakwater. Outside the protection of this breakwater the foreshore is rocky. The small harbour is privately owned and the stone walls are in a good condition.

To the north is a large sandy cove known as Par Sands. The cove is backed by stabilised sand dunes protecting a low lying area. On the west flank is Par Harbour, owned and maintained by the English China Clay Co. It is protected by stone seawalls, breakwaters and quays. The sand beach which extends seawards by almost 1Km at low water has been formed by particles of quartoze and kaolinite, brought downstream from the China Clay works in the St Austell area. Large scale beach accretion has also led to siltation within the harbour

area. Now that the working methods have changed (with less waste being washed out to sea) the beaches have stabilised. To the west of Par Sands is Carlyon Bay. Here the deposition of waste has led to the development of Shorthorn Beach to the east and Crinnis Bay in the west part of the bay. The bay is now being developed as a holiday complex. Since the beaches are no longer accreting there is a slight danger of the area being flooded, particularly if the stream which crosses Shorthorn Beach were to back up the flood waters. These beaches and those further to the west are backed by low slate cliffs. The nett littoral drift is low and intermittent but generally in a west to east direction.

Two other small ports which were built for the once flourishing clay industry are Charlestown and Pentewan. The breakwaters, quays and seawalls at Charlestown are owned and maintained by the Charlestown Estate Co. The now abandoned harbour at Pentewan is also privately owned and the stone seawalls and timber revetment are in variable condition. This port was built in 1826 for the shipping of china clay. However silting, due to clay waste and competition from Par and Charlestown forced its closure in 1918. Pentewan has a wide sandy beach and has few problems with regard to coast protection.

Between these two small ports is the sandy cove of Porthpean. Here the sharply shelving shingly beach is backed by a road. The stone wall protecting the road is maintained jointly by the Restormel Borough Council and by Cornwall County Council.

Westward to the limit of the Restormel Borough boundary at Portholland Cove, the coastline is chiefly of slate cliffs. The cliffs are essentially stable and have a number of sand and shingle beaches which

are also generally stable. The coastline is strongly dissected by headlands and littoral drift is negligible here as elsewhwere along this coast. Mevagissey is the one harbour along this stretch and the Harbour Commissioners there are responsible for the breakwaters and quays.

Of the many coves along this coastline, only two have any protection. At Portmellon, the Cornwall County Council maintain stone sea walls but the road behind the sand and shingle beach is sometimes washed over by waves. Beach erosion has occurred here and studies have been made with the aim of restoring the beach to its former level.

Further south at Gorran Haven the sandy beach is sheltered by a small stone breakwater. The condition of this and the privately owned masonry seawalls is thought to be adequate.

5.3.3 Dodman Point to Carrick Roads

Dodman Point is made up of soft slate or phyllite cliffs and since the strata are steeply inclined in a seaward direction there is some slippage. Further west the cliffs are also mainly of slate but with a number of headlands formed of igneous rock.

West of Dodman Point is a beach of sand and shingle, called Hemmick Beach. The road behind is protected by a short length of stone seawall, maintained by Cornwall County Council.

At the head of the Veryan Bay, on the western boundary of Restormel Borough is Portholland Cove. The beach here is of shingle with sand at low water. The beach is backed by stone and concrete seawalls of varying length which, on the eastern side of the cove are the

responsibility of Restormel Borough and the Cornwall County Council. On the western bank, responsibility for the coast defence is shared by Carrick District Council, Cornwall County Council and various private owners.

West of Portholland Cove the coastline of consists of slate cliffs with short stretches of sand beach, giving way to rock platforms towards Zone Point. West of Zone Point there are numerous inlets with Carrick Roads near Falmouth forming one of the world's largest natural harbours.

With the exception of the coast protection at Falmouth, the Carrick D C have little direct involvement with coast protection. The village of Portloe, fronted by a small shingle beach, is well sheltered with a tiny rock flanked harbour. At Pendower within Gerran's Bay, Cornwall County Council protect the coast road with a short length of seawall. Here a long stretch of sand and shingle, broken up by rock platforms, is backed by slate cliffs.

On the western side of Gerrans Bay are the villages of Porthcurnick and Porthscatho. Porthcurnick has a sand beach and the backshore is protected by a short privately owned sea wall. Porthscatho harbour has a rocky foreshore with patches of sand. Protection at Portscatho is the responsibility of Carrick District with some stretches of wall in private ownership.

The coastal defences on the eastern shore of the Porthcuel River at St Mawes are chiefly for the protection of the coast road and are maintained by Cornwall County Council. The harbour and quay are owned by the St Mawes Pier and Harbour Company.

Further north into Carrick Roads, a 100m long stone wall is maintained by Cornwall County Council and protects the coast road at St Just. The deep water within Carrick Roads is a littoral transport boundary, with very little sediment exchange from the west to east shore or vice versa.

5.4 Falmouth to the Lizard

On the west bank of the Carrick Roads lies the small village of Flushing. Here the quay is protected by stone walls which are partly in private ownership and partly maintained by Cornwall County Council.

Falmouth, sited at the entrance to Carrick Roads, forms a safe refuge and has a large anchorage for ships. The Docks are owned and maintained by British Shipbuilders Ltd. Upstream of the docks are quays, stone and concrete seawalls and gabions, some privately owned, and whose condition is variable. On the south facing frontage, fairly recently constructed concrete walls are thought to be in good condition. There is an unprotected section between them and a scheme was in hand in 1981 to close this gap. At Swanpool Point and at Swanpool Beach, Cornwall County Council protect the road with short stretches of stone and concrete seawalls and rockfill.

South of the sheltered sandy bay at Maenporth, is the southern boundary of the Carrick District Council, with Kerrier D C to the west.

The coastline south of Maenporth and westward around the Lizard is within Kerrier District although they have virtually no direct involvement with coast protection. Cornwall County Council are responsible for some stretches of coast where roads or footpaths are threatened.

Rugged cliffs dominate this undeveloped and relatively inaccessible coastline and any protection is concentrated in the coves and harbours. A stone seawall protects the road at Helford and is maintained by Cornwall County Council. The accreting shingle beaches at Porthallow, Porthoustock and Godfrevy Cove have sand exposed at low tide. The village of Coverack overlooks a sand and shingle bay with a small fishing harbour at its southern end. The harbour is the responsibility of the Harbour Commissioners while other stone seawalls are maintained chiefly by Cornwall County Council. There is a wide stretch of sand punctuated by many rock outcrops at Kennack Sands. Just to the south, a number of buildings are situated close to the high water line at Carleon Cove. Privately owned short lengths of seawall fringe the stone and shingle beach at Cadgwith but beyond that there are no coastal defences to Lizard Point.

5.5 The Lizard to Lands End

The steep cliffs on the western face of the Lizard Peninsula are exposed to the full force of Atlantic storms. The coastline of Kynance Cove, north west of the Lizard Point, is particularly dramatic and this is due to the juxtaposition of hard and (relatively) soft rocks resulting in fissures, caves and offshore stacks. The fairly steep sandy foreshore is exposed only at low tide.

At the eastern end of Mounts Bay there is low lying land and a large sand and shingle spit, known as the Loe Bar, separates a freshwater lake from the sea. Further west shingle gives way to sand beaches of increasing size.

The sea defences north of the Lizard and westward to Kenneggy Sands are the responsibility of Kerrier

District Council. From here west to Lands End Penwith District Council are the coast protection authority. Neither authority has much direct involvement with coast protection. Cornwall County Council are responsible for some stretches where roads or footpaths are threatened.

The first accessible point on this rocky coastline is the harbour at Mullion Cove. Here the enclosing breakwater arms and jetties are built of hard basaltic rock and do not experience any serious problems.

To the north the sandy coves of Pollurian and Church are eroding slowly while between them the sandy beach of Poldhu Cove is sheltered by steep slopes. The beaches are backed by cliffs of soft slate.

The long shingle bank at Loe Bar, was formed when a natural sand bar dammed the River Cober sometime after the 13th century, thereby forming a freshwater lake. The bar had grown to a great size by the 16th century, but there is evidence that erosion is now taking place. South West Water are responsible for the outlet through Loe Bar. This three kilometre long beach of fine flint shingle stretches north eastwards to Porthleven Sands with Porthleven Harbour just beyond. The bar is well aligned to the predominant south-westerly waves and hence the rate of drift of shingle is low.

At the western end of Loe Bar is an area of beach erosion called Blue Buoy. The road behind the beach is protected by Cornwall C C. Porthleven harbour immediately to the north is owned and maintained by the Porthleven Harbour and Docks Company. Its entrance faces into the predominant south westerly waves. The jetties, wharves and quays are

constructed of granite and are believed to be in satisfactory condition.

Praa Sands a long sandy beach is backed by high sand dunes. At its west end there are privately owned seawalls the condition of which seem to be adequate. Both this and its neighbour Kenneggy Sands, are thought to be eroding. The coastal defences at Praa Sands consist of short privately owned sea walls, while at Keneggy Sands the backshore is unprotected.

Coast protection from west of Kenneggy Sands to Lands End and beyond rests with Penwith District Council although their practical involvement is very small. Although erosion is taking place in several areas there are no serious coastal defence problems. The few urban frontages are generally adequately protected.

The sand beach at Perran Sands and the shingle beach east of Marazion are thought to be eroding. Here the slate forms wide rock platforms while the overlying head forms low, easily erodible cliffs. Further west the coast is dominated by St Michael's Mount, an offshore granite island connected to the mainland by a large sand tombolo.

Marazion in the centre of Mounts Bay is protected by stone and concrete seawalls most of which are privately owned. To the west of Marazion the wide stretch of sand is backed by a low lying area of marshland. Here, Cornwall County Council protect the roadway which runs directly behind the beach while British Rail own several hundred metres of seawall where the railway line runs on the seaward side of the road. The condition of these walls is thought to be adequate. Intermittent stretches of stone seawall and gabion work protect the railway line between Marazion and Penzance with rock bund protection at the Penzance

end. The sand beach is continuous along this frontage and apart from local scour in front of the Penzance sea wall, it is stable. The frontage is strongly embayed and the nett west to east littoral drift is slight.

Slate, Greenstone and Hornblende slate form the cliffs at Penzance, while at Newlyn, south west of the town, the rocky foreshore consists of hornfels and greenstone

South of Penzance Harbour a shingle beach extends to Newlyn. Masonry block walls protect this frontage and are partly the responsibility of the Cornwall County Council. The piers, walls and quays of Newlyn Harbour are the responsibility of the Harbour Commissioners. South of the harbour, rock protection extends to Penlee Quarry and is maintained by the Amey Roadstone Company. Stone seawalls extending from there to Mousehole are maintained by Cornwall County Council. Amey Roadstone also share responsibility for a stretch of sea wall south of the quarry.

The pier,quays and stone seawalls at Mousehole are maintained by the Harbour Commissioners while adjacent stone seawalls which front the coast road, are the responsibility of either Cornwall County Council or private owners. There are no coastal sea defences between Mousehole and Lands End. Here the coastline comprises hard granite cliffs punctuated by small sandy coves, and the littoral drift can be considered negligible.

5.6 Lands End to Trevose Head

The exposed west facing coast is largely of high cliffs with rocky headlands and sandy coves. There

are few coastal defence works, short stretches of wall protecting private property in the small coves and some longer stretches fronting the larger sand beaches of the resort towns.

5.6.1 Lands End to Cape Cornwall

The coast protection authority is Penwith District Council. Cornwall County Council are responsible for protection of coastal roads and footpaths and private owners generally have to protect their own property.

From Lands End, high granite cliffs extend northeast to Whitesand Bay. Sheltered in the southwest corner of this bay is the small harbour at Sennen. Here the stone seawalls and jetty are maintained by the Sennen Harbour Commissioners. East of the harbour the coast road runs close to the shore and at its southern end protection to the road is provided by stone walls, being the responsibility of Cornwall County Council and Penwith District. The Bay is exposed to the full force of Atlantic winds and waves. Work has been carried out to stabilise the sand dunes backing the southern end of the bay.

The coastline to Cape Cornwall continues to be rocky with high granite cliffs and a few small coves. In Priest's Cove (south of Cape Cornwall) protection is by a privately owned short length of stone seawall.

5.6.2 Cape Cornwall to St Ives

High granite cliffs continue to the outskirts of St Ives. Littoral drift in this area is negligible. There are many coves along this stretch some of which have sand beaches while others are boulder strewn. The coves are separated by rocky promontories and most

beach material movement is in an onshore/offshore direction, in response to changes in wave activity. There are no coastal defences along this frontage.

5.6.3 St Ives to St Agnes Head

The clay cliffs backing Porthmeor Beach, west of St Ives Head, are eroding. The head of the beach is protected by privately owned stone seawalls. To the east, beyond St Ives Head is the sheltered wide sandy bay of St Ives. Situated in the northwest corner of the bay is the harbour whose quays, piers and stone seawalls are maintained jointly by Penwith District and Cornwall County Council. The stone seawalls fronting the town, and the walls backing Porthminster Beach to the south, are privately owned. The beach is generally stable but subject to seasonal variations in level.

East of St Ives, lies Carbis Bay. Here the 300m long seawall, backing the sandy beach is also privately owned. The sands stretch continuously from here, across the mouth of the River Hayle to Godrevy Point. The widest stretches of sand are at the river entrance.

Porth Kidney Sands, west the Hayle are backed by eroding sand dunes. The erosion is slight and affects the edge of a golf course. The stone seawalls, revetments and quays which fringe the estuary mouth, are all privately owned, with the exception of the protection to the road running east from Lelant across the estuary to Hayle, which is the responsibility of Cornwall County Council.

From Towan Sands to Godrevy Point there is a continuous, wide sand beach. The belt of sand dunes overlie rock and are subject to erosion in places.

The erosion is most severe at public access points to the beach, (much of the hinterland in this area being holiday development). Some erosion of the front line of the dunes is also caused by the severe exposure of the coast to strong winds. There is a slight northward drift within St Ives Bay. There is erosion at Strap Rocks, Gwythian Towans where the slate cliffs are attacked at high tide. Sand dunes at the cliff top have also been badly eroded by the wind. The shingle ridges and sand dunes on the low lying land near the Red River are also badly eroded. This area was used for sand extraction. There is however no housing at risk.

Between Godrevy Point and Navax Point lie the small coves of Mutton and Kynance which are backed by low cliffs. Beyond Navax Point is the boundary between Penwith District to the west and Kerrier District to the east.

The only coastal defences along the rugged coast between Navax Point and Tobban Horse near Porthtowan (the Kerrier District boundary) are at Portreath. Here there are privately owned sea walls backing the wide sand beach. Strengthening the harbour arm so as to prevent flooding of the low lying harbour area has been carried out by Kerrier District Council. High slate cliffs extend north eastwards to the district boundary.

The whole of this stretch is owned by the National Trust and the coastline from Godrevy Point to Portreath is designated as a Heritage Coast. There is negligible littoral movement along this frontage.

Carrick District Council who are the coast protection authority from near Porthtowan to Porth Joke near Newquay have little direct involvement in coastal

defence works. From Tobban Horse a long sand beach, backed by high slate cliffs, stretches north to a small rocky promontory known as Tubby's Head. Running into the sea through gaps in these cliffs are three small rivers. At the head of the southernmost lies the small holiday village of Porth Towan. The only man-made protection here is a short section of gabions plus netting put in at the head of the tidal inlet to control wind blown erosion of the sand dunes. The nett northerly is small. The beaches taper out towards St Agnes Head, a large headland which effectively curtails further littoral movement.

5.6.4 St Agnes Head to Kelsey Head

High slate cliffs dominate the coastline from St Agnes Head to Trevaunance Cove. Here a small harbour, constructed to handle copper and tin ore, was washed away some 70 years ago and all that remains are a few granite blocks embedded in the sands. A short length of privately owned stone wall is situated at the rear of this shingle backed sand beach. Otherwise there are no coastal defences as far north as Perranporth.

Perranporth lies at the southern end of a very wide sand beach. Over the years it has supplied large quantities of shelly sand to the coastal dune belt. The high, vegetated sand dunes stretch well inland from the beach, which extends north to Ligger Point. The town itself lies to the south of a river outlet and is protected by some 200m of stone seawalls, some of which are privately owned. Some dune erosion is taking place to the north of the river as a result of public over use. The port of Penhale which is owned by the Ministry of Defence lies between Ligger Point and Penhale Point.

The wide sandy beach of Holywell Bay lies between Penhale Point and Kelsey Head, two slate headlands. This beach is also backed by high dunes.

5.6.5 Kelsey Head to Trevose Head

Between Kelsey Head and Pentire Point West, is the sandy inlet of Port Joke. This marks the administrative boundary between the coast protection authorities of Carrick and Restormel.

On this part of North Cornwall responsibility for coastal defences is shared with Cornwall County Council and Restormel Borough.

Sheltered from the prevailing winds by Pentire Point West, is Crantock Beach. The beach is backed by extensive sand dunes which show signs of erosion. It is situated at the mouth of the Gannel Estuary which is largely infilled with sand and is now of little commercial use. Protection is confined to stabilising some 500m of sand dunes. Meandering of the River Gannel across the wide expanse of sand proved an amenity nuisance. This has been rectified by training the flow by means of a low rubble mound wall along the northern edge of the beach ie at the foot of the headland of Pentire Point East.

Between Pentire Point East and Towan Head lies Fistral Bay. Here the wide sandbeach faces west and is backed by low sand dunes. On the south and north sides of the beach there are short stretches of stone walls protecting the toe of the friable slate cliffs.

Newquay Bay itself is protected by the promontory of Towan Head to the west and to a lesser extent by Trevelgue Head to the east. The Bay has fine wide sand beaches. To the west of Towan Sands is a small

harbour and the stone and concrete seawalls here are the responsibility of the Restormel Borough. Further east, short lengths of privately owned stone and concrete seawalls protect urban frontage behind the beaches of Tolcarne and Lusty Glaze. St Columb Porth, a sandy beach to the east of the town, lies within a sheltered inlet. Here the stone and concrete walls protect the road on the north and south sides of the inlet. These are maintained by the Cornwall County Council while the central frontage is privately owned.

North of Trevelgue Head is Watergate Bay, a long sand beach overlooked by crumbling slate cliffs.

Mawgan Porth is the last big cove along the stretch of coast within the Restormel Borough, and here eroding sand dunes are being stabilised by sand fencing.

The District boundary lies a short distance northward and here the North Cornwall District Council become the coast protection authority. Their frontage extends to Marsland Mouth, north of Morwenstow.

North to Trevose Head, the rocky coastline is punctuated with sandy coves and wide beaches. There are privately owned stone walls on the south side of Constantine Beach (south of Trevose Head) and the dunes backing the beach have been stabilised (fenced and planted) to deter erosion. A number of these coves have problems of dune erosion, presumably due to overuse.

5.7 Trevose Head to Hartland Point

From Trevose Head north to Dizzard Point the west facing coastline is rocky with slate cliffs and sparse

beach deposits north of the Camel Estuary. North of Dizzard Point the beaches widen into Bude Bay and beyond Sharpnose Point the beaches begin to thin out again.

5.7.1 Trevose Head to Pentire Point

Between Trevose Head and Stepper Point are a number of small sandy bays. In Newtrain Bay the foot of the sandstone cliffs is protected by privately owned stone and concrete sea walls.

The River Camel forms the only major estuary on this stretch of coast and for many years Padstow was the most thriving port on the coast of north Cornwall. The harbour is owned by the Padstow Harbour Commissioners. Upstream of the harbour there are short lengths of rock revetment protecting the road and are the responsibility of the Cornwall County Council.

On the east bank of the estuary the small village of Rock has an old quay and a stone seawall and timber revetment. Downstream from Rock to Pentire Point, the cliffed coastline is thought to be slowly eroding. The wide sand beach at Polzeath near the mouth of the estuary, is enclosed by rocky headlands and has no coastal defence problems.

5.7.2 Pentire Point to Tintagel Head

From Pentire Point to Tintagel Head the rocky coastline only has sparse beach deposits contained within the larger embayments. There is little need for coast protection. At Port Quin, a small sand inlet backed by a shingle ridge, Cornwall County Council maintain a short length of stone sea

wall protecting the road.

At Port Isaac there is a small harbour which is owned by the Port Isaac Harbour Commissioners who look after the short length of stone seawall and the breakwater. The pebble beach at Portgaverne is backed by short lengths of stone seawall, the responsibility the National Trust and the County Council.

From here to Tintagel Head the shoreline is rocky but there are a number of low tide beaches e.g. Tregardock Beach and Trebarwith Strand. The slate cliffs in this area are crumbling.

5.7.3 Tintagel Head to Cambeak

Almost all of this part of the north Cornwall coast is owned by the National Trust, and the eroding slate and sandstone cliffs are unprotected. Boscastle's narrow but deep harbour, is at the mouth of the Valency River. The seawalls and breakwater are maintained by the National Trust. Although there are swift currents close inshore along this coast littoral drift is insignificant.

5.7.4 Cambeak to Higher Sharpnose Point

Crackington Haven is sheltered by the headland of Cambeak and Pencannow Point. The beach here is of shingle but with sand in the middle of the cove. A short length of privately owned stone seawall protects the backshore. The strongly stratified slate cliffs to the north of Crackington Haven have a narrow shingle and boulder strewn foreshore at their toe. Beyond Millook Haven the coastline takes on a north to south alignment and the cliffs are fronted by long expanses of sand.

Widemouth Sand is a good sand beach bounded by extensive rock ledges. At its southern end a privately owned stone wall protects the backshore. Further north a rock revetment protects a car park, this being the responsibility of the North Cornwall District Council. There is some concern with regard to cliff erosion in this area.

Situated at one of the few valleys in this cliffed coast and at the seaward end of what was once a 50Km long canal, lies the town of Bude. Although never commercially viable, the canal still provides shelter to shipping. Bude Haven harbour is protected by stone seawalls and a breakwater. Some concern has been expressed with regard to erosion at Crooklets, north of the Haven, where the existing stone and concrete walls may have to be extended.

The coastline from Duckpool to Higher Sharpnose Point is rocky with embayments having shingle ridges, with sand at low tide. The cliffs at Duckpool are unstable but there are no properties at risk in the area.

5.7.5 Higher Sharpnose Point to Hartland Point

From Higher Sharpnose Point to Hartland Point the high, west facing cliffs form a wild unprotected stretch of coastline. The foreshore has extensive rock ledges and outcrops. Sand deposits are patchy, with narrow shingle beaches at the head of the coves and the littoral drift is insignificant. The cliffs from Sharpnose Point to Marsland Mouth (the county boundary) are within the North Cornwall District, while beyond that the coast is within the jurisdiction of the Torridge District Council. There are no known coastal defences in either area.

5.8 Hartland Point to Avonmouth

5.8.1 Bideford Bay

The largely undeveloped coastline at the west end of Bideford Bay is rocky and precipitous. The rocks are sandstone and shale and the littoral drift is mainly easterly into the bay. Erosion of the rock platform and of the cliff toe (by wave action and aerial weathering) has produced pebbles which are transported eastwards into the central part of the bay. At the eastern end of Bideford Bay the beaches have large deposits of sand with shingle at the mouth of the Taw Torridge Estuary. Sand beaches sep arated by projecting rocky promontories, extend to Morte Point and into the Bristol Channel. The coast protection authority is Torridge District Council as far east as Appledore in the Torridge Estuary. Responsibility for coastal defence is shared by the Devon County Council and private owners at Appledore. North of the Taw-Torridge Estuary the coast lies within the North Devon District.

From Hartland Point the coastline turns sharply east into Bideford Bay. This unspoilt area has continuous high cliffs fronted by a rocky foreshore. At Clovelly there is a small harbour. The beach consists of a pebble ridge giving way to a mixture of sand and pebbles at low water. At low tide the harbour dries out. Minor cliff slippage takes place occasionally but is not a serious problem. Further to the east at Buck's Mill, a small shingle and sand beach fronts the

crumbling shale cliffs. Here there has been slippage of the rock which overlies a clay substratum. A short stone seawall and now damaged gabions protect the backshore west of the stream outfall.

High, hog's back cliffs and a rocky foreshore extend east to Westward Ho! East of Peppercombe there is also a continuous wave cut rock platform backed by a boulder strewn beach. The nett drift is to the north east.

The urban frontage at Westward Ho! is protected by stone and concrete sea walls built in the 1930's, and there is some damage to the toe due to abrasion.

A long shingle ridge extends north into the estuary mouth, with dune development on its landward side (Northam Burrows). This ridge has probably the most urgent coast protection problem on the North Devon coast. Over the last century it has reduced in volume and receded landwards at its southern end, although new recurved ridges have formed at the northern end. Torridge District Council are combatting erosion by shingle recycling together with rock armouring at the southern end. The development of the shingle ridge of Westward Ho! and the deterioration of Crow Spit on the other side of the estuary are described in Chapter 3.

Appledore is at the confluence of the Taw and Torridge rivers. Protection to the urban frontage consists of concrete and masonry sea walls, responsibility for which is shared between Torridge District, Devon County Council and private owners. The coastal defences at Appledore Pool are particularly vulnerable because of the deep water channel which runs close inshore at this point and because of exposure to wave action from the north west.

Offshore is Lundy Island which has a coastline of high cliffs and the only coast protection is at the Landing Beach, at the south east corner of the Island, where

there are short sections of old sea wall and a short jetty.

At Instow, on the eastern bank of the Torridge, there is a large expanse of sand backed by dunes. Responsibility for the seawalls and quayside is shared between North Devon District and Devon County Council. Wave heights at the shoreline are likely to increase should there be diminution in the size of the spits at the mouth of the estuary. This could be a serious problem in the future especially as the south bank of the river Taw is largely in a natural state.

South West Water are responsible for the sea defences along the north bank of the River Taw. These consist of earth embankments protecting Chivenor Airfield and Horsey Island further downstream. The embankment have been overtopped. A study by Hydraulics Research indicates that the railway embankment to the west of Barnstable could be overtopped at extremely high tides.

Saunton Sands are situated on the north side of the estuary mouth. They are backed by the large belt of sand dunes of Braunton Burrows and further landwards low lying reclaimed marshland. There has been damage to the front face of the dunes through public use. More seriously there has been erosion of the spit at the south end of Braunton Burrows, between Airy Point and Crow Point. Attempts to groyne this frontage may have actually exacerbated matters, by concentrating the scour downdrift of each groyne. The groyne system is now derelict, erosion is continuing, and breaching of the Neck is now a possibility. The foreshore to the seaward of Crow Point is used for aggregate extraction and this practice is detrimental to the stability of the spit.

North of the slate headland of Saunton Down is Croyde Bay and north of the shale cliffs of Baggy Point is Morte Bay. The sand beach in Croyde Bay is privately owned. Woolacombe Sand within Morte Bay faces due west and gale force winds carry fine sands inland to pile up against the seaward edge of Woolacombe Down. Wave action results in large seasonal fluctuations in beach level. At the north end of Woolacombe Sands there are sandy coves interspersed with extensive rock platforms. The shale cliffs between Woolacombe and Morte Point are eroding mainly due to weathering.

5.8.2 Morte Point to Foreland Point

From Morte Point to Bull Point high shale cliffs which dominate the coastline are eroding. There are sparse sand beaches along this frontage and little drift.

In Lee Bay, east of Bull Point protection is provided to the coast road by a 150m long stone wall, responsibility for which is shared between North Devon District and the County Council. The rocky unspoilt coastline extends to Ilfracombe. Shale headlands break the coastline up into small sand and rock beaches and drift is negligible.

Coastal protection is centred around Ilfracombe where responsibility for maintaining the harbour walls is shared between North Devon District and South West Water. North of the harbour a recently constructed concrete sea wall, built by South West Water, protects the low lying urban area against flooding. These defences were upgraded in the late 1970's to prevent serious wave overtopping which previously caused problems. East of Ilfracombe the coastline is again rugged and strongly indented. As with the coast west of the town there is no significant littoral drift. The coast road which runs at the head of Combe Martin

beach is protected by a short stone sea wall, the responsibility of Devon County Council.

The unprotected coastline of high cliffs continues eastwards as far as Lynmouth. Here there is a marked change in the appearance of the coastline as the slates and shales give way to Foreland Grits. The shoreline is again largely devoid of beach material.

West of Lynmouth the soft shale cliffs of the Valley of Rocks are highly weathered. At Lynmouth boulders and stones form a large deltaic accumulation at the mouth of the East and West Lyn rivers.

The quay of the small harbour and the stone sea walls are in a reasonable condition. The groynes fronting the sea wall are derelict and redundant, there being practically no sand to be trapped. The defences have been upgraded since the disastrous floods of August 1952.

From Lynmouth to Foreland Point, high shale cliffs, fronted by narrow sand beaches over a rock foreshore, dominate.

5.8.3 Foreland Point to Hurlestone Point

This is a much 'smoother' stretch of coastline and has beach deposits which increase in size to Porlock Bay. Between Lynton and Porlock the Foreland Grits form steep sloped hog's back cliffs. The area is relatively sheltered and does not suffer from serious coastal erosion.

From Foreland Point to the county boundary at County Gates, the coastline consists of high cliffs above a rocky/pebble foreshore. Coast protection east of County Gates comes under the jurisdiction of the West

Somerset District Council. From the county boundary sandstone and shale cliffs form the coastline, trend landwards at the low lying area of Porlock Bay and then reappear at the coast at Hurlestone Point.

From Gove Point a continuous pebble beach stretches across Porlock Bay to Hurlstone Point. At Porlock Weir a small stream is dammed by lock gates to form a small port. The port is owned and maintained by the Blathwayt Estate. Outside the lock gates the entrance channel has to be regularly dredged to prevent it becoming blocked by pebbles. The channel sides are stabilised by means of wooden palisades, which though very old are still quite effective in preventing slumping of the pebbles. To the east a low stone sea wall protecting the small hamlet of Porlock Weir is the responsibility of the Somerset County Council. The west to east littoral drift in this area is strongly unidirectional.

The low lying hinterland to the east is protected by the shingle ridge whose maintenance is the responsibility of Wessex Water. The ridge has had to be stabilised in places with gabions and with timber groynes. Due to the west to east drift the bay continues to accrete adjacent to the sandstone headland of Hurlestone Point.

5.8.4 Hurlestone Point to Hinkley Point

East of Hurlestone Point the coastal cliffs rise again. Mainly of hard Devonian slates they are unstable and crumbling in places. Fronting these cliffs there is a sand or sand and shingle foreshore which widens dramatically within Minehead Bay.

To the west of the small harbour in Minehead Bay, the Somerset County Council share responsibility with West

Somerset District Council for short lengths of vertical sea wall. Minehead harbour is built in the lee of the headland to the west. It consists of a concrete breakwater and a vertical stone quay. In 1986, work was being carried out on what appeared to be a new rock breakwater southeast of the harbour entrance.

The sea walls and promenade fronting the town which are of stone and concrete are maintained by Somerset County Council. These defences are generally in a good condition. At the eastern end of Minehead Bay, a short stretch of concrete and sheet steel piled walls protect low lying land. These walls are the responsibility of Wessex Water, as is the pebble ridge to the east. This ridge is maintained by Wessex Water as prevention against flooding. The western end has been reinforced with pebbles won from the foreshore and given a rock toe. This stretch has always been a problem area and prior to the rock protection, the foreshore was groyned in an attempt to attract beach material. The pebble ridge extends to Dunster Beach and low lying land continues eastwards to Blue Anchor Bay. Parts of this stretch are eroding with some local accretion taking place near Dunster Beach.

Blue Anchor Bay has a sandy beach backed by a shingle ridge. The lower foreshore is very flat and somewhat muddy. The coast road east of Blue Anchor Station is protected by some 1100m of stone and concrete seawalls which are the responsibility of Somerset County Council. The beach in front of the coast road has a long history of erosion. Over the last 120 years the wall has been reconstructed a number of times while beach levels have continued to drop. In 1987 rock protection was added to the toe of the wall, following a hydraulic model investigation by (Ref 49). A rock groyne with a T-shaped head was also constructed near

the eastern end of the frontage. Since that date some accumulation of sand and shingle has taken place on the upper part of the beach. Immediately east of the coast road the cliffs are eroding rapidly. A short stretch is protected by the sea wall and gabions. The gabions are recent and protect an area of cliff where part of the original sea wall had collapsed.

Between Blue Anchor and Watchet the cliffs of red marl and limestone are fronted by an eroding clay foreshore. The net drift in this area is from west to east.

At Watchet the harbour was rebuilt after being largely destroyed by storms in 1901. West of the harbour breakwater there are stone and concrete sea walls, some of which are recent while older stretches have been extensively repaired. The west breakwater was encased in 1981. East of the harbour, short lengths of concrete sea wall and a rock revetment fronting the coast road are maintained by the Somerset County Council. Work has also been carried out recently in providing toe protection to the crumbling red marl cliffs east of the harbour entrance.

The beaches from Watchet to East Quantoxhead are again quite wide consisting of a sand foreshore backed by shingle. Low tables of tilted rock are evidence that the clays overlying the shales have been eroding quite rapidly in this area. To the west of Doniford, Wessex Water have constructed training walls at the outlet of Doniford Stream. A rock revetment, the responsibility of the County Council, fronts a Holiday Camp to the east of Doniford Village. The plateau of low clay cliffs was eroding quite rapidly until the construction of this revetment. The randomly placed stone at the foot of these cliffs dissipates wave

energy effectively and has led to the development of a strip of sand and shell at its toe.

East of Doniford the cliffs of the Quantock Hills extend to Lilstock. These crumbling clay cliffs are subject to wave induced erosion as well as weathering. A continuous but narrow shingle beach skirts these cliffs and is subject to a west to east littoral drift. The foreshore at low water is sandy with a mixture of mud and silt.

At Lilstock the beach is shingle with sand at low water. In 1959 the shingle and clay bank (which bridged a small gap between the cliffs) was pushed back by wave action to form a 2m high ridge. To protect this face from further erosion and overtopping Wessex Water have stabilised it with gabions.

The cliffs of Lower Lias between Lilstock Point and Hinkley Point are the main source of material for the shingle beaches to the eastward.

The coast between Lilstock and Hinkley Point is unprotected and the cliffs are eroding slowly. The land is relatively high and there is little flood risk. Littoral transport is in a nett west to east direction but judging by the small build up east of Hinkley Point, the rate is low.

5.8.5 Hinkley Point to Brean Down

The wide rocky foreshore platform terminates at Hinkley Power Station. From this point eastwards the inter tidal zone widens rapidly and has increasing quantities of mud on the flat lower foreshore. The hinterland becomes low lying and requires protection against flooding.

The Central Electricity Generating Board power station at Hinkley Point and the frontage is protected by a mass concrete sea wall. This wall is about 1Km long with a crest height of 8.8m A.O.D. Although it has been built into the inter tidal zone, this does not appear to have seriously affected the west to east transport of shingle.

Most of the hinterland east of the power station is low lying. The sea defences here (i.e. the Stolford Sea Defences) are the responsibility of Wessex Water and a proposal is in hand to improve them. The present defences are a mixture of lengths of sea wall, shingle and clay embankments, all of which are in need of repair. A feasibility study by Hydraulics Research was followed by a hydraulic model study into the use of rock armouring as a means of defence (Ref 50). It is understood that the armouring to the sea walls in this area will be constructed beginning in 1988. It is likely that a retarded bank will also be constructed to prevent any water overtopping the sea wall from flooding the low lying hinterland.

East of the Stolford sea defences a shingle ridge stretches to Wall Common, where a gap in the ridge is protected by a 250m long low gabion wall. The shingle ridge is protected from westerly waves by the Stolford promontory and is subject to less severe wave action than the defences to the west. There are at present no plans to upgrade the coastal defences along this frontage and maintenance of the shingle ridge is carried out as and when necessary.

The eastern end of Wall Common marks the boundary of the West Somerset District. The coast protection authority from here northwards is the Sedgemoor District Council. However protection for most of this

low lying coastline is the responsibility of Wessex Water.

Between Wall Common and Stert Point (the west bank of the River Parrett) the flat wide foreshore consists of saltings and mudflats and sea defences consist largely of clay embankments. These extend around Stert Point and up the River Parrett to the Schedule 4 boundary. The embankments which protect the east bank of the Parrett, are again the responsibility of Wessex Water. From the mouth of the Parrett to Burnham on Sea the low lying land is protected from flooding, again by Wessex Water.

At Huntspill the clay banks are reinforced on their seaward face by 'Petraflex' armouring and asphalt grouted stone. From Huntspill Pill northwards the embankments and seawalls are again the responsibility of Wessex Water. The new wall at Burnham on Sea is a replacement for an old structure badly damaged in the storms of December 1981. The concrete sea wall is of the stepped type and has a large radius wave return. The beach fronting the town is sandy but with areas of mud since the low water channel of the Parrett runs close inshore along the town frontage.

To the north of Burnham there is a wide expanse of sand and mud (Berrow Flats) which extends to the promontory of Brean Down. This frontage lies within the jurisdiction of Sedgemoor District Council. This shoreline faces west and Atlantic gales carry sand inland to form a large sand dune system.

North of Burnham on Sea the sand dunes require stabilisation in places, due to overuse by holidaymakers. There is ribbon development along this frontage, consisting largely of holiday camps. Coastal defences consist of short lengths of privately

owned sea walls. To the north of Brean the ridge of sand dunes is very thin and the coast road runs fairly close to the high water line. Here stone sea walls (with gabions at the northern end) protect the low lying hinterland from flooding. This area is mainly the responsibility of Wessex Water but also with some private protection. The high limestone rock headland of Brean Down and similar headlands to the north, compartmentalise the coast. The beaches between the headlands can thus be considered in isolation to adjacent beaches.

5.8.6 Brean Down to Avonmouth

Low lying land fringes the Severn estuary and large sand beaches with extensive muddy foreshores, such as Weston and Sand Bay are separated by rocky headlands. To the east the sand beaches give way to mudflats and saltings further up estuary.

The mouth of the River Axe marks the boundary between Somerset and Avon. Clay embankments protect the Somerset side of the river as far as the tidal limit. East of the Axe the coast protection authority is Woodspring District Council. However low lying areas are protected by Wessex Water. The east shore, where the Axe debouches into Weston Bay, is protected by stone sea walls which extend to Uphill. North of Uphill a sand beach and dune system front a golf course and open amenity area at the south end of Weston Bay. The main frontage of Weston Super Mare is in the northern half of the bay and this is protected by substantial sea walls. These defences are the responsibility of the Woodspring District Council. There are no serious erosion problems within the bay and there is little risk of flooding in this area except possibly near Uphill. Storm damage which can occur at the north end of the bay near Knightstone is

due to the exposure of this part of the beach to westerly waves which travel unimpeded up the Bristol Channel.

Sand Bay to the north of Weston is flanked by the headlands of Worlebury Hill and Middle Hope. The low lying land behind this bay is protected by floodbanks sheathed in concrete, the responsibility of Wessex Water. Beach levels at the head of the bay had fallen in recent years and the coastal defences had been overtopped on several occasions. To restore levels at the top of the beach and to prevent the sea reaching the old wall, a substantial beach nourishment scheme was carried out in 1983. Some 300,000m^3 of sand were dredged from offshore and used to raise beach levels by 3m at the foot of the wall. The scheme has been very successful, partly due to the fact that the fill was considerably coarser than the 'native' beach material. Hence there has been little tendency for the borrow material to migrate seawards. There has however been a tendency for sand to blow inland during severe storms. Measures to counter this have included the construction of sand fencing and marram grass planting. Sand dunes are developing on the beach berm and the amount of sand being blown inland is now reduced.

In Woodspring Bay floodbanks, which are the responsibility of Wessex Water, protect the low lying hinterland to the outskirts of Clevedon. The foreshore in this area is partly sheltered by the headland of Middle Hope. It consists of a muddy inter tidal zone and saltings. Coastal defences range from near vertical concrete sea walls backing the more open stretches of foreshore, while in sheltered areas (ie just south of Clevedon) the backshore is largely unprotected. At Kingston Seymour there is a asphaltic grouted stone revetment backed by an asphaltic

pavement. Behind that is a 'retarded' earth bank whose seaward slope and crest has an asphaltic coating. The mature saltings are eroding in some stretches and healthy in others. The revetment is in good condition except for the asphaltic coating on the seaward face of the retarded bank. In some areas this has spalled off and the face has had to be protected by a concrete skim. Some stretches of sea wall towards Clevedon consist of a stone grouted seaward slope and crest, but the grassland behind is unprotected. Here there is clear evidence of erosion of the backshore as a result of wave overtopping. In the vicinity of Gullhouse Point the saltings have been eroding damaging the underlying clay bench. The rather variable condition of the coastal defences in this area can be attributed to local deterioration of the saltings and hence increased wave activity at their toe. The beach at Clevedon is of shingle and rock and is backed by stone sea walls. The southern end of the town is low lying and here the defences are the responsibility of Wessex Water. The northern frontage is the responsibility of the Woodspring District Council.

A narrow strip of sand and shingle with mud on the lower foreshore extends north to Portishead. The backshore is rocky, cliffed and unprotected.

Stone sea walls which are the responsibility of Woodspring District, protect the frontage at the northern end of Woodhill Bay. The mud foreshore and upper shingle beach fronting Portishead is bounded by the Black Nore headland to the west and Portishead Point to the east.

From Portishead Docks to the River Avon, intermittent lengths of floodbank and walled dock areas front what is generally low lying land. Responsibility for the

defences lies with the Port of Bristol Authority (Portishead Docks and the Royal Portbury Docks), Portbury Sea Wall Commissioners (Portbury Wharf) and Wessex Water (low lying land between Portbury Wharf and the Royal Portbury Docks.

Avonmouth Docks are the responsibility of the Port of Bristol Authority and the estuarial shoreline is protected by stone and rubble revetments. Littoral transport along this section of coast is low, since the area is well protected from wave activity. North of Avonmouth flood banks and sea walls which protect the south shore of the Severn Estuary are within the jurisdiction of the Northavon District Council. The land is low lying and the coastal defences are maintained by Severn-Trent Water.

6 ACKNOWLEDGEMENTS

We would like to thank Mrs S M Beven, formerly of Hydraulics Research, for kindly preparing a report on geology and coastal process for the South West coast of Britain.

7 REFERENCES

1. Carr A P and Blackley M W L. Geological composition of the pebbles of Chesil Beach, Dorset. Proceedings of the Dorset Natural History and Archeological Society, Vol 90, 1969.

2. Jolliffe I P. West Bay and Chesil Bank, Dorset. Coastal regimen conditions, resource use and the possible environmental impact of mining activities on erosion and flooding. Department of Geography, Bedford College, University of London, 1979.

3. Carr A P. Size grading along a pebble beach: Chesil Beach, England. Journal of Sedimentary Petrology, Vol 39, 1969.

4. Carr A P. Experiments on longshore transport and sorting of pebbles: Chesil Beach, England. Journal of Sedimentary Petrology, Vol 41, 1971.

5. Hydraulics Research Ltd. Report No EX 1301. West Bay Harbour; a numerical study of beach changes east of the harbour entrance. 1985.

6. Carr A P and Gleason R. Chesil Beach, Dorset and the cartographic evidence of Sir John Coode. Proceedins of the Dorset Natural History and Archeological Society, Vol 93, 1972.

7. Carr A P. Chesil Beach: Environmental, economic and sociological pressures. Geog J, Vol 149, 1983.

8. Brunsden D and Jones D K C. Relative time scales and formative events in coastal landslide systems. Zeitschrift fur Geomorphologie, Supplementband 34, 1- 19, 1980.

9. Arber M A. The coastal landslips of West Dorset. Proc Geol Assoc, Vol 52, 273-283, 1941.

10. Arber M A. The coastal landslips of South-east Devon. In Applied Coastal Geomorphology, ed J A Steers, Macmillan, London, 138-153, 1971.

11. Arber M A. Landslips near Lyme Regis. Proc Geol Assoc, Vol 84, 121-133, 1973.

12. Kidson C. Dawlish Warren: a study of the evolution of the sand spits across the mouth of the River Exe in Devon. Trans Inst Brit Geogr, Vol 16, 67-80, 1950.

13. Kidson C. Dawlish Warren, Devon: late stages in sand spit evolution. Proc Geol Assoc, Vol 75, 176-184, 1964.

14. Hydraulics Research Ltd. Report No EX 212. Devon coast erosion survey. 1963.

15. Hydraulics Research Ltd. Report No 304. Teignmouth harbour flourescent tracer experiment. 1966.

16. Robinson A H W. Cyclical changes in shoreline development at the entrance to Teignmouth harbour, Devon, England. In Nearshore sediment dynamics and sedimentation. Ed J Hails amd A Carr. Wiley. 1975.

17. Derbyshire E, Cooper R G and Page L W F. Recent movements on the cliff at St Marys Bay, Brixham, Devon. Geog J, Vol 145, 86-96. 1979.

18. Carr A P, Blackley M W L and King H L. Spatial and seasonal aspects of beach stability. Earth Surface Processes and Landforms, Vol 7, 267-282, 1982.

19. Gleason R, Blackley M W L and Carr A P. Beach stability and particle size distribultion, Start Bay. J Geol Soc, Vol 131, 83-101, 1975.

20. Job D A. Beach changes on Slapton Sands shingle ridge. Unpubl M Phil Thesis, Department of Geography and Geology, Huddersfield Polytechnic, 1987.

21. Robinson A H W. The hydrography of Start Bay and its relationship to beach changes at Hallsands. Geog J, Vol 121, 63-77, 1961.

22. Hails J R. Submarine geology, sediment distribution and Quaternary history of Start Bay, Devon. J Geol Soc, Vol 131, 1-5, 1975.

23. Everard C E. Mining and shoreline evolution near St Austell, Cornwall. Trans Roy Geol Soc Cornwall, Vol 19, 199-219, 1959.

24. Hydraulics Research Ltd. Report No EX 1628. Beach changes in Carlyon Bay, Cornwall. 1987.

25. Arber E A N. The coastal scenary of North Devon. Kingsmead Reprints, Bath. 1911.

26. Arber M A. Cliff profiles of Devon and Cornwall. Geog J, Vol 114, 191-197, 1949.

27. Arber M A. The cliffs of North Devon. Proc Geol Assoc, Vol 85, 147-157, 1974.

28. Steers J A. The coastline of England and Wales, 2nd Edition. Cambridge University Press, 1969.

29. Kidson C. The growth of sand and shingle spits across estuaries. Zeitschrift fur Geomorphologie, Vol 7, 1-22, 1963.

30. Stuart A and Hookway R J S. Coastal protection at Westward Ho! North Deveon. A report to the Coastal Protection Committee of the Devon County Council, 1954.

31. Kidson C. The shingle complexes of Bridgewater Bay. Transactions Institute of British Geographers, Vol 28, 75-87, 1960.

32. Carr A P. Coastal changes at Bridgewater Bay 1956-64. Proc of Bristol Nat Soc, Vol 31, 91-100, 1965.

33. Ranwell D S. Spartina salt marshes in southern England II: Rate and seasonal pattern of sediment accretion. Journal of Ecology, Vol 52, 79-94, 1964.

34. Parker W R and Kirby R. Sources and transport patterns of sediment in the inner Bristol Channel and Severn Estuary. Severn Barrage. Thomas Telford, 1982.

35. Dyer K R. Sedimentation processes in the Bristol Channel/Severn Estuary. Marine Pollution Bulletin, Vol 15, No 2, 1984.

36. Hydraulics Research, Wallingford. HINDWAVE - A Wave Hindcasting Model, Report EX 1486, September 1986.

37. Golding B. A wave prediction system for real time sea state forecasting.

38. Department of Energy. Environmental parameters on the United Kingdom Continental Shelf. Report No OTH 84 201, prepared by Noble Denton and Associates Ltd. HMSO, 1984.

39. Marine Information and Advisory Service. Catelague of wave data. Institute of Oceanographical Sciences. Wormley, Surrey, 1982.

40. Hydraulics Research Ltd. OUTRAY - A wave refraction models. Report EX 1561, September 1987.

41. Dodson A T and Warburg H D. Admiralty Manual of Tides. HMSO, 1941.

42. Hydraulics Research Ltd. SE Dorset Water Services. Mathematical simulation of tidal currents between Portland Bill and St Catherine's Point. Report EX 1474, July 1986.

43. Fornerino M and Le Provast C. A model for prediction of the tidal currents in the English Channel, International Hydrographic Review, LXII, 2, July, 1985.

44. Miles G V. Impact on currents and transport processes. Symposium on Severn Barrage. Institute of Civil Engineers, London, 1981.

45. Miles G V and Worthington B A. The influence of Severn tidal power schemes on sediment transport processes. Second International Symposium on Wave and Tidal Energy. Cambridge, September 23-25 1981.

46. Graff J. An investigation of the frequency distributions of annual sea level maxima at ports around Great Britain. Estuarine Coastal and Shelf Science, 12, 1981.

47. Hydraulics Research Ltd. Statistical treatment of seawall overtopping. Summary Sheet 87, 1982.

48. Hydraulics Research Ltd. North Wales Coast Road. A55 Llanddulas to Aber, sea defences at Llanddulas. A study of return periods for overtopping discharges and armour stability, Report EX 808, March 1978.

49. Hydraulics Research, Wallingford. Blue Anchor Bay. Model studies of protection to the sea wall. Report EX 1290, March 1985.

50. Hydraulics Research, Wallingford. Sea defence scheme, Stolford, Somerset. Report EX 1536, January 1987.

8 BIBLIOGRAPHY

Coastline Topography, Geology etc

AA Illustrated Guide to Britain's Coast. 1st Edition, 1984.

Arber MA. The coastal landslips of west Dorset. Proc Geol Ass, 52:273-83, 1941.

Arber MA. The coastal landslips of south-east Devon. Proc Geol Ass, 51:257-71, 1940.

Arkell WJ. The effects of storms on Chesil Beach in November 1954. Proc Dorset Nat Hist Archaeological Soc, Vol 76, 1956, p141-145

Arkell WJ and others. The geology of the country around Weymouth, Swanage, Corfe and Lulworth. HMSO, 1947.

Baden-Powell DFW. Notes on the raised beach mollusca from the Isle of Portland. Proc Malacological Soc, 19:67-76, 1930.

Baden-Powell DFW. On the geological evolution of Chesil Bank. Geol Mag, 67:499-513, 1936.

Bird ECF and May VJ. Shoreline changes in the British Isles during the past century. Division of Geography, Bournemouth College of Technology, 1976.

Bond WRG. Theories as to the origin of the Chesil Beach. Proc Dorset Nat Hist Archaeological Soc, 73:163-70, 1951.

Bristow HW and Whitaker W. On the formation of Chesil Bank, Dorset. Geol Mag, 6:443-50, 1869.

Carey AE and Oliver FW. Tidal lands. A study of shore problems. Blackie, 1918.

Carr AP. Chesil Beach: environmental, economic and sociological pressures. From 'Endangered Coastlines of Geomorphological Importance'.

Carr AP. Size grading along a pebble beach: Chesil Beach, England. Journal of Sedimentary Petrology, Vol 39, No 1, p297-311, March 1969.

Carr AP and Blackley MWL. Geological composition of the pebbles of Chesil Bank, Dorset. Proc Dorset Nat Hist Arch Soc, 90:133-140, 1969.

Carr AP and Blackley MWL. Ideas on the origin and development of Chesil Beach, Dorset. Proc Dorset Nat Hist Arch Soc, 95:9-17, 1974.

Carr AP and Blackley MWL. Investigations bearing on the age and development of Chesil Beach, Dorset, and the associated area. IBG Transactions, No 58, March 1973.

Carr AP, Blackley MWL and King HL. Spatial and seasonal aspects of beach stability. Earth Surface Processes and Landforms, Vol 7, No 3, p267-282, May-June 1982.

Carr AP and Gleason R. Chesil Beach, Dorset, and the cartographic evidence of Sir John Coode. Proc Dorset Nat Hist Arch Soc, 93:125-131, 1972.

Carr AP, Gleason R and King AC. Significance of pebble size and shape in sorting by waves. Sediment Geol, 4:89-101, 1970.

Clarke RH. Quaternary sediments off south-east Devon. Q J Geol Soc Lond, 125:277-318, 1970.

Codrington T. Some remarks on the formation of Chesil Bank. Geol Mag, 7:23-5, 1870.

Coode J. Description of the Chesil Bank, with remarks upon its origin, the causes which have contributed to its formation, and upon the movement of shingle generally. Minutes of Proc ICE, Vol XII, 1852-53.

Corbyn PR. The size and shape of pebbles on Chesil Beach. Geographical Journal, Vol 133, Part 1, p54-55, March 1967.

Cornish V. On sea beaches and sandbanks. Geographical Journal, Vol II, 1898.

Cornish V. On the grading of Chesil Beach shingle. Proc Dorset Nat Hist Antiq Fld Club, 19:113-121, 1898.

Courtney-Fitch B. Putting new life into a downtrodden old cove. Surveyor, Vol 156, No 4630, 12 March, 1981.

Damon R. Geology of Weymouth, Portland and coast of Dorsetshire. Weymouth, 1884

Davies GM. The Dorset Coast. 2nd Edition, 1956.

De Boer G and Carr AP. Early maps as evidence of coastal change. Geol J 135(1), p17-39, 1969.

De Selincourt A. The channel shore. Robert Hale Ltd, 1953.

Delderfield ER. The Lynmouth flood disaster. Raleigh Press, Exmouth, 1953.

Edmonds EA, McKeown MC and Williams M. British Regional Geology. South-west England. Institute of Geol Sciences, HMSO, 3rd Edition, 1969.

Freshney EC and Others. Geology of the coast between Tintagel and Bude. HMSO, 1972.

Flett JS and Hill JB. Geology of the Lizard and Meneage. HMSO, 2nd Edition, 1946.

Gleason R and Hardcastle PJ. The significance of wave parameters in the sorting of beach pebbles. Estuarine and Coastal Marine Science, 1:11-18, 1973.

Hoyle JW and King GT. The origin of beaches. Proc Inst Mun Eng, 83:1-12, 1956.

HR EX 212. Devon coast erosion survey. Coast erosion problems on certain Devon beaches. June 1963.

HR EX 282. Weston-super-Mare. Field investigation. August 1965.

Humbert FL. Selection and wear of pebbles on gravel beaches. Groningen, Netherlands: 'Geologisch Institut' publication, No 190, 1968.

Joliffe IP. West Bay and the Chesil Bank, Dorset: coastal regime conditions, resource use and the possible environmental impact of mining activities on erosion and flooding. Bedford College, University of London, July 1979.

Joliffe IP. Weymouth Bay, Dorset. Coastal regime conditions and resource use. Report to the Weymouth and Portland Council, December 1976.

Kidson C and Carr AP. The movement of shingle over the sea bed close inshore. Geogr J 125, p380-389.

King CAM. Beaches and coasts, 2nd edition. Edward Arnold, 1972.

May VJ. Changes in the coastline of south-west England - a review. In 'Les Cotes atlantiques de l'Europe, evolution, amenagement, protection - Brest, France'. Edited by A Guilcher, p67-76 (Actes de Colloques No 9) Brest: CNEXO.

May VJ. Reclamation and shoreline changes in Poole Harbour, Dorset. Proc Dorset Nat Hist Arch Soc, 90:141-54, 1969.

McKeown MC and Others. Geology of the country around Boscastle and Holsworthy. HMSO, 1973.

Neate DJM. Underwater pebble grading of Chesil Bank. Proc Geol Ass. 78:419-426, 1967.

Prestwich J. Notes on the phenomena of the Quaternary period in the Isle of Portland and around Weymouth. Q J Geol Soc Lond, 31:29-54, 1875.

Prestwich J. On the origin of Chesil Bank, and on the relation of the existing beaches to past geological changes independent of the present coast action. Min Proc ICE, 40:61-114, 1875.

Prior ES. The Bridport shingle. A discussion of pebbles. Proc Dorset Nat Hist Antiq Fld Club, 40:52-65, 1919.

Reade TM. The Chesil Bank. Geol Mag, 10:573-574, 1873.

Reid C. The geology of the country around Mevagissey. HMSO, 1907.

Roberts EK. Estuaries and coastal waters of the British Isles. A bibliography of recent scientific papers. Numbers 4-7. Marine Biol Ass of the UK, January 1980-1983.

Robinson A and Millward R. The Shell book of the British coast. David and Charles, 1983.

Robinson AHW. The hydrography of Start Bay and its relationship to beach changes at Hallsands. Geog J, Vol 127, Part 1, p63-77, March 1961.

Selwood EB and others. Geology of the country around Newton Abbot. Memoir for 1:50,000 geological sheet 339. HMSO, 1984.

Steers JA. The coastline of England and Wales. Cambridge University Press, 2nd Edition, 1964.

Steers JA. The coast of England and Wales in pictures. Cambridge University Press, 1960.

Strahan A. The geology of the Isle of Purbeck and Weymouth. Mem Geol Surv of GB.

Taylor D. Natural distribution of trace metals in sediment from a coastal environment, Tor Bay, England. Estuarine and Coastal Marine Science, Vol 2, p417-424, 1974.

Ussher WAE. The geology of the country around Kingsbridge and Salcombe. HMSO, 1904.

Ussher WAE. The geology of the country around Torquay. HMSO, 2nd Edition, 1933.

Valentin H. Present vertical movements of of the British Isles. Geogr J, 119, 299-305, 1953.

Waters B. The Bristol Channel. Dent, 1955.

Wilson V and others. Geology of the country around Bridport and Yeovil. HMSO, 1958.

Wind and Waves

Department of Energy. Environmental parameters on the United Kingdom continental shelf. HMSO, 1985.

Edwards HAS and Smith LJ (HR). Instrumentation to measure wave forces on submarine pipe lines at Perranporth. Part 1. HRS, Technical Memorandum, May 1979.

Hardcastle PJ and King AC. Chesil Beach sea wave records. Civil and public works review, p299-300, 1972.

HR EX 738. Lower Severn basin study. Wave heights in the Severn Estuary, July 1976.

HR EX 887. The Severn Estuary - wave climate study. April 1978 - March 1979. July 1979.

HR EX 933. The Severn Estuary - wave climate study - wind-wave correlation. Waves, April 1978 - March 1979. Winds, April 1960 - March 1979. July 1980.

HR EX 1024. Wave hindcasting along the Somerset and Avon coastline. September 1981.

HR EX 1063. Study of wave spectra transformation. June 1982.

HR EX 1121. Torquay harbour. Wave disturbance studies of a proposed marina in Torquay outer harbour. April 1983.

HR EX 1207. Severn barrage - wave prediction study. May 1984.

HR EX 1256. Wave refraction study, Bridgwater Bay. October 1984.

HR EX 1327. Plymouth marine events base - performance of wave screens. July 1985.

HR EX 1358-1362, Hawkes PJ. Wave measurements in Portland harbour 1985-1986. September 1985 - January 1986 monthly reports. October 1985 - February 1986.

HR EX 1365. Falmouth container terminal. Wave analysis offshore and at the proposed site. March 1986.

HR IT 176, Huntington SW. The quality of the waves in the complex sea basin. April 1978.

HR IT 235, Bellamy PH. Statistics of waves recorded off the north Cornwall coast. August 1982.

Lewis WV. The effect of wave incidence on the configuration of a shingle beach. Geogr J, 78:129-148, 1931.

Meteorological Office. Frequency of observations of visually estimated wind speeds and non coarse-code wave heights in the main Marine Data Bank. Marine Climatology, 1985.

Meteorological Office. Marine climatology, observation count (world distribution of wind and visual wave observations). Meteorological Office, Bracknell, August 1985.

Meteorological Office. Tables of surface wind speed and direction over the United Kingdom, MO 792. HMSO, 1968.

Shellard HC and Draper L. Wind and wave relationships in United Kingdom coastal waters. Estuary and Coastal Marine Sciences, 1975.

White PA. The offshore wind-energy resource around the United Kingdom. BWEA International Symposium on Offshore Wind Energy Systems. Royal Aeronautical Society, London, 21 October 1983.

Tides, Tidal Currents and Sea Bed Topography

Admiralty Hydrographic Office. Approaches to Portland. Tidal stream atlas. NP 257, 1949 revised 1965.

Craig-Smith SJ. A hydrographic analysis of the approaches to Teignmouth harbour. MSc Thesis, University of Leicester, 1970.

Crickmore MJ. Data collection - tides, tidal currents, suspended sediment. Paper for ICE symposium on the Severn Barrage, October 1981.

Donovan and Stride AH. An acoustic survey of the sea floor south of Dorset and its geological interpretation. Phil Trans R Soc, B, 244, p299-330, 1961.

Ferentinos G and Collins M. Effects of shoreline irregularities on a rectilinear tidal current and their significance in sedimentation processes. Journal of Sedimentary Petrology, Vol 50, No 4, December 1980.

Green FWH. Poole harbour. A hydrographic survey 1938-9. Geographic Publications Ltd, 1940.

Green FHW, Ovington JD and Madgewick HAI. Survey of Poole harbour. Changes in channels and banks during recent years. Dock and Harbour Authority, Vol 33, No 383, September 1952.

Hails J ed and Carr A ed. Nearshore sediment dynamics and sedimentation. An interdisciplinary review. Wiley, 1975.

Hamilton P. The circulation of the Bristol Channel. Geophysical Journal of the Royal Astronomical Society, Vol 32, 1973.

Hamilton D, Channon RD, Griffiths EC and Somerville JH. Sediments and tidal energy in the south-western approaches to Britain and the Severn Estuary. Mem Inst Geol Bassin Aquitaine, Vol 7, 1974.

Hawkins AB and Sebbage MJ. The reversal of sand waves in the Bristol Channel. Marine Geology, Vol 12, No 4, pM7-M9, 1972.

Heath RA. Tidal energy loss in coastal embayments. Estuarine, Coastal and Shelf Science, Vol 12, No 3, March 1981.

HR EX 229. Bristol Avon investigation - model investigation into flood levels reached in the Bristol Avon due to combined fresh water and tidal flows. January 1964.

HR EX 369. Port of Bristol - west dock scheme. A model investigation of currents of the entrance to the proposed west dock. January 1968.

HR EX 943. The Severn Estuary. Recording of tidal levels in 1980. September 1980.

HR EX 959. The Severn Estuary. Measurements of tidal currents over offshore banks. November 1980.

HR EX 965. The Severn Estuary. Measurements of the vertical and lateral distribution of mud suspensions. December 1980.

HR EX 966. The Severn Estuary. Observations of tidal currents, salinities and suspended solids concentrations. January 1981.

HR EX 967. The Severn Estuary. Sand flux measurements. January 1981.

Hydrographic Department. Admiralty Chart 18. Falmouth inner harbour, natural scale 1:5000, Hydrographer of the Navy, February 1983.

Hydrographic Department. Admiralty Chart 26. Harbours on the south coast of Devon:

Torquay harbour, natural scale 1:4000;

Brixham harbour; Teignmouth harbour, natural scale 1:7500;

Tor Bay, natural scale 1:12500,

Hydrographer of the Navy, June 1986.

Hydrographic Department. Admiralty Chart 28. Salcombe harbour, natural scale 1:12500; Salcombe, natural scale 1:5000, Hydrographer of the Navy, October 1982.

Hydrographic Department. Admiralty Chart 30. Plymouth Sound and approaches, natural scale 1:12500, Hydrographer of the Navy, March 1986.

Hydrographic Department. Admiralty Chart 31. Harbours on the south coast of Cornwall:

Charlestown harbour, natural scale 1:5000;

Fowey harbour, natural scale 1:6250;

Par harbour, natural scale 1:7500;

River Fowey - Mixtow to Saint Winnow; Saint Winnow to Lostwithiel, natural scale 1:15000;

Hydrographer of the Navy, April 1985.

Hydrographic Department. Admiralty Chat 32. Falmouth harbour, natural scale 1:12500; Continuation of Truro river, natural scale 1:12500; Continuation of Tresillian river; Continuation of River Fal (Ruan Creek), natural scale 1:20000, Hydrographer of the Navy, August 1984.

Hydrographic Department. Admiralty Chart 147. Plans on the south coast of Cornwall:

Mevagissey harbour, natural scale 1:2500;

Looe harbour, natural scale 1:5000;

Helford river, natural scale 1:12500;

Hydrographer of the Navy, February 1982.

Hydrographic Department. Admiralty Chart 148. Dodman Point to Looe Bay, natural scale 1:30000; Polperro harbour, natural scale 1:3500, Hydrographer of the Navy, October 1983.

Hydrographic Department. Admiralty Chart 154. Approaches to Falmouth, natural scale 1:35000, Hydrographer of the Navy, October 1985.

Hydrographic Department. Admiralty Chart 442. Lizard Point to Hope's Nose, natural scale 1:150000, Hydrographer of the Navy, March 1979.

Hydrographic Department. Admiralty Chart 777. Land's End to Falmouth, natural scale 1:75000, Hydrographer of the Navy, March 1979.

Hydrographic Department. Admiralty Chart 871. Rivers Tamar, Lynher and Tavy, natural scale 1:12500; River Tamar, Cargreen to Calstock, natural scale 1:12500; Calstock to Gunnislake: River Lynher, River Tavy, natural scale 1:20000; Hydrographer of the Navy, May 1984.

Hydrographic Department. Admiralty Chart 1148. Isles of Scilly to Land's End, natural scale 1:75000, Hydrographer of the Navy, April 1982.

Hydrographic Department. Admiralty Chart 1149. Pendeen to Trevose Head, natural scale 1:75000, Hydrographer of the Navy, May 1979.

Hydrographic Department. Admiralty Chart 1152. Watchet to Weston-super-Mare and Barry to Newport, natural scale 1:50000, Hydrographer of the Navy, February 1986.

Hydrogaphic Department. Admiralty Chart 1156. Trevose Head to Hartland Point, natural scale 1:75000, Hydrographer of the Navy, July 1982.

Hydrographic Department. Admiralty Chart 1160. Plans on the coast of Somerset and Devon:

Ilfracombe, natural scale 1:12500;

Lynmouth, Porlock, Minehead, Watchet, natural scale 1:20000;

Barnstaple and Bideford, natural scale 1:25000;

Hydrographer of the Navy, August 1986.

Hydrographic Department. Admiralty Chart 1164. Hartland Point to Ilfracombe including Lundy, natural scale 1:75000; Lundy, natural scale 1:25000, Hydrographer of the Navy, February 1979.

Hydrographic Department. Admiralty Chart 1165. Worms Head to Watchet, natural scale 1:75000, Hydrographer of the Navy, February 1979.

Hydrographic Department. Admiralty Chart 1166. River Severn - Avonmouth to Sharpness, natural scale 1:25000, Hydrographer of the Navy, March 1979.

Hydrographic Department. Admiralty Chart 1168. Harbours on the north coast of Cornwall:
Newquay Bay, natural scale 1:12500;
Approaches to Padstow; St Ives Bay; River Camel to Wadebridge, natural scale 1:25000;
Hydrographer of the Navy, April 1979.

Hydrographic Department. Admiralty Chart 1176. Severn estuary - Steep Holm to Avonmouth, natural scale 1:40000; Newport, natural scale 1:20000; Redcliff Bay, natural scale 1:25000; Hydrographer of the Navy, April 1979.

Hydrographic Department. Admiralty Chart 1267. Falmouth to Plymouth, natural scale 1:75000, Hydrographer of the Navy, March 1979.

Hydrographic Department. Admiralty Chart 1613. Eddystone Rocks to Berry Head, natural scale 1:75000; Eddystone Rocks, natural scale 1:7500, Hydrographer of the Navy, April 1979.

Hydrographic Department. Admiralty Chart 1634. Salcombe to Brixham: Start Point to Brixham, Salcombe to Start Point, natural scale 1:25000, Hydrographer of the Navy, February 1972.

Hydrographic Department. Admiralty Chart 1859. Port of Bristol: King Road, River Avon, City Docks, natural scale 1:10000, Hydrographer of the Navy, April 1979.

Hydrographic Department. Admiralty Chart 1901. Smeaton Pass and the Narrows, natural scale 1:5000, Hydrographer of the Navy, March 1979.

Hydrographic Department. Admiralty Chart 1902. Hamoaze, natural scale 1:5000, Hydrographer of the Navy, March 1979.

Hydrographic Department. Admiralty Chart 1967. Plymouth Sound, natural scale 1:7500; River Plym, natural scale 1:15000, Hydrographer of the Navy, March 1979.

Hydrographic Department. Admiralty Chart 2290. River Exe and approaches including Exeter canal, natural scale 1:12500, Hydrographer of the Navy, February 1979.

Hydrographic Department. Admiralty Chart 2345. Plans in south-west Cornwall:
Mousehole, Newlyn and Penzance harbours, natural scale 1:5000;
Mullion Cove; Porthleven, natural scale 1:5000;
Penzance Bay, natural scale 1:12500;
Longships; Runnel stone; Lizard Point, natural scale 1:15000;
Hydrographer of the Navy, August 1976.

Hydrographic Department. Admiralty Chart 2454. Start Point to the Needles, natural scale 1:150000, Hydrographer of the Navy, March 1979.

Hydrographic Department. Admiralty Chart 3315. Berry Head to Bill of Portland, natural scale 1:75000; Bridport harbour, natural scale 1:3500; Lyme Regis harbour, natural scale 1:12500, Hydrographer of the Navy, February 1979.

Institute of Oceanographic Sciences. Investigation of turbidity structures in the Severn Estuary and inner Bristol Channel. Report No 92, 1977.

Lee AJ and Ramster JW. Atlas of the seas around the British Isles, Fisheries Research Technical Report No 20. Ministry of Agriculture, Fisheries and Food, 1979.

Liverpool Observatory and Tidal Institute. Report on the tides and tidal streams in the Bristol Channel and Severn Estuary. August 1948.

Miles GV. Impact on currents and transport processes. Symposium on the Severn Barrage, ICE, October 8-9 1981.

Miles GV and Webb DG. Influence of Severn Barrage on the tidal regime. Chapter 2 in "An environmental appraisal of tidal power stations', by TL Shaw, 1980.

Pugh DT. Estimating extreme currents by combining tidal and surge probabilities. Ocean Engineering, Vol 9, No 4, 1982.

Robinson IS. A tidal flushing model of the Fleet - an English tidal lagoon. Estuarine, Coastal and Shelf Science, Vol 16, No 6, p669-688, June 1983.

Sparks B and West RG. The Ice Age in Britain. Methuen, 1972.

Coastal Engineering Studies

Bird ECF and Ranwell DS. The physiography of Poole Harbour. Dorset, J Ecol, 52:355-366, 1964.

Blanchard LM. Sidmouth sea defences. Proc IMCyE, Vol 78, 1951-2.

Carr AP. Chesil Sea Defence Scheme: assessment of environmental implications. Report to WWA by IOS, IOS Internal Document, No 106, 1980.

Clark FH. The survey and reconstruction of the Lyme Regis sea defences. Proc ICE, Selected Engineering Paper No 177, 1935.

Contract Journal. Devon: tight site for sea wall. 15 November 1979.

Dobbie CH and Partners. Chesil Sea Defence Scheme. Report to Wessex Water Authoity and Weymouth and Portland Borough Council, 1980.

Dock and Harbour Authority. Penzance sea wall. August 1967.

Economic Advisory Council. Report of the Severn Barrage committee 1933. HMSO, reprinted 1945.

George AB. Devon floods and the waterways of bridges. Proc ICE, Part 2: Research and Theory, Vol 73, p125-134, March 1982.

Goodacre EJ. Municipal works of Poole during the last 10 years. Proc IMCyE, Vol 64, 1937-8.

Gracey JW. Severn Barrage Scheme. Memorandum (on Gibson 1933 Report) by JW Gracey. Port of Bristol Authority, 1947.

Gray TJ and Gashus OK. Tidal Power. Proceedings of an international conference on the utilization of tidal power held May 24-29 1970 at the Atlantic Industrial Research Institute, Nova Scotia Technical College, Halifax, Nova Scotia. Plenum Press, 1972.

Greatorex AD. Exmouth: a decade of progress in a residential seaside town. Proc IMCyE, Vol 38, 1911-1912.

Hall J. Some account of the public works in Torquay. Proc IMCyE, Vol 11, 1884-5.

Harrison AJM. The 1960 Exmouth floods: an investigation of the flood discharges of Withycombe Brook. Surveyor, February 4, 1961.

Heaps NS. Estimated effects of a barrage on tides in the Bristol Channel. Proc ICE, Vol 40, August 1968.

HR EX 144. Proposed slipway at Noss Works, Dartmouth, Devon. Report on the probability of siltation. January 1961.

HR EX 179. Avonmouth investigation. Model study of entrance schemes associated with a proposed new dock system between Avonmouth and Portishead. June 1962.

HR EX 272. North Devon pumped storage scheme. Report on preliminary survey of tidal streams and general conditions in Bideford bay. March 1965.

HR EX 303. Portland harbour - south ship channel. Model investigation, Parts 1, 2 and 3, October 1965.

HR EX 304. Teignmouth harbour. Fluorescent tracer experiment. February 1966.

HR EX 331. North Devon pumped storage scheme. Barnstaple or Bideford Bay. Text and Plates, June 1966.

HR EX 348. Proposed dock system at Portbury, near Bristol. Model investigation of navigation into and out of the dock entrance, and other aspects of the proposed scheme. February 1967.

HR EX 369. North Devon pumped storage scheme. Tombolo study. The effect of gatehouse structures on the beach. August 1967.

HR EX 441. Bridport sewage outfall. A study of the security of an existing submarine outfall. May 1969.

HR EX 587. Portland harbour. Closure of the south ship channel. February 1972.

HR EX 623. Port of Bristol - West Dock Scheme. Mud flow tests. May 1973.

HR EX 711. River Avon Barrage. Appraisal of siltation at projected barrage sites. October 1975.

HR EX 735. Portbury Power Station. The effects on navigation caused by the influence of cooling water flow on current distribution. June 1976.

HR EX 753. Severn barrage study. November 1976.

HR EX 863. West bay, Bridport, Dorset. A sea defence and coast protection study. January 1979.

HR EX 1071. The Severn model users guide. Avonmouth to Worcester flood alleviation study. February 1983.

HR EX 1117. Motyka JM. Dredging for tin off north Cornwall. February 1983.

HR EX 1121. Torquay Harbour. 1983.

HR EX 1138. Barnstaple urban flood defences.

HR EX 1227. Queen Anne's Battery Marina, Plymouth Interim report on silt monitoring. July 1984.

HR EX 1248. Chesil Beach interception drain. Percolation study. October 1984.

HR EX 1327. Plymouth Marine Events Base - Performance of wave screens. July 1985.

HR EX 1364, Kendrick MP and Derbyshire BV. Proposed container terminal at Falmouth. Desk study of tidal flow and sediment distribution. February 1986.

HR EX 1365. Falmouth container terminal. March 1986.

HR EX 1396. Bridport flood alleviation scheme. East beach works. January 1986.

HR EX 1461, Odd NVM, Mann K, Brampton AH, Southgate HN. Swash Channel Study - phase I. Preliminary assessment of the feasibility of deepening the channel. June 1986.

HR EX 1536. Sea defence scheme, Stolford, Somerset. January 1987.

HR EX 1628. Proposed leisure development, Carlyon Bay. September 1987.

HR EX 1636. Lyme Regis Harbour, new slipway. September 1987.

HR INT 114, White WR and Whitehead E. The effects of adverse approach conditions on the calibration of a compound weir. May 1973.

HR IT 215. Proposed dredging off Lavernock Point, Bristol Channel. Report on a visit made by JM Motyka, 25 January 1981.

Humphreys RJ. Exmouth sea defences. Proc IMCyE, Vol 78, 1951-2.

Hutton S. Exmouth - 30 years of work of a municipal engineer in a seaside town. Proc IMCyE, Vol 59, 1932-3.

Hutton S. Sea defences on the south-east coast of Devon. Proc IMCyE, Vol 50, 1923-4.

Proc IMCyE. Carrick DC works. Vol 103, 1976.

Proc IMCyE. South-western district meeting, Torquay - Meadford sea wall. Vol 57, 1930-1.

Proc IMCyE. Two public works in Exmouth. Vol 75, 1948-9.

Izatt EP. Reconstruction of Custom House Quay, Weymouth harbour. Proc IMCyE, Vol 77, 1950-1.

Kemble JR and Young JA. Weymouth and Portland marine treatment scheme: introduction, history and options. Proc ICE, Part 1: Design and construction, Vol 76, February 1984.

Ladmore PW. Work of the Surveyor's Department, Torquay. Proc IMCyE, Vol 62, 1935-6.

Macgregor WG. The development of a real-time flood forecasting model for the south-west of England. Report for the Central Water Planning Unit, Reading, September 1979.

Maddock L and Pingree RD. Numerical simulation of the Portland tidal eddies. Estuarine and Coastal Marine Science, Vol 6, No 4, p353-363, 1978.

Miles GV and Worthington BA. The influence of Severn tidal power schemes on sediment transport processes. Paper submitted to 2nd International Symposium on Wave and Tidal Energy, Cambridge, September 1981.

Nachson M. Protection of Preston Beach, Weymouth. Proc IMCyE, Vol 75, 1948-9.

Parker WR and Kirby R. The behaviour of cohesive sediment in the inner Bristol Channel and Severn estuary in relation to construction of the Severn barrage. Institute of Oceanographic Sciences, Taunton, Report No 117, 1981.

Penning-Rowsell EC and Parker DJ. Chesil Sea Defence Scheme: benefit assessment. Report to WWA by Middlesex Polytechnic Flood Hazard Research Centre, 1980.

Prosser MJ and Bruce BA. Hydraulic Model study of the River Avon barrage. BHRA Fluid Engineering, RR 1310, September 1975.

Radford PJ. Severn tidal power. Predicted effects of proposed tidal power schemes upon the Severn estuary ecosystem. Volume 1 - Water quality. Institute for Marine Environmental Research, 1980.

Radford PJ and Young KME. Severn tidal power. Predicted effects of proposed tidal power schemes upon the Severn estuary ecosystem. Vol 2, ecosystem effects. Inst Mar Env Research, 1980.

Roberts DGM, Flint GR and Moore KH. Weymouth and Portland marine treatment scheme: tunnel outfall and marine treatment works. Proc ICE, Part 1: Design and Construction, Vol 76, p117-143, February 1984.

Robinson AHW. The harbour entrances of Poole, Christchurch and Pagham. Geogr J, 121: 33-50, 1955.

Severn Barrage Committee. Tidal power from the Severn estuary, Vol 1. HMSO, 1981.

Severn RT, Dineley DL and Hawker LE. Tidal power and estuary management. Proceedings of the thirtieth symposium of the Colston Research Society. University of Bristol, April 1978. Scientechnica, Bristol, 1979.

Shaw TL. An environmental appraisal of tidal power stations, with specific reference to the Severn barrage. Pitman, 1980.

Symonds H. Bridport harbour through seven centries. Dorset Nat Hist Antiq Fld Club, 33:161-99, 1912.

US Army, Corps of Engineers. Shore Protection Manual. Vol 2, 1973.

Vaughan-Lee AG, Halcrow W and Dorkin SB (Ministry of Fuel and Power). Report on the Severn barrage scheme. HMSO, 1945.

Wilson A. The lesson of Hallsands. Cause of the calamity was dredging offshore for shingle. New Scientist, p311, 12 February 1970.

Wilkes JHH. Blue Anchor sea defences. Proc IMCyE, Vol 78, 1951-2.

FIGURES

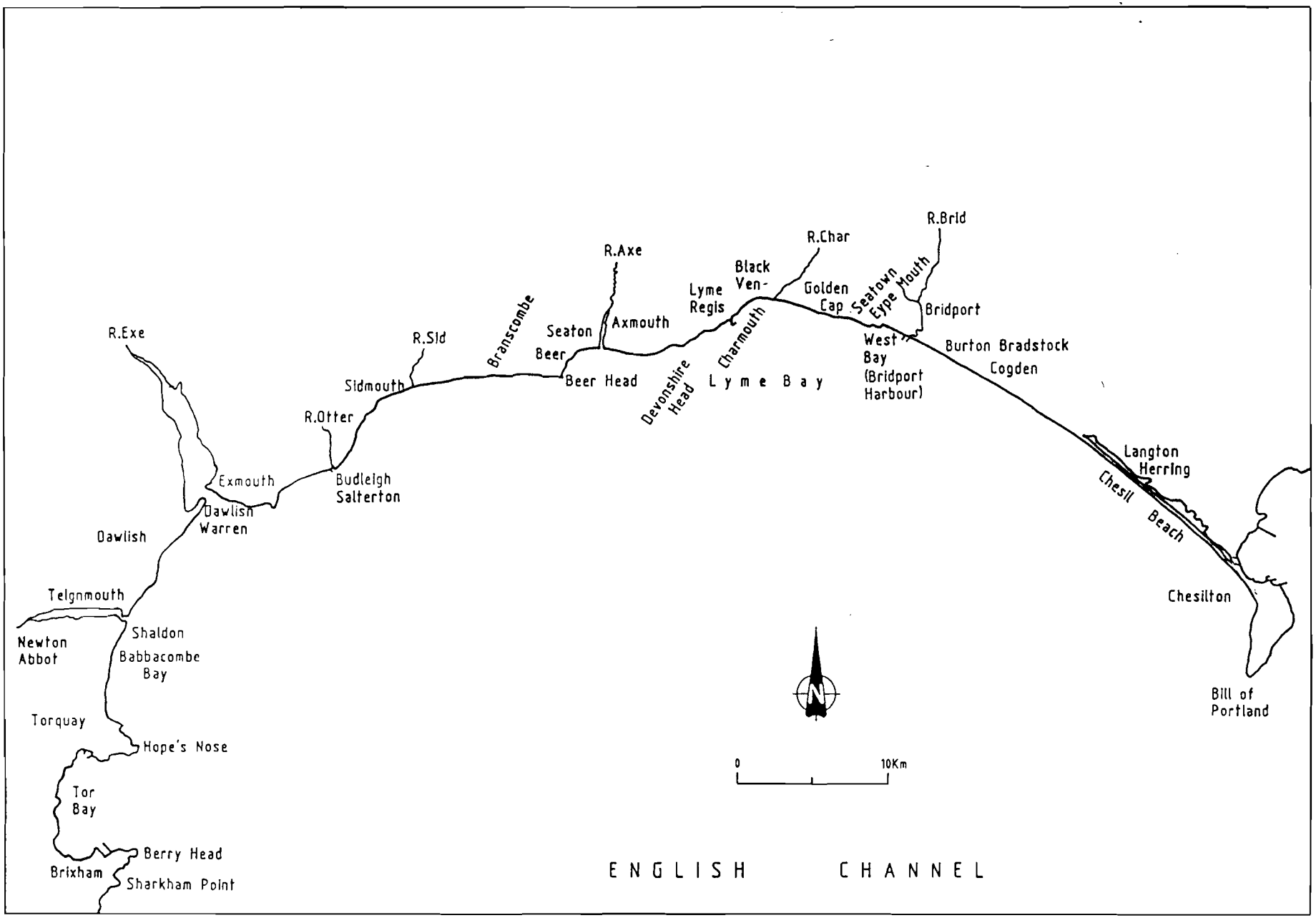

Fig 1 Portland Bill to Torbay

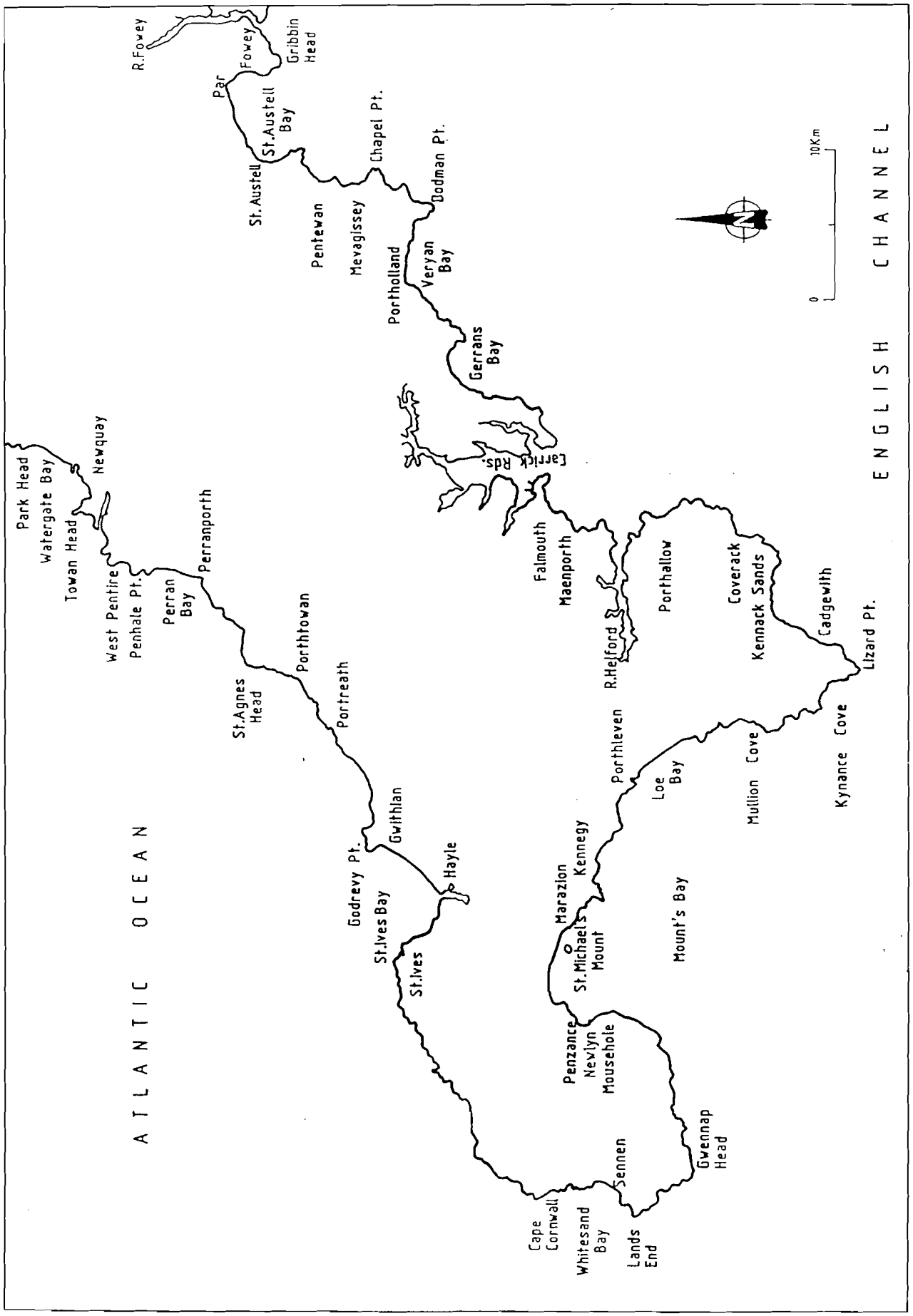

Fig 3 West Cornwall (Fowey to Newquay)

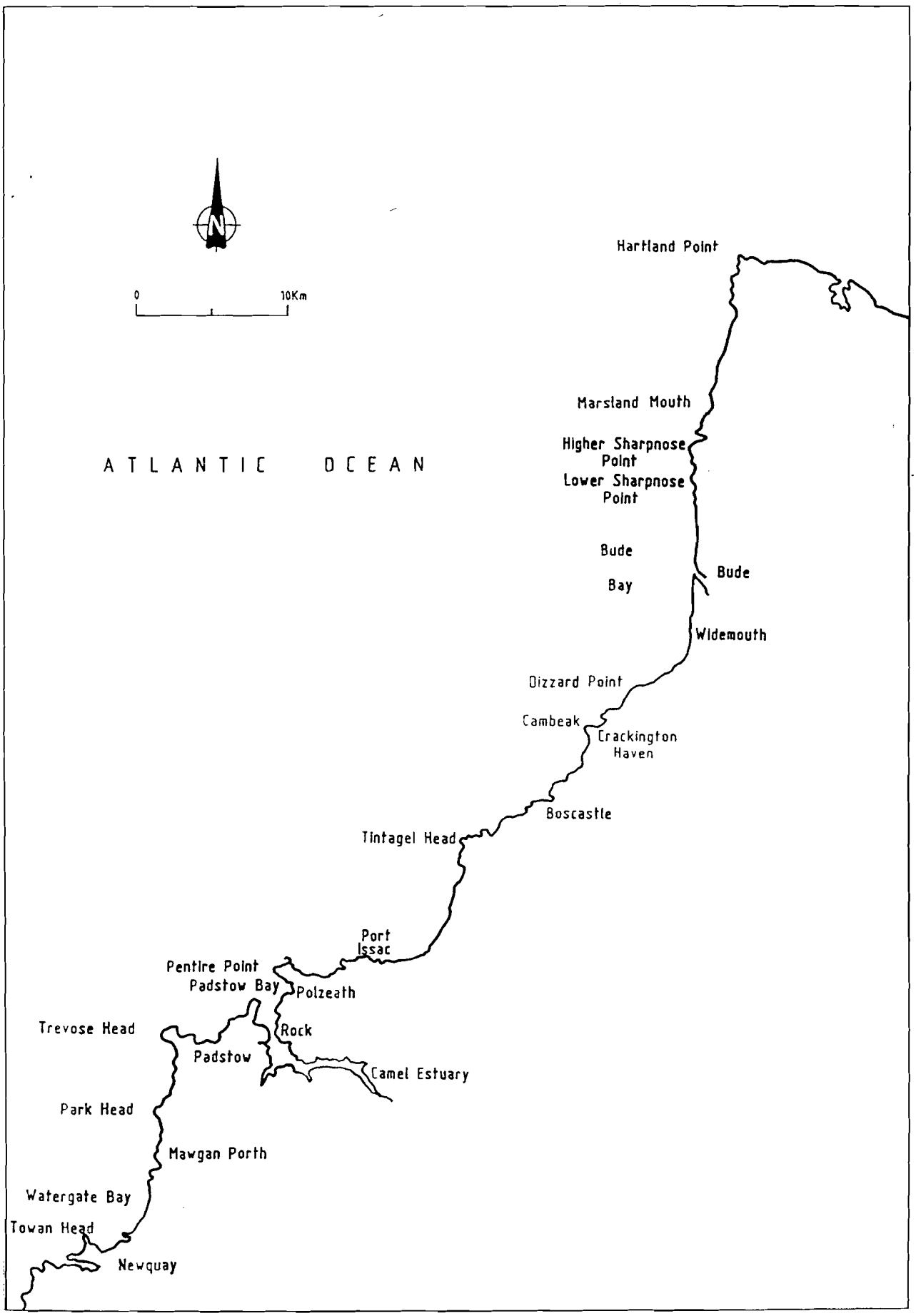

Fig 4 Newquay to Barnstable Bay

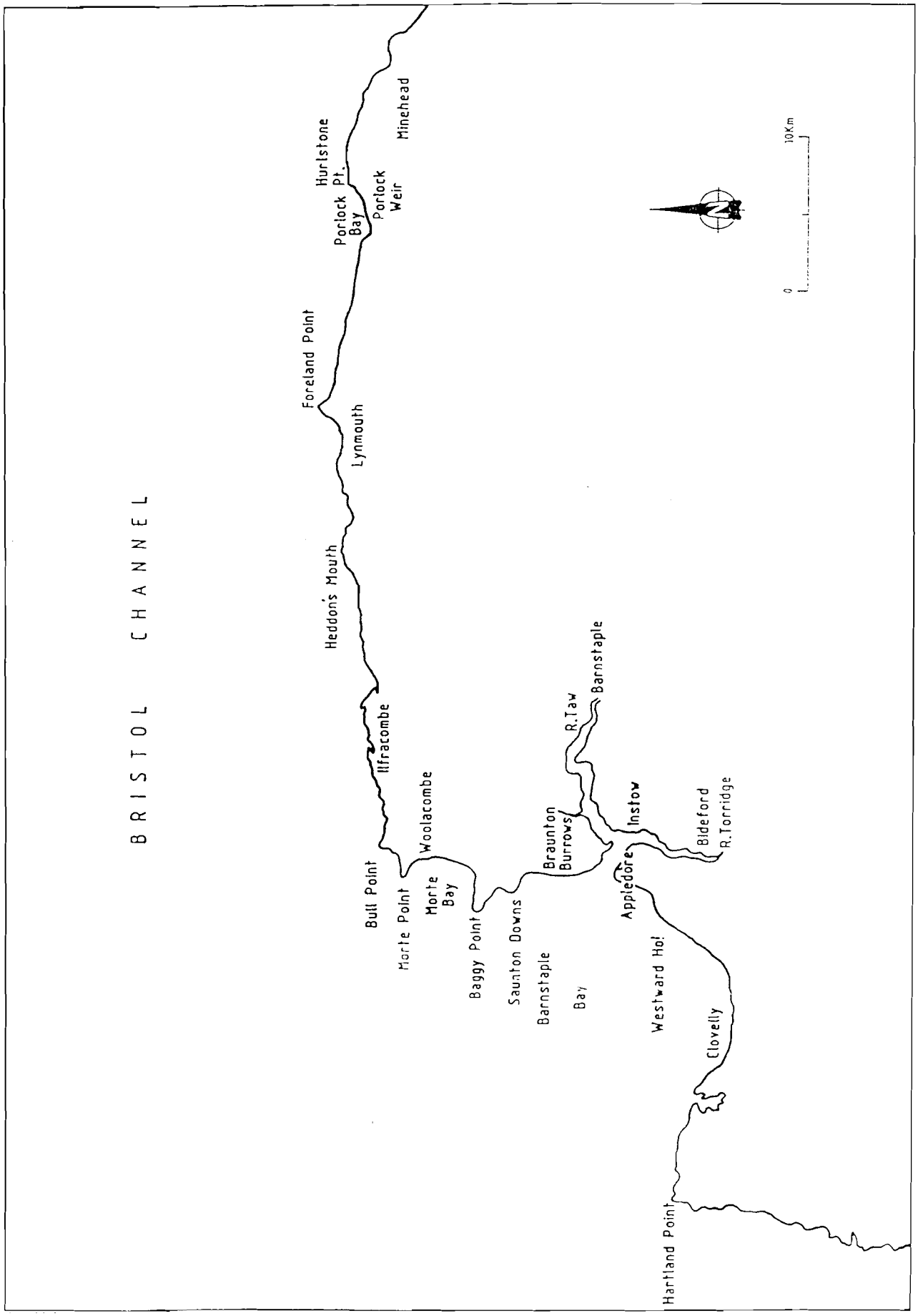

Fig 5 Barnstable Bay to Bridgwater Bay

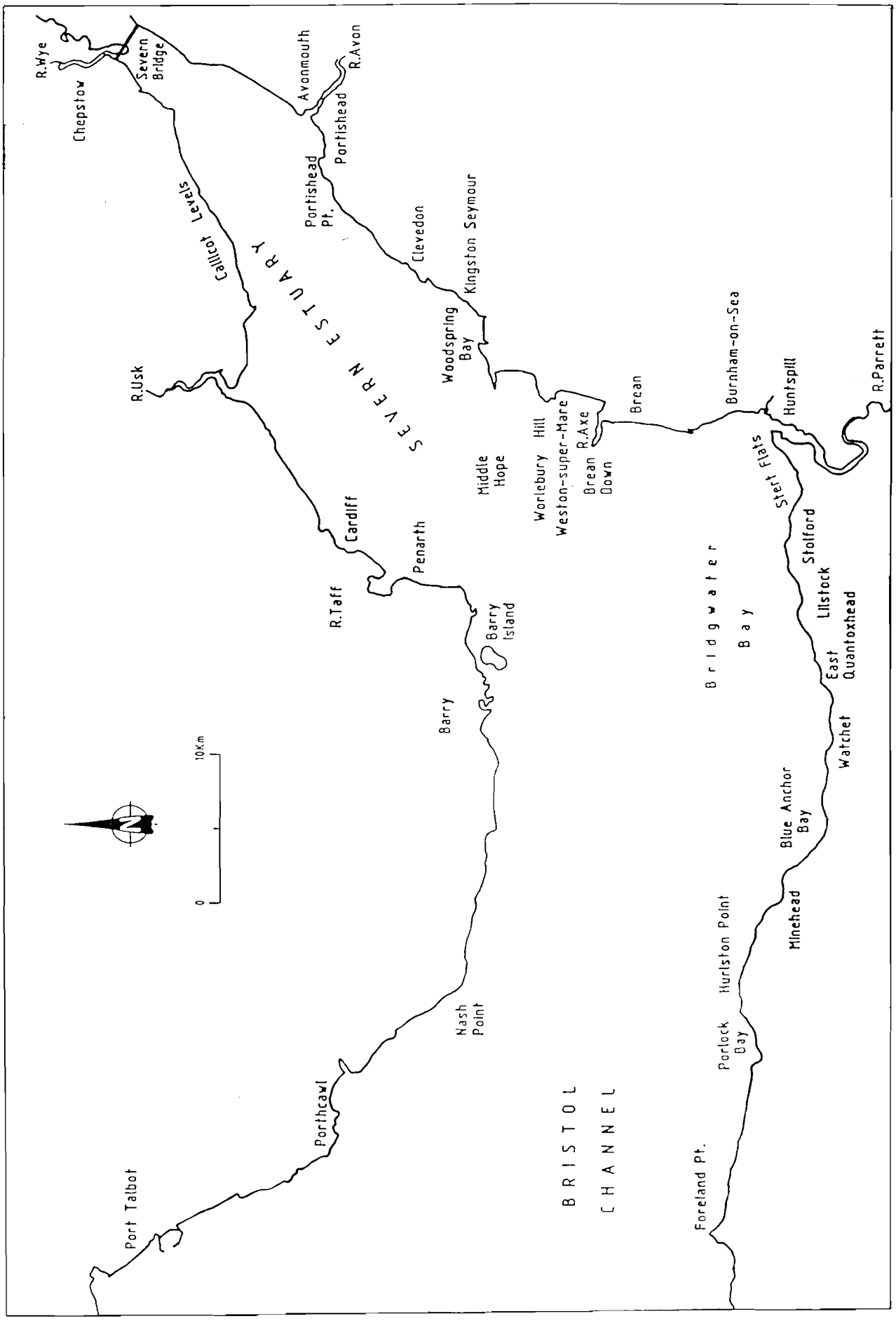

Fig 6 Bridgwater Bay to Avonmouth