Part C

SHORELINE EVOLUTION

The way in which a shoreline naturally evolves is dictated by both physical (geology/geomorphology) and forcing (coastal conditions) components. Man's intervention can influence this and the impact on its physical and natural environment can be significant through not appreciating these factors. This understanding is central to the SMP so that appropriate strategies may be developed in the light of this knowledge.

SHORELINE EVOLUTION

CONTENTS

1 INTRODUCTION

The shoreline presents a mobile environment and regardless of whether it is accreting or eroding, an understanding of how littoral material is moving is essential to effective future management. The way in which the shoreline naturally evolves is dictated by both physical (geology /geomorphology) and forcing (waves, currents) conditions. Man's intervention can influence this and the impact on the physical and natural environment can be significant when these factors are not appreciated. Central to shoreline management planning within Poole and Christchurch Bays is understanding these processes and developing appropriate strategies in the light of this knowledge.

The following text is divided up into the seven Process Units that have been delineated from work presented within the Geology / Geomorphology section of this SMP. In terms of Shoreline Evolution, where, appropriate, attempts have been made to separate text under two sub-headings :

- *Geomorphological history and natural evolution* – refers to landform characteristics, Holocene evolution and natural retreat rates where these have been published.
- *Anthropogenic Intervention* – refers to chronological details of coastal defence history and / or Man's actions along the shoreline.

This text is then complemented, where necessary, by up to date historical analysis using Geographical Information System techniques to appraise the validity of existing work and measurements carried out. Where information on shoreline evolution has already been well covered and documented, no further analysis has taken place.

Details are also provided on bathymetric change within Poole and Christchurch Bays where this information has been made available. This is presented in Section 2.8.

The reader should note that the details on conceptual process models are presented in a separate section. When finally compiled, a Volume shall be set up specifically for the Physical Environment covering sections on Coastal Conditions, Geology / Geomorphology, Shoreline Evolution and Conceptual Process Models (incorporating Sediment Transport).

1.1 Overview of Shoreline Evolutionary Trends

Some parts of the coastline of Poole and Christchurch Bays are eroding, while others are gaining sediment. However, determining whether there is a net gain or loss from the system over time is still a difficult issue to confidently predict. Prior to interference by Man, the cliffs of the two bays retreated naturally and the materials released by this retreat provided sediment for the beaches that fronted the cliffs and the down-drift coastline. There is uncertainty as to whether natural supplies of beach building materials (i.e. Plateau Gravel beds) would have been sufficient to continually supply material to the coast. These deposits were believed to be more significant up to 1000 years ago, though through the processes of natural erosion, these potentially erodable deposits became less in magnitude over time so leaving relic supplies on the fronting beaches prior to the onset of coastal engineering schemes in the Bays. Once Man attempted to limit cliff retreat, the beaches down-drift became depleted in sediment and retreat rates increased locally. Therefore, one needs to acknowledge that intervention has taken place and coastal managers need to deal with the existing situation in Poole and Christchurch Bays, particularly if potential sediment sources are less in magnitude than before.

Presently the system of sediment delivery from the cliffs into the bays is limited to a few specific areas, namely Hengistbury Head and sections of the cliffs between Chewton Bunny and Hordle.

The frontage displays distinct geomorphological characteristics:

- the coast of Handfast Point promontory is characterised by high cliffs (up to 130m) formed of chalk which are eroding slowly (May, 1971 and 1977).
- the northern coastline of the Poole and Christchurch embayments are characterised by rapidly eroding cliffs of Tertiary rocks between 5 and 40m in height (HR Wallingford, 1977; Lacey, 1985; Bray *et al*, 1991a & b).
- the coast around the tidal inlets of Poole and Christchurch Harbours, which in the long term have been areas of accumulation, are characterised by long sand and/or gravel barrier beaches (Steers 1946; Robinson 1955; Carr 1971; Nicholls 1985; Nicholls and Webber 1987).

Where conditions have allowed, sediments supplied to embayments from eroding coastal cliffs have accumulated along parts of the coastline. These sediments are medium or coarse-grained, consisting of mixtures of gravel or sand. Local accumulations of such material have led to the development of extensive barrier-spits, semi-enclosing Poole and Christchurch Harbours and creating Hurst Spit at the entrance of the West Solent.

Fine-grained sediments, which have entered the embayment, following erosion of the Tertiary muds of the cliffed coast, have not been found within the coastal environment (Lacey, 1985). Their absence may be in response to the winnowing effect of the wind-driven waves combined with the tidal currents and swell components (McCave, 1978; Nordstorm, 1989) transferring fine-grained sediments offshore, and to a lesser extent, through the tidal inlets to the more sheltered harbour areas (Gao, 1992, 1993).

The erosion of the coast in Poole Bay and Christchurch Bay has been the subject of many investigations, summarised in Bray *et al* (1991b). This report provides a full description of the sediment inputs, littoral drift and sediment outputs along the coast, but for this study the critical information is that related to sediment budgets.

2 HISTORIC EVOLUTION OF COASTLINE

2.1 Area 5F-1 Hurst Spit to Hengistbury Head Long Groyne (CBY)

2.1.1 Review of Existing Information

Information on coastline recession within this Process Unit has been derived from four key sources. The Ph.D Thesis by Nicholls (1985) presents a series of measurements detailing estimated coastline recession between Barton on Sea and Hurst Spit between 1843 and 1983, based on the analysis of old Ordnance Survey data and aerial photography. The change in cliff top position, cliff base and mean high water (MHW) were recorded and the cliff recession at a number of locations within Christchurch Bay were ascertained. Secondly, historical analysis of the Hampshire coastline was undertaken by Hooke and Riley (1987) which identifies the major changes that have taken place on the coastline between the period 1870 to 1965. Thirdly, the Draft CIRIA Sea Bed Mobility (1998) report provided a summary of sediment types and transport rates along the coast. Finally, Robinson (1955) describes the principal evolutionary changes to Mudeford Sandbank, firstly in response to ironstone mining and secondly the building of Hengistbury Head Long Groyne.

General Overview

It is interesting to note that although historically erosion is the dominant response along the coast of Christchurch Bay, based upon recent beach profile results, there are noticeable variations within the Bay including a significant zone of beach accretion in the vicinity of Hordle Cliff. The differential rates of erosion can be accounted for by changes in geological composition coupled with the hydrodynamical impact of long wave fetch that influences this Process Unit. More recently, particularly over the past sixty years, coastal evolution and appearance has been increasingly influenced by piecemeal coast protection measures.

Much of Christchurch Bay is backed by rapidly eroding cliffs of up to 30m height which provide a major sediment input. The rate of erosion experienced is determined by differentiations in cliff geology, fluctuations in wave energy levels, the degree of protection afforded by the natural beach or coast protection structures and current cliff stabilisation measures in place.

Bray *et al* (1991b) estimate that the input of cliff material of >0.08mm diameter (silt / fine sand) into Christchurch Bay has declined from 63,000m^3/year between 1887 and 1932, to 44,000m^3/year between 1932 and 1968. Cliff protection measures put in place since 1968 have reduced the figure still further and the aggregated figures provided by Bray *et al* (1991b) suggest that during the 1990s, the value is closer to 20,000m^3/year. The total volume of material introduced onto the beaches has always been greater than this value, but about 50% of the material is mud grade which is removed in suspension and not retained on the beaches (Lacey, 1985). Nicholls (1985) suggested that the cliff gravel supply may have been twice as great in the past, and sand supply between 8 and 10 times as great as a result of variations in cliff heights and the thickness of the capping gravels. This suggestion is impossible to prove as the site of these deposits has now disappeared.

Contemporary natural changes on the beaches have been modified by recent recharge schemes and as a result, natural and man-induced effects are becoming increasingly more difficult to distinguish along this coast. Modern changes have been measured by a survey of beach profiles designed to identify these changes with time.

Hengistbury Head to Highcliffe

Geomorphological History and Natural Evolution

Hengistbury Head effectively divides Christchurch and Poole Bays. It previously was a more significant landform feature, though was substantially eroded during the late Holocene and the eroded section of the Head only remains as the submerged shoal of Christchurch Ledge which extends several kilometres to the south-east (Bray and Hooke 1996). Removal of this point of resistance triggered the erosion of Christchurch Bay which is therefore younger than Poole Bay (Nicholls and Webber 1987). It must be stressed that the remaining headland is critical to the stable configuration of both embayments within this SMP study area.

Two barrier spits, Mudeford Sandbank and Mudeford Quay flank Christchurch Harbour entrance. The historical development of the inlet during the past 200 years (Robinson, 1995; Lacey, 1985) demonstrates that it has been a very dynamic morpho-dynamic element. The study of its evolution does not, however, provide substantial evidence to explain the origin of its coastal components. Nevertheless, it may be suggested that Mudeford Sandbank has been formed in response to northerly littoral drift from Hengistbury Head. The importance of this drift has been demonstrated by the impact of Long Groyne on the evolution of the spit.

The origin of Mudeford Quay is not easy to establish, although two models may be suggested. According to Fitzgerald *et al* (1984), Mudeford Quay is a "down-drift offset barrier" (Sha 1989), formed through a process of sediment by-passing and swash-bar welding. Littoral drift from the east (under waves from the south-east), supplied with material from the erosion of the cliffs at Highcliffe, might have assisted in the formation of the spit and further modified it.

An alternative explanation is that Mudeford Spit originated as the "beheaded" northern part of the Southern Spit, which was breached by either storm waves or excessive hydraulic pressure on its landwards side (Robinson, 1955).

Mudeford Sandbank is of variable width and length and is largely formed of sand-dunes rising to a height of about 20 feet. The dunes are fronted by a spread of shingle and sand and typical strand-line plants are common.

In recent years, although minor changes have taken place, there has been no further growth and extension of the spit, with the river still running out to sea opposite Sandhills. The site of the fluctuating portion of the spit is marked by an offshore bar, part of which dries at low water. The lagoon at Avon Beach was gradually infilled with blown sand and by the 1960's, had completely disappeared.

Anthropogenic Intervention

An Act for the making of the River Avon navigable from Christchurch to the new city of Sarum (Salisbury) was presented to Parliament in 1664. One of the measures contained in the Act was the construction of the ironstone boulder rock-fill training bank now known as Clarendon Rocks. This training bank was originally constructed as a pier or jetty to secure a new harbour entrance cut through the sand dunes, on the south side of the new pier. It was intended that a second pier constructed to the south of the first would secure the southern shore of the new cut. A report in 1762 shows that the new cut of 1670 was already silted up, the waters of the Avon and Stour catchment having broken through Mudeford Sandbank in the area of the original channel near Haven House.

The introduction of ironstone mining at Hengistbury Head during the mid 19th century caused an increase in the rate of erosion of this length of coast, a sharp increase in the drift of sand and shingle into Christchurch Bay and the consequent growth in Mudeford Sandbank (Mudeford Spit). The Spit extended up to 2.5km east of the present quay but was periodically 'broken through' by a combination of high tides and south easterly wave attack, (Figure 2.1.1). By 1846, the beach extended north-eastwards and the inshore channel known as the 'Run', extended in length of a quarter of a mile. By 1869, an elongated bank of shingle and sand stretched to Steamer Lodge and in 1880 the end of the Spit was south of Highcliffe Castle.

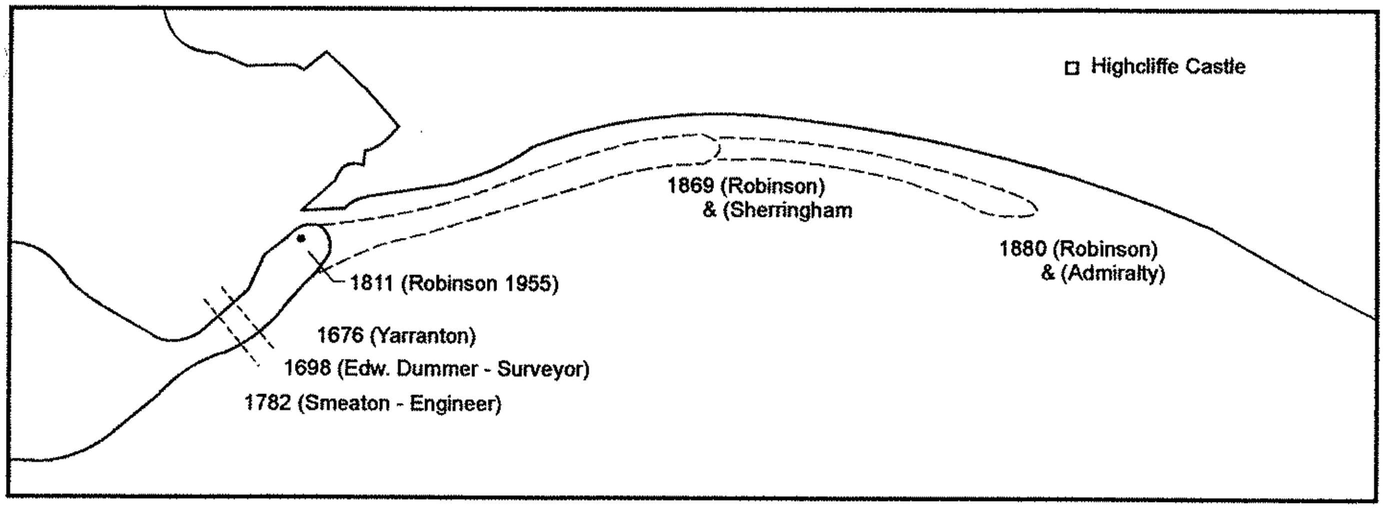
Throughout the remaining parts of the nineteenth century to the mid twentieth century, there have been various breaches and extensions or diminutions affecting the overall length of the 'Run'. The various extensions to the Sandspit were due to various amounts of drift material from Hengistbury Head and further west. Each time storms breached Mudeford Sandbank, growth started again at Christchurch Harbour entrance, when it extended typically as far as Highcliffe before being breached at its root. The cut off spit rolled inshore, which accounts for the varying rates of erosion along this section of the coastline. This cycle typically took fifteen to twenty years. It should be noted that erosion also resulted in a high river flow being diverted along the coast.

The end of Mudeford Sandbank, which is exposed at low water, is periodically moved by the occurrence of high waves from the south or south-east combined with high water levels. The Run channel is known to be a varying mobile feature at its seaward end but becomes more stable at its western end when the protection offered by Mudeford Sandbank from southerly wave attack becomes significant.

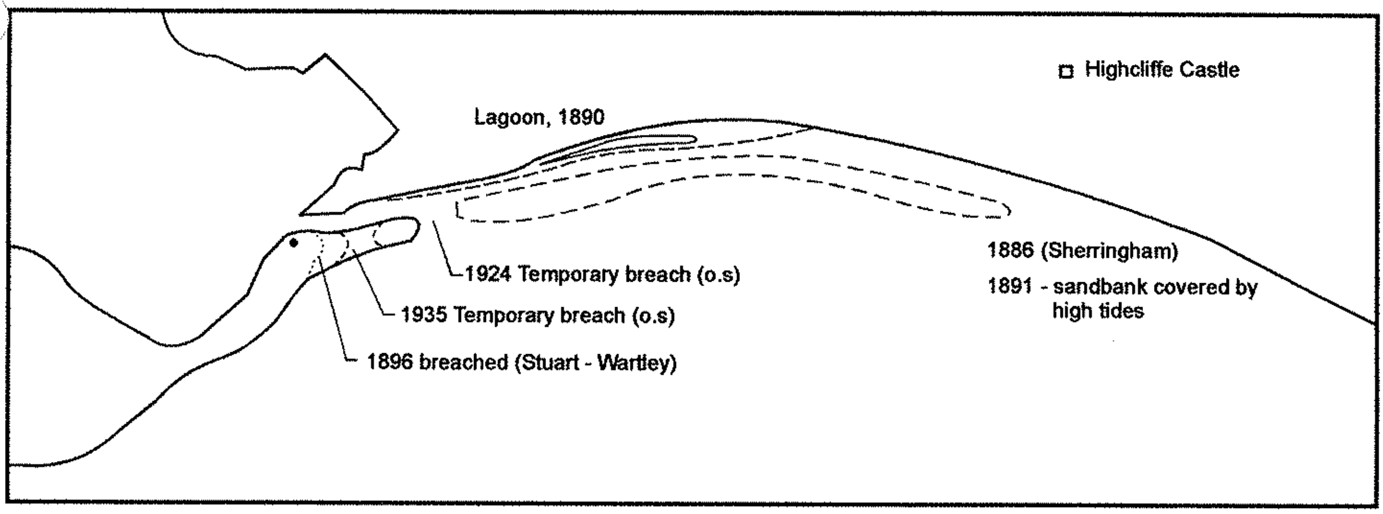
Since 1931 Christchurch Borough Council has carried out coast protection duties on Mudeford Sandbank under the terms of the lease of the Sandbank from Bournemouth Borough Council. A constant programme of works has been carried out to prevent the sea breaking through the Spit and this is only now reaching completion. All the Council's experience here has suggested that the Sandbank is a vulnerable feature with an intensely high-energy seaward frontage.

In 1935 the Spit was breached again and Highcliffe gained a large beach from its remains. It was not until the construction of the Long Groyne at Hengistbury Head in 1938, that any permanent reduction in the length of the Spit resulted. The Long Groyne immediately attracted a large beach updrift most of which still exists today and leeside scour became evident soon after. This feature effectively cut off the majority of littoral drift supply from Poole Bay. Mudeford Sandbank which was 2 miles longer in 1936 had substantially shortened by 1944, to the extent that the Black House opposite Mudeford Quay was in danger of being cut off and Christchurch Borough Council were forced to construct several large rubble groynes to save the remainder of the spit (see Coastal Defences section in Volume 3).

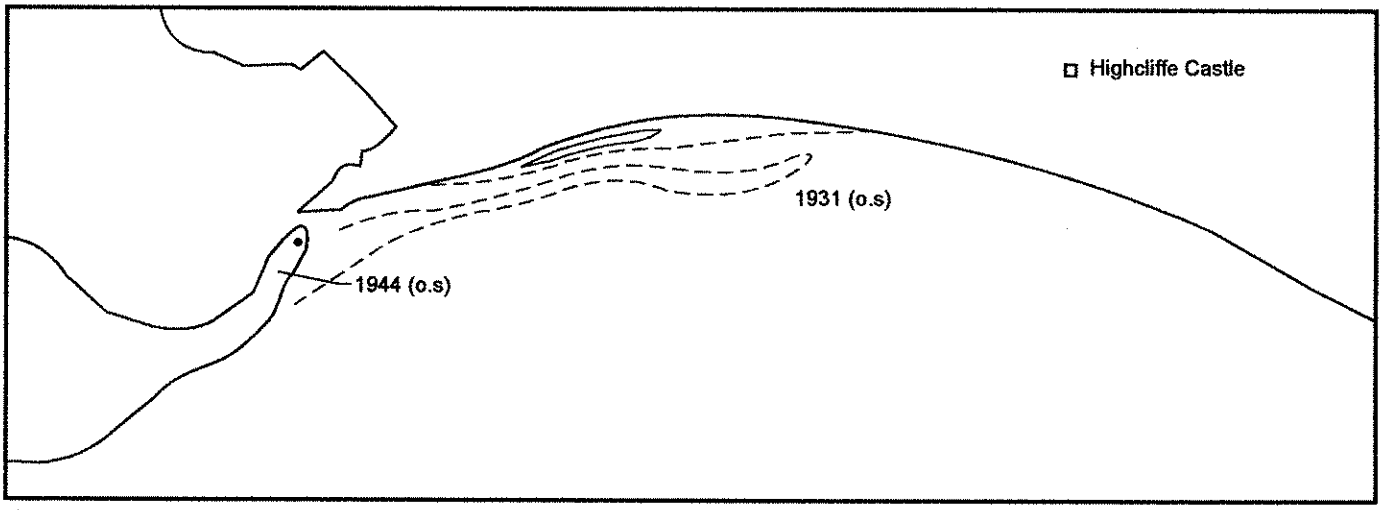
The coast of Highcliffe-on-Sea has been subjected to intensive coastal protection activity over the last 30 years. As mentioned previously, ironstone mining on the foreshore of Hengistbury Head led to increased sand supply into Christchurch Bay from the mid 1800's, leading to cyclical growth of Mudeford Sandbank up to 2



GROWTH OF MUDEFORD SANDBANK
DURING IRONSTONE MINING, 1850



VARIED HISTORY OF SANDBANK, 1880-1930



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DISAPPEARANCE OF SANDBANK IN THE EARLY 1940'S

(from Christchurch Borough Council)

miles longer than present followed by breaching opposite Mudeford Quay. The extended spit acted as both protection and episodic large scale beach feed. From the late nineteenth century this portion of Christchurch Bay was protected by the extended seaward spit of Mudeford Sandbank.

From 1935 onwards beach levels gradually lowered, eroding the toe of the cliffs and making them more unstable. The result was an erosion rate being experienced of half a metre per year. A timber revetment and groyne system was constructed at Highcliffe in the 1960s. This scheme limited erosion at the toe of the cliffs but failed to retain a beach in front. Importantly, the Barton Clay cliffs continued to slip in the area because an important secondary factor, cliff drainage, was poor.

Starting in 1973 the Council undertook a programme of cliff stabilisation works. The programme succeeded in stabilising the cliffs but the beach in front continued to erode. Waves battered the revetment causing undermining at the eastern end, where erosion of the unprotected cliffs to the east created a stepback in the coast.

Since 1939, coast protection schemes have been built virtually continuously from Hengistbury Head to Highcliffe, so that the coastal position is now fixed. Details are provided in the Coastal Defences section in Volume 3.

At Highcliffe some 4400m3/yr of material (>0.08mm) was calculated by Lacey (1985) to have been deposited on the beach by cliff erosion between 1932 and 1968. Cliff protection measures, introduced since 1970, have stopped material from the cliffs moving onto the beach, which now need to rely on natural littoral feed from the west and artificial recharge.

Historical records of cliff retreat at Highcliffe indicate that retreat may once have been extremely rapid and a possibly unreliable rate of 6mpa is quoted for the period 1760-1830 (Nicholls 1985). This is supported by an account suggesting loss of up to 1km of land (10mpa) between the late 1700s and late 1800s (Mockridge 1983). Subsequently, the cliffs became significantly more stable, probably due to improved drainage and toe protection by an accreting beach (Mockridge, 1983). Mean recession of 0.18mpa was recorded over the period 1908-59 by comparison of maps and a cliff-top survey (Wise 1959). The rate was spatially and temporally variable with maximum recession for the central cliff section of 0.95mpa for 1931-39 (Wise 1959). The cliff toe periodically advanced and retreated over this period as landslide debris intermittently surged seaward and was eroded (Barton 1973). This phase of relative stability ended in the late 1950s and thereafter Highcliffe was characterised by beach erosion, increased cliff landsliding and cliff-top retreat rates which increased to 0.68mpa (Barton 1973, Mockridge 1983, Tyhurst 1986).

Coast protection and cliff stabilisation schemes have included construction of a timber revetment and groynes by 1970, cliff drainage and stabilisation in 1973/74 and 1978/79, vegetation establishment in the undercliff, beach nourishment and rock groyne construction in 1985, with further nourishment and rock groyne construction in 1991. From 1986 onward, cliff drainage measures were inserted further west towards Highcliffe Castle (Mockridge 1983, Tyhurst 1986, Christchurch Borough Council 1991). The outcome of these intervention measures is that sediment input from the cliffs is now not possible whilst these measures are effective so maintenance of beach volumes need to rely upon natural littoral feed and artificial beach nourishment.

Chewton Bunny to Barton West

Geomorphological History and Natural Evolution

Chewton Bunny to Barton-on-Sea is confined to the west and east by coast protection schemes at Highcliffe and Barton respectively. No coast defence measures therefore occur in between. Consequently, this sub-division of text does not include an assessment of 'Anthropogenic Intervention'.

The coast between Chewton Bunny and Barton is unprotected for a distance of some 1.3km. At Highcliffe, west of Chewton Bunny, the cliff is fully protected but there is an abrupt change at the Naish Farm frontage, where the cliff is undergoing unrestrained retreat (Bray *et al* 1991b).

The frontage is characterised by a complex landslide system (Naish Cliffs) which is typically 30m high. The cliffs are provided a limited degree of protection by a sand and shingle foreshore which falls seaward at a gradual gradient of the order of 1:60. The foreshore is starved of fresh material due in part to the groyne field at Highcliffe, the stepback in the coastline and general insufficient sediment supply in Christchurch Bay.

A long term cliff retreat rate of approximately 1m/year has been characteristic of these cliffs, between 1867 and 1959 (May 1966, Nicholls 1987, Hooke and Riley 1987). However, this figure conceals spatial variations of up to 5m/year and a trend for increasing retreat in recent years. This is likely, in part, to be linked to groundwater – geotechnical interactions in addition to cliff toe erosion caused by wave attack. The cliff recession rate between 1869 and 1939 was 0.3m/year, increasing to 1.3m/year in the 1960s and 1.9m/year in the 1970s. Most recent work carried out by HR Wallingford suggests that the erosion rate since construction of defences at Highcliffe in 1971 has attained a rate in the order of 3.0 mpa (Bray *et al*, 1991). Site reconnaissance surveys served to confirm that the plan shape of the frontage is similar to the profile of an immature crenate bay formed between two fixed headlands. The erosion rate given above should therefore be considered as an upper limit since further bay development will provide a more sheltered environment and thereby reduce the average rate of retreat. Research by Bray suggests a slightly less average cliff top retreat rate in the order of 2.0 mpa.

Wave action and land drainage provide both preparatory and triggering factors which influence the erosion rate. Slope destabilisation is predominantly governed by groundwater seepages that give rise to landslide mechanisms including bench sliding, mudslides, slumping and debris slides. Triggering events necessary to initiate a failure may simply include heavier than average seasonal rainfall or one off extreme precipitation events. Wave action during periods of normal spring tides provides a sufficient transport mechanism to remove debris at the cliff toe and contributes to destabilisation of the cliff face by removing fallen detritus from the toe.

Academic research that involved the analysis of aerial photography (Barton 1973, 1984, 1985) indicates that cliff erosion does not consistently occur over time. Periods as long as 2 years can occur without significant or measurable erosion of the cliff top, followed by cliff falls of between 2 to 8 metres width which can occur in a single erosion event.

Significantly, along much of the western section of the Barton Cliffs, the cliff line had retreated faster than MHW (Hooke and Riley 1987). Between 1867 and 1969 the average net rate of erosion for MLW mark has been calculated as 1.01m/year, MHW mark at 0.72m/year whilst along the cliff edge, erosion is greater than 0.98m/year. Although the figures represent mean erosion per year, it should be noted that much of the movement in this area is periodic and related to the incidence of storms as well as cliff saturation levels.

If recession continues between the two fixed frontages, it will produce a concave embayment, and calculations quoted by Bray *et al* (1991b) indicate that about 150m of erosion is likely in the bay before it acquires an equilibrium form. At the present rate of retreat, this implies many decades of erosion are still to be expected along this frontage if it is left unprotected.

The total supply of cliff derived sediment with a mean diameter >0.08mm (very fine sand) is calculated to be 9,000m^3/year (Lacey, 1985). The rate of gravel supply from the erosion of Plateau Gravel capping is estimated to be 2,400m^3/year (Bray *et al*, 1991b).

Barton West to Becton Bunny

Geomorphological History and Natural Evolution

The 5-9m thick Plateau Gravels capping the cliffs here and the sandy nature of the Barton Formation give a potential yield of some 13,000m^3/year. This sector did represent a significant source of littoral material, as prior to protection schemes introduced in 1966, this figure was greater. However, following work carried out in 1991, Bray *et al* (1991b) concluded that the sediment input from the cliffs would largely cease.

Historically, this coastal segment was extremely unstable and subject to rapid cliff recession measured at 0.75mpa for the period 1867-1959 (Hooke and Riley 1987).

Anthropogenic Intervention

Increased cliff top recession of 2.0 - 2.4mpa for 1959-66 (Barton 1973) endangered cliff top properties and lead to a coast protection scheme which was started in 1966 and completed in 1968. This involved toe protection comprising groynes and a timber revetment retaining rock armour. Cliff stabilisation included steel sheet piling driven through the undercliff to intercept groundwater flow along the clay/sand interface, and drainage of the groundwater that this intercepted (Clark Ricketts and Small, 1976). These measures were only partially effective because deep seated failures in the undercliffs in the winter of 1974-75 penetrated beneath the sheet piling causing rotation, bowing and splitting of the barrier.

Cliff-top recession averaged 5mpa over a 150m front in 1975 (Clark, Ricketts and Small 1976, Indoe 1984). Various emergency works and beach restoration using rock groynes/strongpoints and beach nourishment have been successful in preventing further major slides (New Forest District Council 1987). The eastern part of the frontage towards Beckton Bunny remains largely unprotected and has retreated at 1.63mpa from the late 1970s to early 1980s (Lacey 1985).

The 30m high cliffs at Barton on Sea have receded at a rate of 0.75m/yr between 1867 and 1959 (Orangewoud 1990). Since the construction of the drainage system and cliff toe revetment by Halcrow between 1961 -1980, the cliffs have become much more stable. There have, however, been some minor landslips and two major ones (1975 and 1993). The crest and sloping surfaces of the cliffs continue to degrade as they evolve towards a more naturally stable profile. This subsection contains groynes to reduce littoral drift in front of the cliffs. The significance of groyne spacing is raised in the Coastal Defences section of the SMP, however, the relevance of this issue is important since erosion at the upstream end occurs between the widely spaced groynes (500m).

Becton Bunny

Geomorphological History and Natural Evolution

Historically, retreat averaged 0.85mpa over the period 1869-1959 (Hooke and Riley 1987), although more rapid retreat of 1.5mpa was recorded for the period 1932-68 (Lacey 1985). In recent times, retreat has accelerated significantly with 4.2mpa recorded for the period 1968-82 (Nicholls 1985) and 3.6mpa between the late 1970's and early 1980s (Lacey 1985). This acceleration is partly attributed to terminal scour resulting from reinforcement of the Beckton Bunny outfall which created an impermeable groyne in 1971 (Nicholls 1985).

Erosion rates are not uniform along this frontage. Current erosion / instability of cliffs here appears to be instigated by marine erosion at the base of the cliff, causing over steepening of the cliffs followed by rotational failure. These may be quite large measuring as much as 60m wide by 30m from crest to toe (Scott Wilson Kirkpatrick 1996). Such a slip may introduce several thousand cubic metres of soil into the beach system.

Anthropogenic Intervention

To the east of Becton outfall the rate of recession has increased since 1968 (Scott Wilson Kirkpatrick 1996). The outfall at Becton Bunny is functioning as an effective groyne interrupting eastwards littoral drift. Hooke and Riley (1987) calculated the average nett rate of erosion here for MLW to be 1.24m/yr, MHW to be 0.59m/yr and for the cliff edge erosion at 0.85m/yr. Since 1843, some 120m of land appears to have been lost, with over 30% occurring since 1975. Orangewoud (1990) claim that since 1959, erosion rates have tripled due to a decrease of longshore transport from the west. It is suggested that this is linked to the construction of the Barton sea defences.

Taddiford Gap

The information presented in Table 2.1 indicates that although considerable recession has occurred at the location of Taddiford Gap over the past 150 years, the rate of cliff recession since the late 1960's has been negligible, with both the cliff base and crest remaining essentially static. This fact is reinforced by recent observations from aerial photography showing the cliff faces here to be well vegetated. The link between cliff stabilisation and offshore sediment movement (Nicholls and Webber 1987) is believed to be a significant factor. During the same period, however, the MHW mark receded some 10m, reversing a period of beach shingle accretion during the previous 30 years (Scott Wilson Kirkpatrick, 1996).

TABLE 2.1 **Cliff Recession at Taddiford Gap**

Date	Cliff Recession (Metres)		
	Cliff Top	Cliff Base	MHW
1843	-20	-	-
1867	0	0	0
1898	18	20	22
1908	20	34	25
1939	23	34	29
1968	38	45	30
1983	38	45	30

Hordle and Rook Cliffs

Geomorphological History and Natural Evolution

At Hordle Cliff, retreat is extremely slow averaging 0.12mpa for the period 1809-1969 with no retreat recorded between 1931-69 (Hooke and Riley 1987). This is due to accretion of a substantial shingle beach which protects the cliff toe and prevents marine erosion and sediment input (Nicholls 1985).

Map comparisons indicate retreat at 0.4mpa over the period 1869-1969, but virtually all retreat was over the latter part of the period: 0.97mpa for 1931-69 (Hooke and Riley 1987) and 1.14mpa for 1932-68 (Nicholls 1985).

Anthropogenic Intervention

Continued supply despite protection can be attributed to rapid recession of unprotected parts and continued instability of protected cliffs. Between Becton and Hordle inputs of sediment within a mean size of >0.08mm into the littoral zone from the cliffs were estimated to be 15,000m^3/year (Lacey, 1985) and gravel input was calculated at 7,000m^3/year (Nicholls, 1985). Between Hordle and Milford input of material >0.08mm was calculated to be about 3,000m^3/year (Lacey, 1985).

Cliff recession here has been less pronounced amounting to some 25 to 30 m of erosion since 1867 in the vicinity of Hordle House School. The accretion of the shingle beach has contributed to cliff stability here with the most noticeable accretion (60m) occurring between Hordle House and Rook Cliff. Hooke and Riley (1987) calculated the average net rate of movement in the area. It was noted that between 1867 - 1969, MLW moved seaward at 0.34m/yr, MHW also at 0.34m/yr whilst along the cliff edge erosion has been negligible at 0.12m/yr. At the western end of Hordle Cliffs, mudflows from the cliff may sometimes push the shore seaward causing intertidal accretion, however, to the east, the accretion is due to littoral processes creating shingle accumulations on the beach in front of the cliff (shown from beach profile comparisons). Since 1968, MLW mark has receded at a rate of 2m/yr and with the reduction in the magnitude of the nearshore bar fronting

Hordle due to storms in 1990, it is predicted that erosion of MHW mark may increase to this rate in the future.

Cliff top recession in front of the school appears to have accelerated over the last 2-3 years judging by the narrowing footpath along the cliff edge.

Milford-on-Sea

Geomorphological History and Natural Evolution

Between Milford Hospital and Milford East, cliff top erosion occurred at a rate of 0.5 - 1m/yr (Orangewoud 1990) from 1867 to 1968. Although the MLW mark here is presently receding, this is not the case for MHW and so consequently, intertidal steepening is occurring. Hooke and Riley (1987) calculated that the average net rate of erosion at Milford-on-Sea for MLW is 0.65m/yr and for MHW, 0.45m/yr. Cliff edge erosion is occurring at a similar rate of approximately 0.40m/yr.

Anthropogenic Intervention

The construction of sea defences at Milford-on-Sea in the period 1936 to 1968 modified the sediment budget of the area with Hurst Castle Spit experiencing a phase of rapid evolution, with maximum recession rates increasing from 1.5m/yr (1867 - 1968) to 3.5m/yr (1968 - 1982). Nicholls and Webber (1987) have studied the recent evolution of Hurst Spit from cartographic and photographic evidence. Historically, shingle was extracted from the active recurve between 1694 and the early part of the twentieth century. The Point of the Deep appears to have been stable between 1742 and 1908 though rapid accretion has since taken place. This suggests that during the eighteenth and early nineteenth century, the rate of extraction approximately balanced that of littoral drift volumes. Shingle was extracted for building purposes at Milford-on-Sea during the last century which created washover sites, however, it is believed that this action did not contribute to any significant coastal recession.

At Milford-on-Sea, the first coast defence structure was a groyne built between 1867 and 1898. The historical evolution of the shoreline after this date has subsequently been further distorted by a series of major coast protection schemes constructed between 1936 and 1968. These in fact have been blamed for more serious recent erosion events including frequent overwashing and crest lowering during storm action.

Hurst Spit

Geomorphological History and Natural Evolution

Hurst Spit lies to the east of the Tertiary sandy and clayey coastal cliffs of Milford-on-Sea, and extensive saltmarshes have formed on its lee side. It is an elongate gravel beach, orientated at 130°N, with its original length (2km) having decreased since 1968 due to the armouring of the proximal 600m of the beach. The distal end of the spit, orientated at 100°N, turns sharply at Hurst Point towards the N-NW to form a 800m long active recurve (three former recurve features are also present, with dimensions which increase from west to east with decreasing age).

It shows a transgressional form of accumulation, with a "multi-recurved" spit form that has extended into deep water under the influence of two distinct ridge-forming wave trains (Lewis, 1938; King and McCullagh, 1971; Nicholls, 1985; Velegrakis, 1994). It is composed predominantly of sub-angular to sub-rounded flint pebbles (gravel) with subsidiary fine- to medium-grained sand; this marks an important difference in composition to the tidal inlets described elsewhere.

The Spit is a transgressive feature, moving landwards as a result of overtopping and overwashing. The rate of transgression had increased from approximately 1.5m per year (1867-1968) to 3.5m per year (1968-1982. Evidence from field observations, together with analysis of aerial photographs (taken prior to 1989) show that storms change the morphology of the spit considerably. Several recent severe storms have resulted in extensive damage to Hurst Spit. In particular the storms of October and December 1989 caused dramatic crest lowering and roll back across the saltmarshes coupled with outflanking of the rock armouring. Crest lowering in excess of 2.5m and roll back of the seaward toe by up to 60m resulted in displacement of more than 100,000 tonnes of shingle overnight (Mackintosh and Rainbow 1995).

The historic evolution of Hurst Spit has been studied by Nichols (1985), using an extensive topographic database. The orientation of the Spit has not changed during the past 200 years though there had been a landwards shift in the position of the structure, probably in response to storm wave action. The northern extremity of the active recurve was found also to have extended during this time. Recent observations show that such changes are continuing. Parts of the Spit regressed by some 50m during the storms of December 1989, whilst the tip of the active recurve has pro-graded further to the north.

Spit recession rates have been calculated by comparisons of Ordnance Survey Maps, air photos and recent beach profile information. Mean recession of 1.5mpa was determined for the spit as a whole for the period 1867-1968 (Nicholls 1985, Nicholls and Webber 1987) with an alternative of 1.0mpa covering 1863-1963 (Halcrow 1982). Spatial variations have been identified with maximum recession of 1.8mpa for the northern neck and minimum of 0.2mpa at the middle neck during the period 1931-69 (Hooke and Riley 1987).

In the period between 1870 and 1970, the neck of the spit has shifted progressively north eastwards up the Solent, although the rate and nature of movements does vary. This means that the spit has moved over the saltmarshes at a rate of approximately 1.5m/yr. Hooke and Riley (1987) state that between 1867 and 1897, 45m of MHW movement was mapped on the western facing edge, but between 1897 and 1910, there was negligible change. Following this, between 1910 and 1932, MHW mark shifted about 28m increasing to 67m between 1932 and 1968. Since 1939, the width of the ridge has become smaller due to a decrease of longshore transport from the west (Orangewoud 1990).

Anthropogenic Intervention

The coastal changes that have occurred between Milford-on-Sea and Hurst Point cannot be understood without an appreciation of the nature of the littoral drift. The recorded historical recession here is largely a response to the decrease in the littoral drift of shingle east of Hordle Cliff. The construction of sea defences at Milford-on-Sea has put the sediment budget in this area into deficit and the resultant decline in the volume of Hurst Beach has caused the increase in recession rates mentioned above (Wright 1996).

The construction of coast protection and flood defence structures over the last 70 years has stopped the erosion of sand and gravel from the soft cliffs along much of Poole and Christchurch Bays. Consequently the volume of shingle moving onto the Spit has declined and, as a result, the Spit has decreased in size; a process which has accelerated markedly since the 1940s when large scale groyne construction began at Bournemouth and Christchurch. In 1954, for the first time, the Spit suffered breaching due to storm induced overwashing, although non-damaging overtopping must certainly have occurred before that time.

The Spit has been breached many times since 1954, notably in January 1962 when the recently constructed timber groynes were outflanked as the Spit rolled back during storms which caused widespread flooding in Milford and Keyhaven. The increased frequency of storm damage and sharply rising maintenance costs since the 1970s indicate that a threshold of stability had been passed and that the Spit was no longer able to withstand even moderate storms without suffering severe damage. Sediment transport calculations confirmed that the rate of loss from the Spit was more than double the rate of shingle movement onto the Spit.

During the winters of 1981/82 and 1984/85 and again in 1989/90, storm induced overwashing lowered extensive areas of the Spit. In the aftermath of the 1989/90 event, tidal breaches were recorded for the first time through the remains of the Spit, allowing water to flow through at all states of the tide and resulting in rapid erosion of the salt marsh in its lee. Restoration works, reforming sections of the Spit using large volumes of imported beach material, were initiated before the storms had ceased and were successful in preventing further damage.

Annual nourishment has been undertaken on Hurst Spit since at least 1981 and increased from 715 tonnes in 1982/83 to 4285 tonnes in 1983/84 (Nicholls 1985). Material supplied generally comprises flint gravel from inland pits, but significant quantities of sea dredged material were used in 1985/86. It was subsequently found that particle size of much was too small to remain on the beach (Reina 1990). Subsequent nourishment was therefore with material larger than the indigenous shingle and comprised 25,000 tonnes in 1989/90 and 5,000 tonnes in 1990/91.

Hurst Spit Stabilisation Scheme was constructed in 1996 and involved; 300,000m3 of shingle beach renourishment to increase the level and width of the Spit; the construction of a nearshore breakwater at the junction of the shingle spit and the reconstruction of the existing rock revetment immediately to the west of Hurst Spit. Material for recharging the beach was obtained from The Shingles Bank offshore of Hurst Spit which was thought to be the destination of material moving off the end of the Spit.

Sturt Pond

One interesting feature present to the western end of the feature is Sturt Pond. This has an outlet to the east behind the shingle ridge, but the earlier pond itself extended further southwards and has been progressively shortened by the northward movement of the shingle ridge. Historical analysis shows that Sturt Pond had experienced a period of significant retreat amounting to 45m between 1947 to 1957 (ie 4.5m/yr, Stopher 1957).

Opposite Sturt Pond, recession was 1.3mpa between 1867 and 1939 and increased to 2.0mpa during 1939-68 (Nicholls 1985). The trend for increasing recession has continued and affects the whole spit except for the "fixed" Hurst Castle. Recession of 3.5mpa is recorded for 1968-82 (Nicholls 1985) and 2.5mpa for 1958-82 (Halcrow 1982). Although recession of southern parts has increased over recent time, total gravel supply may have reduced due to stabilisation of parts of the beach at Milford and Sturt Pond by sea walls/rock groynes and rock armouring (Nicholls 1985).

2.1.2 Analysis of Historic Data

Cliffs

Figure 2.1.2 portrays the steady erosion experienced at Chewton Bunny with approximately 60m of erosion at Naish Cliffs occurring between 1907 and 1994 (0.7m/yr). According to measurements taken, over 20m of erosion has occurred since 1975. To the east of Barton on Sea (in front of the golf course) little cliff erosion occurs apart from a noticeable slump which is apparent to the east of the golf course (approximately 30m movement since 1975) to beyond Becton Bunny. Little movement of cliffline position has occurred here along the stretch of coast from Hordle Cliff to the White House at Milford on Sea.

MHW

Fronting Barton on Sea, a review of high water position from 1870 to 1975 shows a steady recession MHW. On analysis of 1994 aerial photographs, it is clear from Figure 2.1.2 that littoral drift occurs in an easterly direction as MHW accretes on the west facing side of rock groynes along the frontage. No net MHW accretion, however, can be postulated for this stretch.

A change in historical MHW position becomes apparent to the east of Becton Bunny (towards Hordle Cliff) where distinct accretion occurs. This has contributed to cliff stability here between 1907 and 1975. The most noticeable accretion (60m) of MHW occurs between Hordle House and Rook Cliff. Accretion reduces further east turning into a slight erosive trend towards the White House at Milford on Sea. It should be noted that upon analysis of 1995 aerial photography, MHW position has retreated slightly over the past decade. The presence of a nearshore sand bar running parallel to the coast in front of Hordle Cliff is noticeable on recent photographs, however, its magnitude is believed to have been reduced due to winter storms in 1991. The consequence of this is a slight retreat in MHW position since this date.

Figure 2.1.3 shows that the whole shingle ridge of Hurst Spit has moved more than the width of the neck in the past century. The middle part of Hurst Spit has experienced more variable movement (erosion and accretion) between the periods 1870 - 1907 and 1907 - 1975. MHW has changed considerably adjacent to the neck between 1870 and 1994. This has amounted to 115m in places, confirming similar measurements taken by Hooke and Riley (1987) in this area. In contrast to the mobile neck of the feature, the head is much more stable. There has been some erosion on the south east side adjacent to the castle and some slight accretion to the north east of the castle (approximately 60m since 1907) with a lengthening and slight eastwards rotation of the northern tip. Hurst Point itself has receded in parallel with Hurst Beach, resulting in Hurst Castle developing into a "hard point" headland.

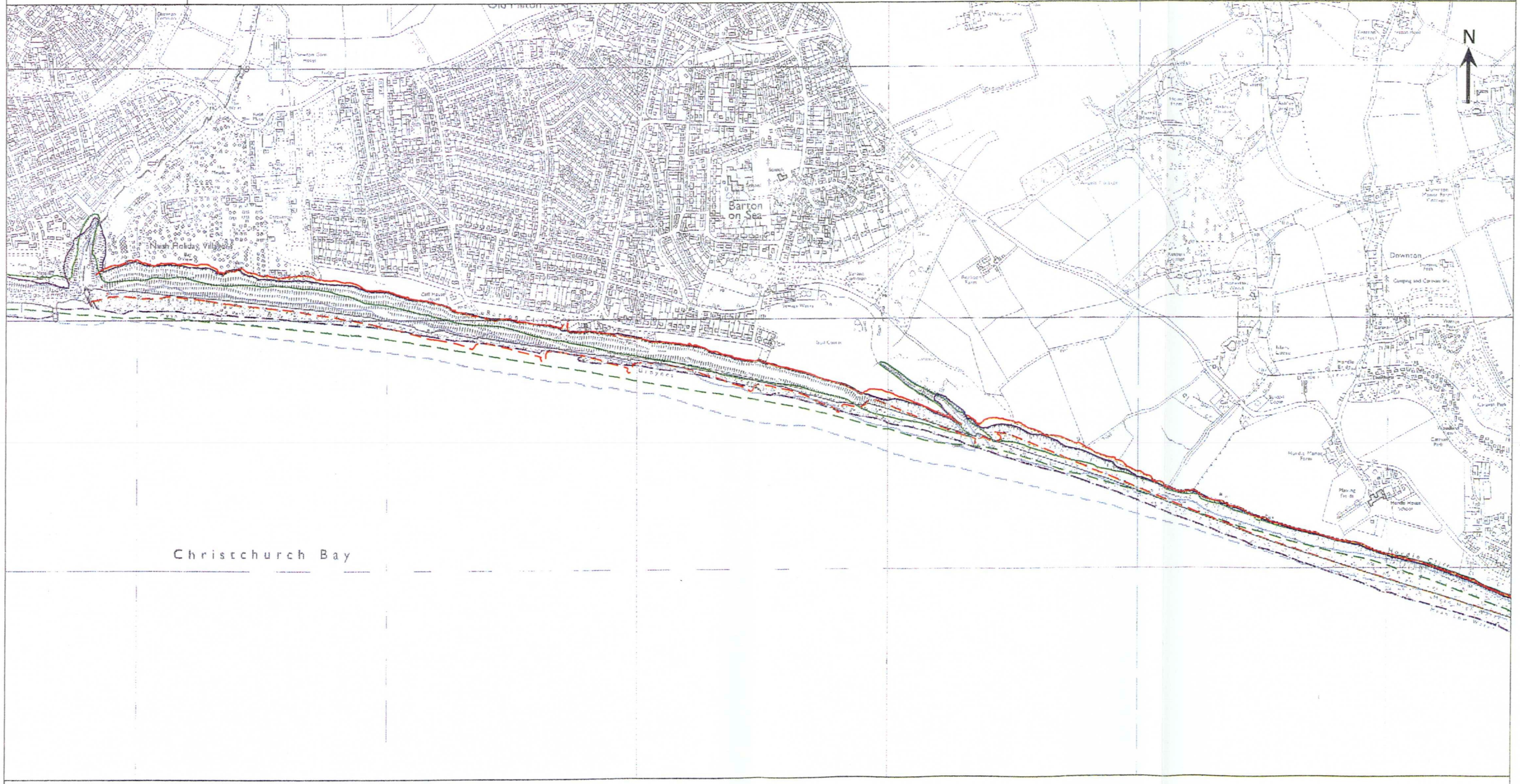
MLW

Figure 2.1.2 shows that in front of Barton Cliffs, extending east towards Hordle Cliffs, a steady MLW mark erosion trend is apparent between 1870 and the present day. Measurements of such movement conform with those presented by Hooke and Riley (1987). They suggest that an average erosion of 1m/yr is common along this frontage. MLW accretion is apparent in front of Hordle Cliffs

Western Solent and Southampton Water Coastal Group

SHORELINE MANAGEMENT PLAN
SUBCELLS 5f (part), 5c & 5b (part)
WESTERN SOLENT AND SOUTHAMPTON WATER

HALCROW
1996



COASTAL PROCESSES: Historical Coastline Evolution

1994 or 1991 Coastline*	1975 Coastline*	1907 Coastline*	1870 Coastline*
1994 MLW	1975 MLW	1907 MLW	1870 MLW
1994 or 1991 Marsh Edge			

* Note : Where no distinguishable coastline feature is present MHW has been used

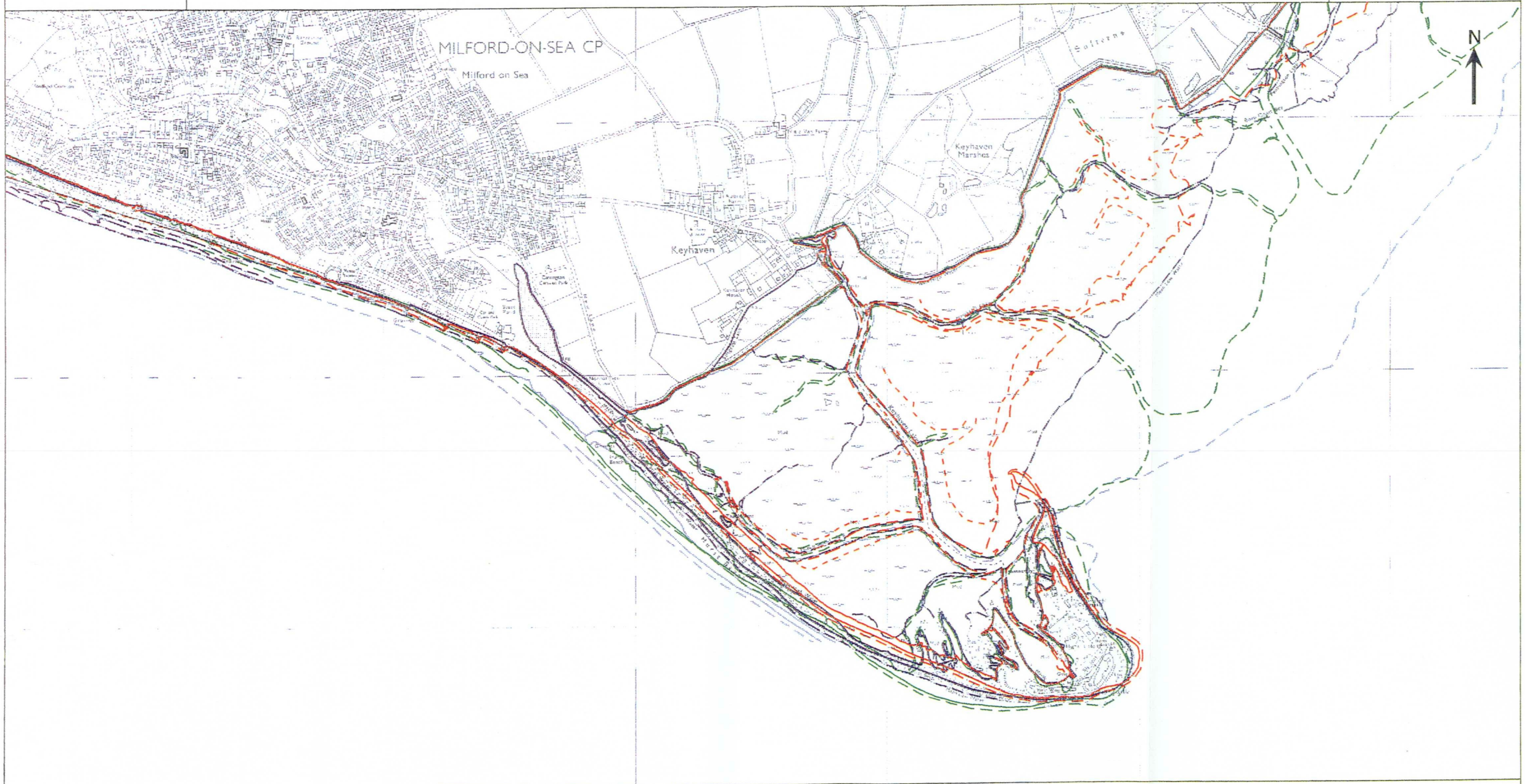
0 200 400 600 800 1000 m

FIG 2.1.2

Western Solent and Southampton Water Coastal Group

SHORELINE MANAGEMENT PLAN
SUBCELLS 5f (part), 5c & 5b (part)
WESTERN SOLENT AND SOUTHAMPTON WATER

HALCROW
1996



COASTAL PROCESSES: Historical Coastline Evolution

* Note : Where no distinguishable coastline feature is present MHW has been used

- 1994 or 1991 Coastline*
- 1994 MLW
- 1994 or 1991 Marsh Edge
- 1975 Coastline*
- 1975 MLW
- 1907 Coastline*
- 1907 MLW
- 1870 Coastline*
- 1870 MLW

0 200 400 600 800 1000 m

FIG 2.1.3

between 1907 and 1975. Figure 2.1.3 shows the position of MLW in 1975 which formed an elongate sand spit protecting the frontage of Milford on Sea. This has subsequently been removed during storms and a net erosive trend is experienced at present in front of both Hordle Cliffs and Milford on Sea, amounting to 2.5m/yr since 1975. Further east, the erosion of MLW mark along Hurst Beach as a whole (between 1870 to 1994) amounts to 200m in places.

2.2 Area 5F-2 Christchurch Harbour (CHB)

2.2.1 Review of Existing Information

Information on the historic development of Christchurch Harbour was derived primarily from the paper by Robinson (1955), which discusses the historical evolution of the Harbour entrance and the importance that Hengistbury Head plays in its setting. Further information was obtained from the Draft CIRIA (1998) report on Sea Bed Sediments along the SCOPAC frontage.

General Overview

Geomorphological History and Natural Evolution

The tidal basin of Christchurch Harbour covers an area of 1.9 square km at Mean High Water, with a tidal prism of 1.43 x $10^6 m^3$ under spring tidal conditions (Tosswell, 1978). Within the Harbour the water depths are shallow, with extensive inter-tidal flats and salt marshes.

The entrance to Christchurch Harbour is almost an exact replica on a smaller scale of that at Poole Harbour. The former deep embayment, in this case the drowned lower courses of the combined Avon and Stour rivers, has been almost completely enclosed by two spits.

The development of Mudeford Sandbank and Mudeford Quay is described in Section 2.1.1.

Anthropogenic Intervention

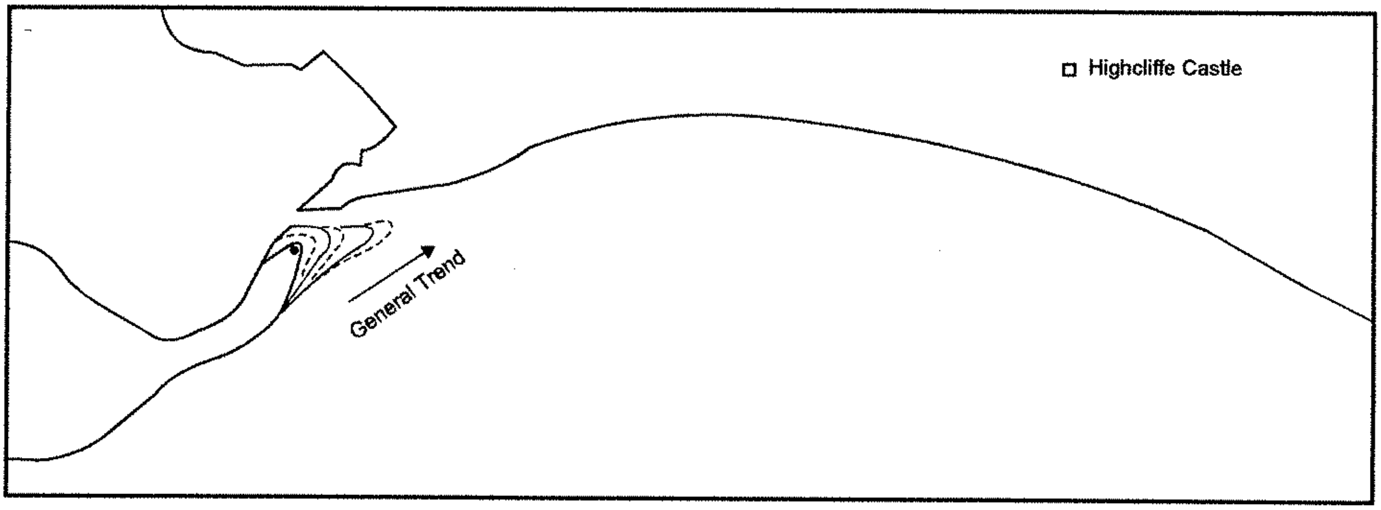
Much of the natural setting around Mudeford Quay was altered with the construction of a promenade adjacent to the old quay of Haven House. This building, which was probably built about 1700, stands on a spread of shingle near the distal end of the spit overlooking the Harbour entrance. Like the Sandbanks Peninsula near Poole, Mudeford Quay has a narrow neck less than 100 feet across.

Since the 1940s, the Spit has maintained a fairly constant form, particularly since the introduction of groynes north of Clarendon Rocks in the mid 1980s, Figure 2.2.1 shows the shape of the Spit between 1973 and 1987.

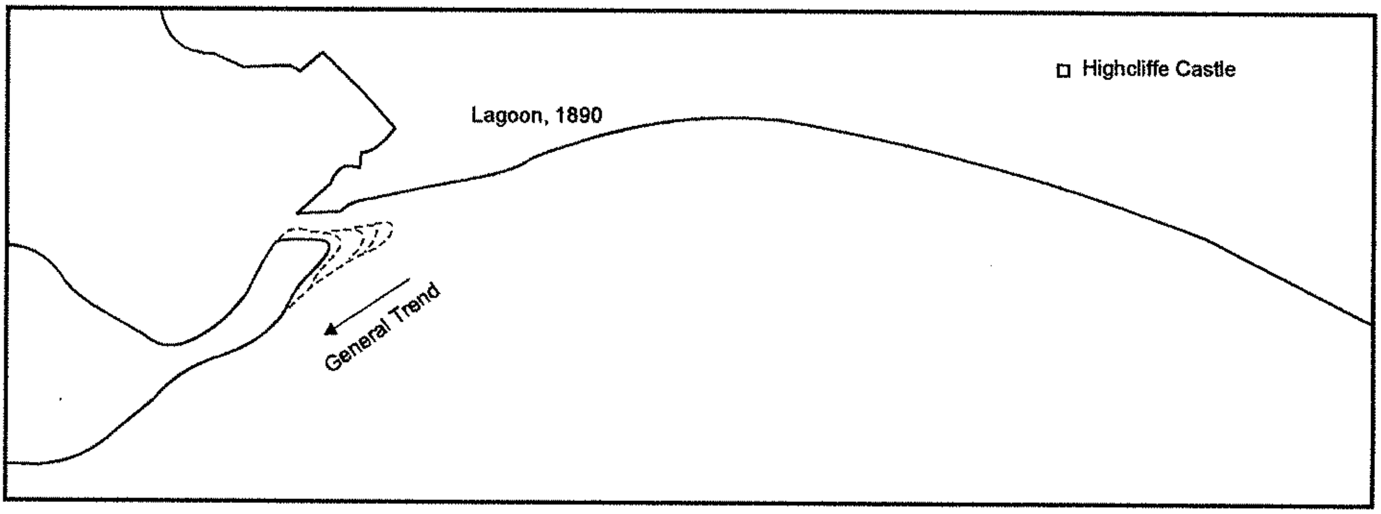
Throughout this period, which has seen so many changes and fluctuations in the southern spit, Mudeford Quay has remained relatively stable. On many occasions, including January 1950, the sea threatened to break across the narrow neck east of Haven House and so establish another entrance to the Harbour. In an attempt to counteract this, a wide promenade was built between the quay and the sea-wall in front of Sandhills as part of a more extensive scheme of coastal protection at Mudeford (details are provided in the Coastal Defences Section on Volume 3).

The northern side of the Harbour, from Mudeford Quay to Fishermans Bank, has a man made edge whilst Stanpit Marsh has low bunds in places with gaps and saltmarsh. The silted up former quarry access point known as Holloways Dock lies in the lee of Mudeford Sandbank.

Figure 2.2.1



SLOW GROWTH AFTER START OF COAST PROTECTION WORKS, 1944 -1973



EROSION OF SANDBANK, 1973 - 1987

GRAPHICS/W/WBMTH05/MP/7.8.98

(from Christchurch Borough Council)

2.3 Area 5F-3 Hengistbury Head Long Groyne to Sandbanks Ferry Slipway (PBY)

2.3.1 Review of Existing Information

General Overview

Key document sources for this Process Unit include the Portsmouth Polytechnic 'Coastal Sediment Transport Study – Volume 4' (1991); 'Harbour entrances of Poole, Christchurch and Pagham' prepared by Robinson (1955); the University of Glasgow Coastal Research Group's 'Estuaries Management Plan, Coastal Processes and Conservation, Poole Harbour' (1993) and the Draft CIRIA (1998) report to identify the major changes on the coast within this Process Unit.

Between Hengistbury Head and Poole Head, the landward margin of Poole Bay is predominantly an eroding cliffed coast, 20-35m in height, that is frequently interrupted by a series of chines to the west and a much lower cliffed segment between Solent Road and Double Dykes to the east. Between Poole Head and South Haven Point the coast is composed of low lying recent sandy accumulations.

Lacey (1985) estimated that 115,000m^3yr^{-1} of material had been eroded from the cliffs of Poole Bay during the early part of the last century and that on average, 18% of the eroded material was fine grade material and thus was "winnowed" away in suspension. As a comparison, Gao and Collins (1994) estimated that the volume of sediment eroded from the cliffs, before coastal defence construction, was 136,000m^3yr^{-1} of which 46% is likely to be stored on the beach.

Harlow and Cooper (1996) considered that beach profiles measured within this Process Unit were not sufficiently accurate to estimate littoral drift volumes. However, Gao and Collins (1994), on the basis of changes in total sediment volumes between A21 and A27 (see Figure 2.3.1), estimated that this coastal section loses sedimentary material at a rate of 100,000m^3yr^{-1}. This volume is similar to that calculated to represent sediment volume retained on the beaches from coastal erosion before the interference of Man. Of key importance to note is that sediment losses are now greater than the present rate of sediment supply (now that engineering structures are in place).

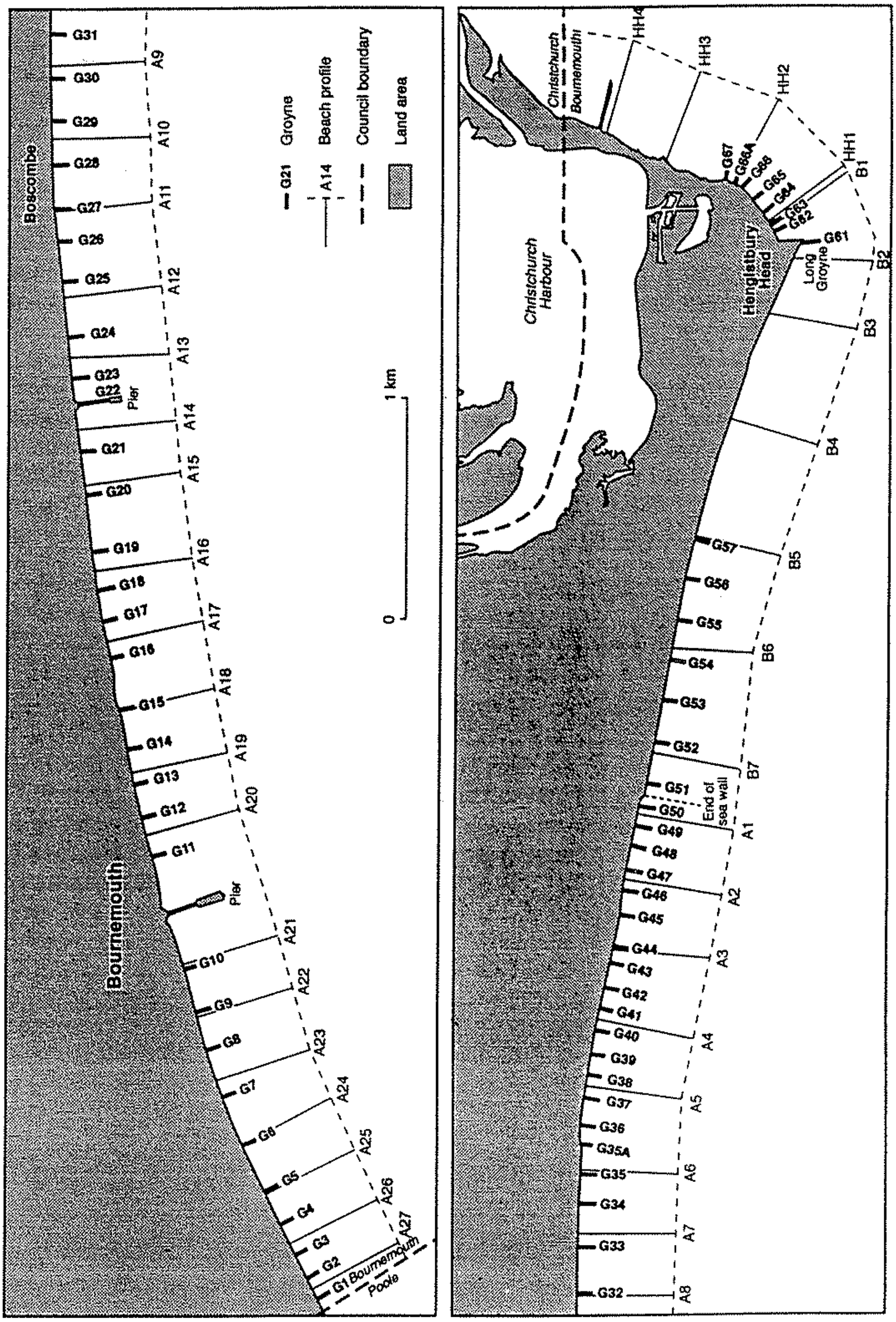
Poole Harbour Tidal Inlet

Geomorphological History and Natural Evolution

The Poole Harbour tidal inlet is located at the western part of Poole Bay. The main coastal components are the South Haven Peninsula south of the inlet, the tidal mouth of Poole Harbour, east Hook Sands and the Sandbanks spit to the north of the harbour mouth. Understanding how the tidal inlet has evolved requires an assessment of historic information, using Admiralty bathymetric data sets collected during various surveys over the past 205 years. This methodology is presented in detail within Section 2.8.

Several stages of evolution have been identified (Figure 2.3.2). In 1785, the South Haven Peninsula was much smaller than at present, consisting of a single ridge of sand dunes. This ridge was flanked along its seaward side by a relatively wide (300-400m) foreshore. Small, elongated nearshore sand bars lay parallel to the shoreline; the most northward of these was attached to the foreshore itself. The Sandbanks spit at this time displayed similar characteristics to today, containing a

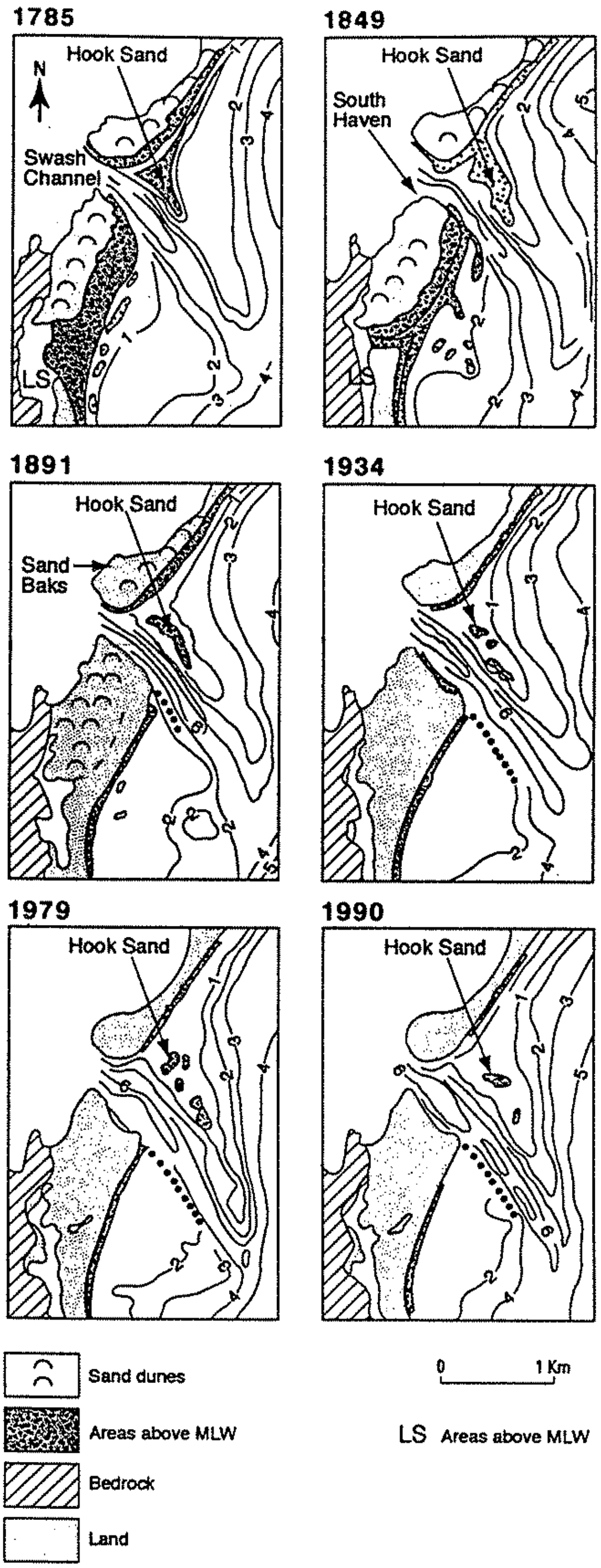
Figure 2.3.1



POOLE BAY

From Harlow and Cooper 1995

Figure 2.3.2



EVOLUTION OF THE COASTAL GEOMORPHOLOGY AND BATHYMETRY OF THE POOLE HARBOUR TIDAL INLET DURING THE PAST 205 YEARS
(from Velegrakis, 1994)

similar sand dune field. The Spit was flanked along its seaward side by a wide (200m) foreshore that was separated from the planar surfaces of Hook Sand by a narrow, shallow marginal channel.

By 1849, several changes had already taken place. Over the South Haven Peninsula, a sand ridge had formed on the foreshore, probably due to the consolidation of the nearshore sandbars observed some 64 years previously. A sand dune field had developed on the landwards side of the ridge. Two bars which were attached obliquely to the beach developed, whilst the offshore part of Studland Bay deepened considerably. The Sandbanks foreshore had decreased in width and the narrow marginal channel, which separated it from the Hook Sand planar surfaces, had silted up on its eastern side. The morphology of the Hook Sand shoal had also changed. The main planar surface of the shoal had increased in size, whilst the orientation of its crest-line and the asymmetry of its profile appeared (for the first time) to change along its length.

From the data of 1891, further morphological changes can be identified. The foreshore sand ridge had been incorporated into the South Haven Peninsula, with a relatively wide beach (c 100m) forming its seaward side. The oblique sandbars, noted 42 years earlier, had also amalgamated with the beach. The position of the sand bar at the seaward end of Swash Channel had changed, having moved towards the Milkmaid Bank.

Anthropogenic Intervention

The first important human interference to the system took place when construction of a 350m training bank along the western side of Swash Channel took place in at the end of the century, whilst a seawall had been built at the narrow neck of the Sandbanks spit, close to its junction with the cliffs. In addition, groynes were constructed here in 1896 from timber and stone (Borough of Poole – pers com).

By 1943, additional human intervention occurred. Timber and stone groynes were constructed along the Sandbanks spit and to the east, whilst the training wall along the western flank of the Swash Channel had been extended considerably (1500m). Therefore, the most important morphological changes that had taken place since 1891 were:

- the segmentation and further decrease in size of the main planar surface of Hook Sand
- the change in its crest-line orientation (now the same along its full length) and
- the incorporation of the sand bar at the seaward end of Swash Channel into the Milkmaid Bank.

In 1979, the morphology of the area had developed further. The water depth to the east of the Hook Sand had increased, indicating quite severe erosion. The orientation of the shoal's crest differed, once again, along its length. The foreshore of the South Haven Peninsula had decreased in width, and in Studland Bay (Process Unit 5F-5) the 2m bathymetric contour had moved onshore, indicating a steepening of the foreshore.

The average depth of the Swash Channel had increased. The most recent survey undertaken, in 1990, shows morphological changes continuing. Accretion has taken place along the eastern flank of the Hook Sand, whilst the Swash Channel has deepened considerably, the latter in response to extensive navigational dredging in recent years.

At the Sandbanks spit, extensive residential development has taken place, which resulted in total destruction of the sand dune fields. Beach protection works have also taken place, consisting of the construction of a reflective sea wall at its narrow neck (1890) and stone / timber groynes along the rest of the beach. In the area of the Swash Channel, the most important human impacts are considered to be the construction of the Training Bank (1876-1929) and the recent capital dredging of the channel involving the removal of 25,000m^3 (Appleton, pers com) (to increase water depth). The evolution of the Poole Harbour tidal inlet can therefore, be distinguished as being natural only until 1876 and since then, it has been modified by human activity.

In summary, the Poole Harbour tidal inlet system is a "two fixed-spits" tidal inlet system (Zenkovich, 1967) and its development over the past 200 years demonstrates that it is a dynamic morpho-dynamic feature. During the past century, however, human interference has influenced its natural evolution. The morphology of the area has also shown considerable change over the past 200 years. The most important of these is the development of the South Haven Peninsula. Intensive human interference during the past century has had an important impact, mainly in stabilising the Swash Channel and limiting the development of the South Haven spit.

North Haven Peninsula (Sandbanks)

Geomorphological History and Natural Evolution

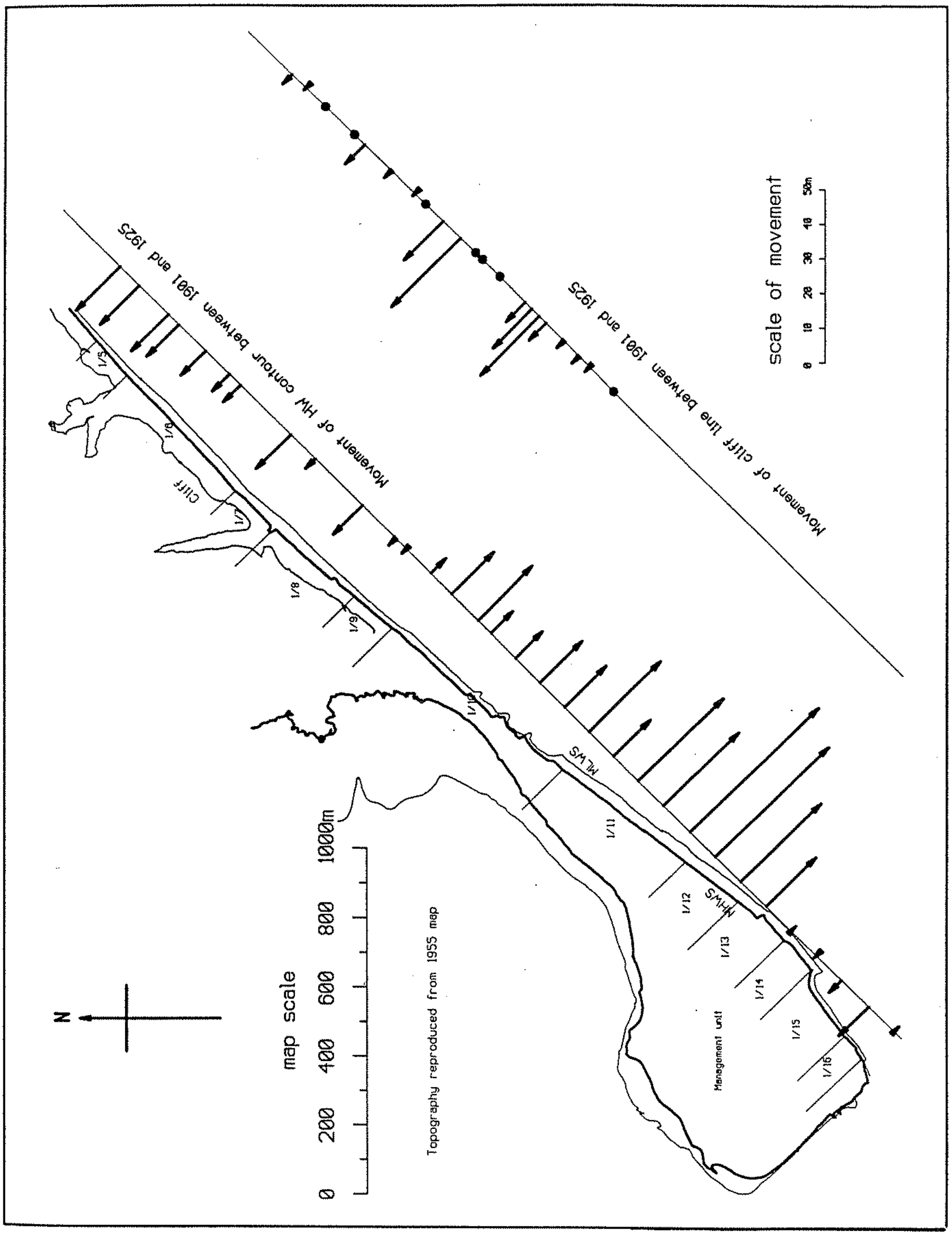
The different prevailing and anthropogenic conditions to which the two peninsulas on either side of Poole Harbour's entrance have been subjected to during the past two centuries, has meant that they are very dissimilar at the present time. Whilst the shoreline along the South Haven Peninsula has gradually extended seaward, the Sandbanks Peninsula has retreated.

The North Haven (Sandbanks) Peninsula has been subject to erosion since its form was first accurately delineated in 1785. The recession here is intimately connected with coast erosion in Poole Bay as a whole. Before anthropogenic intervention along the coast (ie: before the promenade was constructed at Bournemouth and Poole), the cliffs were being eroded through sub-aerial erosion as well as direct wave attack. Throughout this retreat, the smooth shoreline curve of the bay has remained, being unbroken by the change from cliffs to sand-dunes at Sandbanks.

Anthropogenic Intervention

A break-through across the narrow neck of the Sandbanks peninsula has always been a distinct possibility and in an effort to counteract this threat, a sea wall was built along its seaward face in 1890. The wall was quickly undermined and the beach in front of it lowered throughout, thus increasing the danger of a breach at its most vulnerable point.

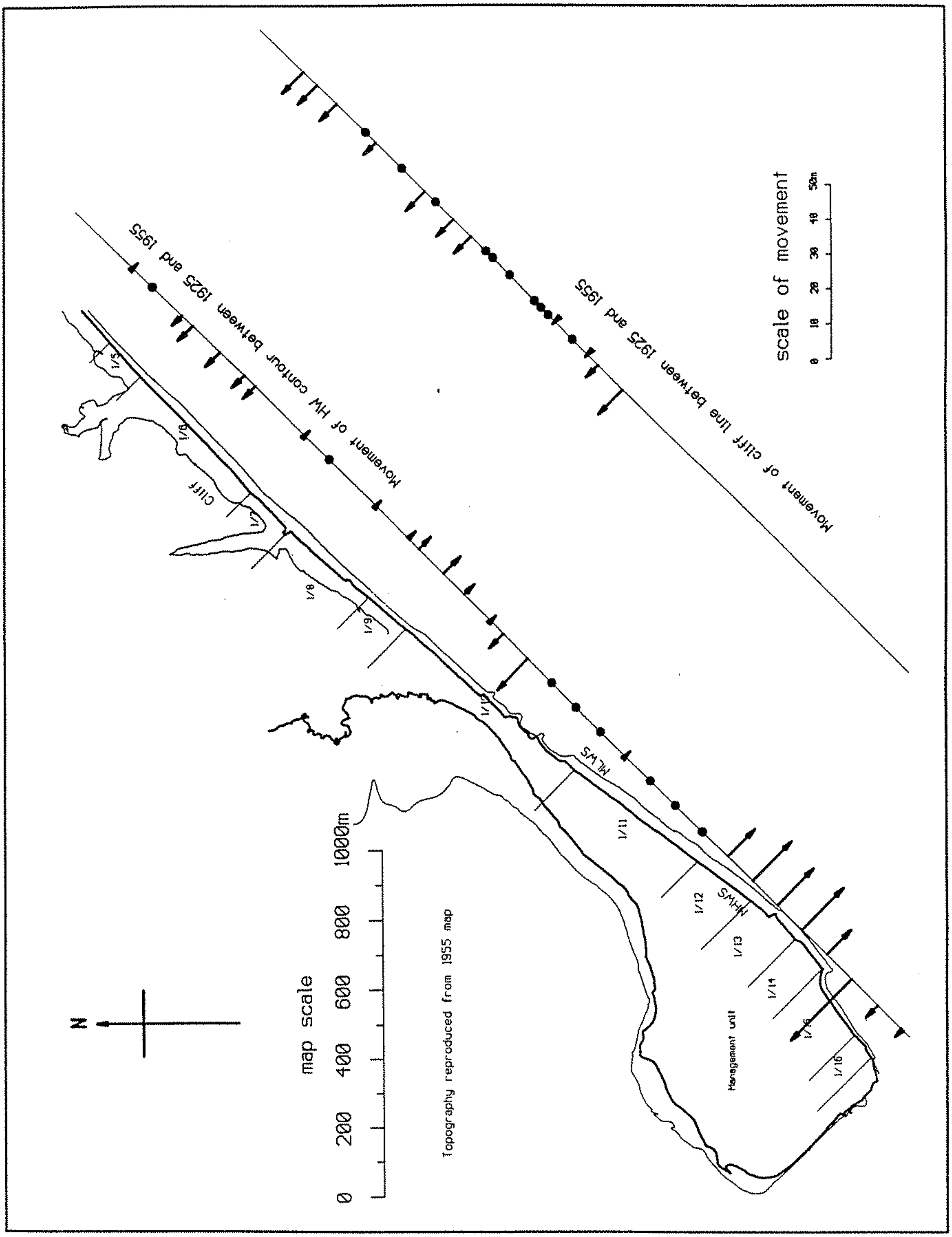
Between 1894 and 1898, the Harbour Authority constructed 14 groynes along the seaward frontage of Sandbanks. Within a few years these structures had the desired effect in accumulating a wide beach and between 1903 and 1904, the low water line moved some 100ft offshore. It was noted that each groyne accumulated a greater deposit of sand on the side nearest to the entrance of Poole Harbour.



MOVEMENT OF HIGH WATER MARK AND CLIFF TOP BETWEEN 1901 AND 1925

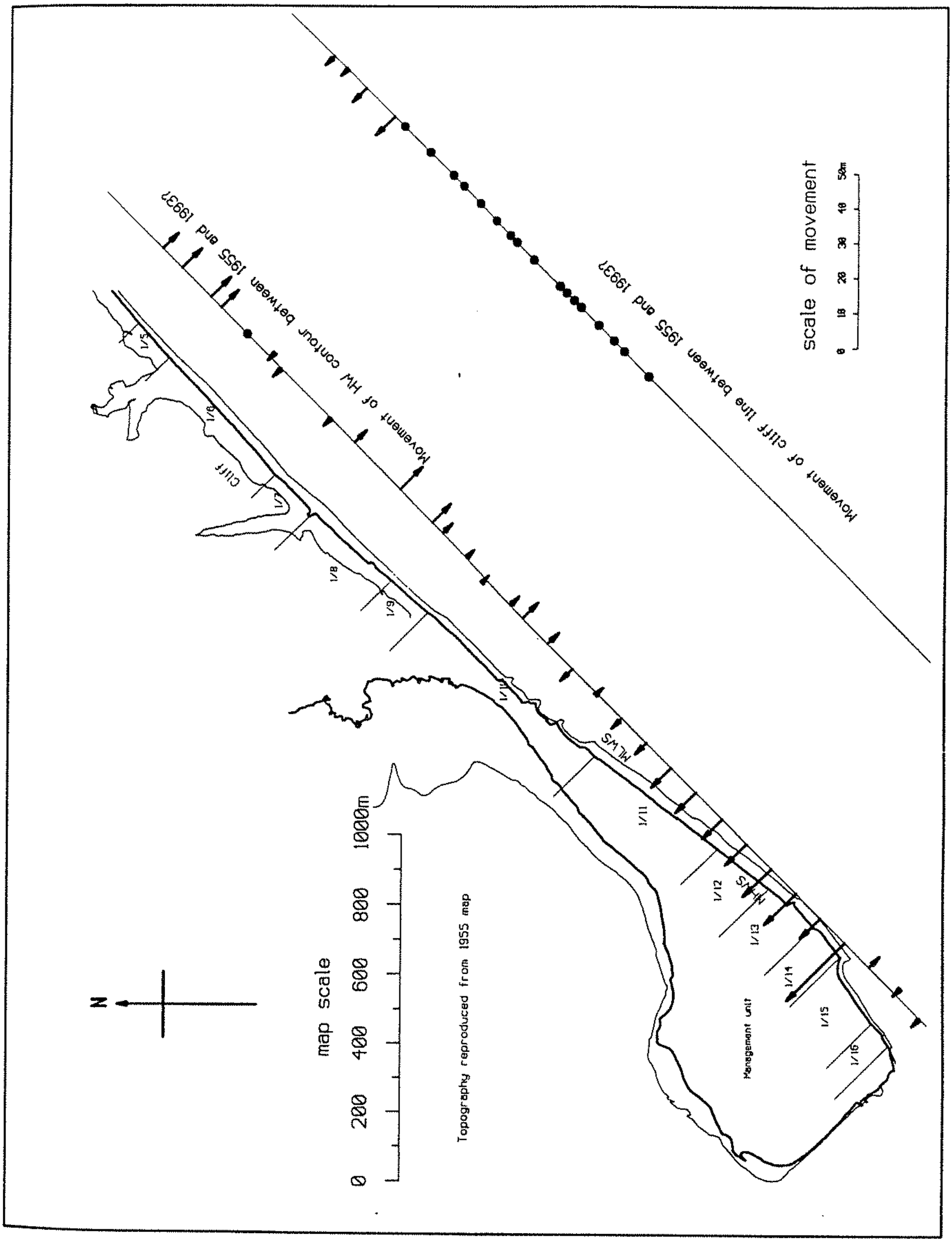
From H R Wallingford Report Ex 2881 (1995)

Figure 2.3.4



MOVEMENT OF HIGH WATER MARK AND CLIFF TOP BETWEEN 1925 AND 1955

From H R Wallingford Report Ex 2881 (1995)



MOVEMENT OF HIGH WATER MARK AND CLIFF TOP BETWEEN 1955 AND 1993

From H R Wallingford Report Ex 2881 (1995)

Accretion continued at the western end of Sandbanks from 1925 to 1952, during this period the eastern end was stable. Figures 2.3.3 to 2.3.5 outline the movement of MHW and clifftop between 1901 and 1993.

From 1955, the properties were not perceived to be under threat from erosion due to the width of the beach and thus the groynes fell into disrepair. Concern for public safety prompted the removal of the majority of the groynes, except three groynes at the western end of the site (at Midway Path) and two remaining ones in the centre of Sandbanks. In 1990, these three groynes were considered to be both redundant and a danger to public safety and were removed in late 1991 and early 1992. Almost immediately, the beach showed considerable sand loss as a result of a series of south-easterly storms. It is now recognised that structures in this frontage prevent onshore movement of the East Looe Channel. As a secondary function, they allow foreshore buildup. Emergency works were undertaken consisting of one rock groyne, seawall rock armour toe protection and a limited amount of beach replenishment was deposited at the end of Sandbanks. Despite these works, beach levels continued to fall to such an extent that in 1994, the sheet pile seawall, installed in 1990, was considered to be in danger of collapse. Beach erosion that occurred between 1955 and 1994 accelerated after the removal of the groynes in 1991 and the rate of erosion being experienced increased up to 10m/yr. The foundations of the 1890 groynes were exposed and sand dunes were lost in December 1994.

During February 1994 further emergency works were undertaken. The seawall rock armour toe protection was reinforced and extended to the east and an additional leg was installed at the head of the existing rock groyne. The toe protection works were extended to the east in early 1995. At this time, four rock armour groynes were constructed and the existing rock groyne was extended. These groynes appeared to have stabilised most of the southern end of the Sandbank, except for some minor problems in holding the beach near the Haven Hotel at the southern tip of Sandbanks.

The northern half of Sandbanks now has an ongoing erosion problem. The Borough of Poole are now investigating means of securing this frontage.

Poole Head to Solent Road

Geomorphological History and Natural Evolution

Over recent geological time, the coast between Poole Head and Hengistbury has been subject to continuous erosion throughout the Flandrian period resulting in development of steep cliffs 20m-35m in height and considerable supply of sand and gravel to the beach. This situation was altered in the 1890s by the construction of coast protection structures west of Canford Cliffs Chine.

Anthropogenic Intervention

After the 1890's, further schemes involving protection by seawalls and groynes followed in 1907-11 (Poole-Bournemouth-Boscombe), 1927-35 (Boscombe-Southbourne) and 1955-75 (Southbourne). By 1975, virtually the whole frontage from Poole Head to Solent Road was protected (Lacey 1985, Lelliott, 1989). These measures involved provision of groynes, seawalls and grading/cliff stabilisation, thus supply of sediments to the beach was progressively reduced as protection spread eastward along the frontage. Map comparisons over the period 1867-1933 indicated cliff retreat at 0.15-0.40mpa between Poole Head and Bournemouth Pier and 0.20-0.50mpa between Bournemouth and Southbourne (Lacey 1985).

Historically, protection measures along this frontage have had limited success in retaining beach material. The conventional philosophy of 'hard' defences altered following a period of damage in the 1960s (Lelliott, 1989) to establish, in 1974, one of the largest and longest running programmes of beach replenishment in the UK (May, 1990). This programme (specific to the Bournemouth BC frontage only) included three phases of sand replenishment.

A pilot replenishment scheme was carried out in 1970 which involved placing 84,500m^3 of dredged sand at MLW along a 1.8km frontage (Lelliott, 1989). The experience gained from this pilot scheme gave the Local Authority the confidence to undertake a full-scale scheme in 1974-1975. This involved pumping directly onto the beaches over a 8.5km frontage, some 654,000m^3 of marine dredged sand which was specified to replicate the indigenous material. Due to the two stage placement operation adopted, a further 749,300m^3 of dredged sand was left in artificially created nearshore dumpsite pits, ultimately a large proportion of this material moved onshore to further nourish the beaches (Hodder, 1993).

Critically low beaches recurred in 1987, with MHW migrating landward. A third sand replenishment scheme was undertaken in three phases from 1989 to 1990 involving the deposition of 998,730m^3 of dredged fill directly onto the beach. The material was pumped onshore above MHW and subsequently left to form a stable profile. The coincidental dredging of the Poole Harbour entrance at the same time substantially reduced the costs.

Solent Road to Hengistbury Head

Geomorphological History and Natural Evolution

At Hengistbury Head, a section of coast extending for some 2.5km west of the headland occurs which is unprotected by sea walls, though groynes restrict longshore drift rates. Hengistbury Head, which plays such an important part in the setting of the harbour, effectively divides Christchurch and Poole Bays, each with their distinct smooth shoreline curve when seen in plan. Until the building of the concrete bastion (Long Groyne, 1938) at its foot, the headland was being worn back at an alarming rate. Its entire removal would lead to a single unbroken shoreline curve running from Poole Harbour entrance in the west to Hurst Castle spit in the east, Christchurch Harbour disappearing in the process of shoreline adjustment.

Recession of the cliffs between Solent Road and Hengistbury Head has been studied using a variety of sources and timescales including OS maps (1840-60) and Bournemouth Borough Council Surveys (1923-1986). These surveys revealed cliff-top erosion at the following rates for the period 1840-1896: 1mpa at Solent Road; 1.5mpa at Double Dykes and 3.5mpa at Hengistbury Head (Hydraulics Research 1986).

Anthropogenic Intervention

Several episodes of beach volume change have been identified (BBC, 1998) where the rate of erosion (or accretion) is constant. Table 2.3.1 below shows the topographic beach volumes and change in volumes which have been calculated using beach profiles surveyed from the seawall to 100m offshore. (NB: BIS represent Beach Improvement Scheme).

TABLE 2.3.1: Topographic Beach Volumes

Date	Episodes	Initial Volume (m3)	Rate of Change (m3/yr)
1974 - 1975	BIS2	1,048,231	+570,000
1975 - 1977	Early decay after BIS2	1,835,104	-174,000
1977 - 1987	Later decay after BIS2	1,594,650	-25,500
1987 - 1990	BIS3	1,342,244	+205,000
1990 - 1998	Decay after BIS3	1,970,000	-44,000

Taking account of the effects of sea level rise it has been predicted that BIS4 will be required in 2003 in order to maintain the volume of material on the beach above the critical level (1,350,000m3) at, and below which, unacceptable damage to the seawall will begin to occur.

The permeable groynes resulted in a reasonable measure of control in the rate of cliff line attrition in their immediate vicinity. However, east of the groynes, the cliffs continued to erode rapidly threatening to breach the cliff line east of Double Dykes. This would have created a flood channel into the southern side of Christchurch Harbour and would have separated Hengistbury Head from the mainland.

In 1986, two conventional timber groynes were constructed to the east of the existing groyne field and emergency gabions and mattress protection to the cliffs were installed on either side of Double Dykes together with two rock armour groynes. Also in 1986, three rock groynes were constructed at Double Dykes which extended the groyne field eastwards and the northern end of the flood channel, to the south side of Christchurch Harbour, was protected with gabions.

It is uncertain whether these coast protection works undertaken at Solent Beach have influenced the present day rate of erosion, in particular at Double Dykes. Research by Bray (1993) suggests that the current rate of erosion is of the order of 0.2-1.0mpa (similar erosion rates to those determined by HR Wallingford prior to construction of defence at Solent Beach). Hewitt estimated an average and maximum cliff recession rate (between 1987 and 1994) using aerial photography of 0.8m/yr and 1.3m/yr respectively.

The beneficial effects of the Long Groyne do not extend as far west as Double Dykes or Solent Beach and these areas have suffered continuing rapid erosion at up to 1mpa over the period 1933-67 (Lacey 1985) and 0.4-1.1mpa over the period 1976-1986 (Hydraulics Research 1986). This situation may be related to sediment starvation resulting from progressive eastward construction of groynes and seawalls from Canford Cliffs (1890s) to Southbourne (1975). These measures both prevent sediment input from cliff erosion and intercept eastward drift of sediment which could replenish these banks. Calculated figures show that erosion has reduced to 0.5mpa at Solent Beach in the vicinity of permeable groynes installed in 1976-77 (Hydraulics Research 1986). A cliff foot survey indicated rapid erosion of 0.9mpa over the period 1974-82 at Solent Beach/Double Dykes.

Hengistbury Head

Geomorphological History and Natural Evolution

Hengistbury Head is composed of an elongated (up to 36m OD) outlier of predominantly sandy lower Tertiary (Barton Group) materials. It forms a prominent headland of steep eroding cliffs and affords valuable protection to Christchurch Harbour and its residential margins.

Anthropogenic Intervention

Hengistbury Head has a long history of coastal erosion (Turner, 1996), and at the turn of the last century was retreating at about a metre/year. The Long Groyne was built in 1938 to encourage accumulation of sediment in front of the cliffs forming the eastern end of the headland, but this resulted in starving the beaches to the north and an increase in the rate of slippage of the adjacent cliffs. Erosion continues today but the SSSI status of the site, (partly for geological and partly for biological conservation reasons), and the conflicting requirement to restrict erosion to preserve a cliff top prehistoric site, have presented the local authority with a management dilemma.

A major contributory factor to rapid erosion at Hengistbury Head was the foreshore and nearshore mining of ironstone boulders over the period 1848-1870 (Tyhurst, 1985a, Hydraulics Research 1986). This involved both direct removal of cliff toe protection and also facilitated littoral drift that caused beach depletion. Thereafter, erosion declined at Hengistbury due to cessation of ironstone mining, construction of the Long Groyne in 1938 and deployment of World War II anti-invasion works.

2.3.2 Analysis of Historic Data

Cliffs

A number of different analyses of cliff recession rates have been carried out and are detailed in the previous section. It is not considered that a repeat of this exercise would provide any additional information.

MHW and MLW

The Mean High Water Springs (MHWS) and Mean Low Water Springs (MLWS) lines have been surveyed along this frontage at different intervals by the Ordnance Survey. In addition, Bournemouth Borough Council (BBC) have conducted bi-annual surveys along the frontage since 1974. BBC's beach profile data provides the most detailed source of information and has been analysed to provide the historic recession rates of Mean High Water (MHW) and Mean Low Water (MLW). The spring and autumn beach profiles were compared separately in order to remove the effects of seasonal variation from the long term trends.

For the purposes of beach monitoring, BBC have divided their frontage into five sections;

- West Cliff to Bournemouth West,
- Bournemouth Pier to Boscombe Pier,
- Boscombe (Boscombe Pier to Fisherman's Steps),
- Southbourne (Fisherman's Steps to the end of the seawall) and

- Solent Beach (from the end of the seawall to Hengistbury Head).

The data was analysed along these sectors and the trends for the following periods have been established.

1974 to 1987

MHW

The average long term trend in the plan position of MHW between 1974 and 1987 was –1.36m/yr (recession) in autumn and –0.02m/yr in spring. However in a given year, the position of the MHW line could fluctuate by +10m and –15m on average (accretion and recession respectively) in both autumn and spring. It was noticeable that the beaches in the centre of the bay, around Boscombe, appeared to fluctuate more than the overall average, +30m and –30m, in both autumn and spring.

MLW

The average long term trend in the position of MLW was -1.26m/yr in autumn and 0.62m/yr in spring. However, in a given year, the position of the MLW line could fluctuate on average by +/-20m in autumn and +25m and –15m in spring. In this case there does not seem to be any obvious increase in beach volatility in the centre of the bay.

1988 to 1990

MHW

As anticipated, the beach accreted during this period with an average long term trend of +2.74m/yr in autumn and +7.1m/yr in spring. The beaches fluctuated around these trends by an average of +15m and –10m in autumn and +20m and 0m in spring, with no obvious increase in beach volatility towards the centre of the bay.

MLW

The beach along this frontage accreted with an average long term trend of +3.84m/yr in autumn and +0.88m/yr in spring. The beaches fluctuated around these trends by an average of +/-22m in autumn and +/-15m in spring. During spring the MLW line appeared to fluctuate by around +/-40 to 60m along Boscombe and Southbourne during this period.

1991 to 1997

MHW

The MHW line receded with an average long term trend of –0.3m/yr in autumn and –1.2m/yr in spring. However in a given year its position could fluctuate by +/-10m on average, with no apparent increase in beach movement towards the centre of the bay.

MLW

The average long term trend in the plan position of MLW was +0.2m/yr in autumn and +0.5m/yr in spring. The position of MLW could fluctuate in a given year, by an average +/-15m about these trends, with no apparent increase in beach movement towards the centre of the bay.

2.4 Area 5F-4 Poole Harbour (PHB)

2.4.1 Review of Existing Information

Amongst the key documents used, information on the historic development of Poole Harbour was derived from Robinson (1955), The University of Glasgow Coastal Research Groups 'Estuaries Management Plan, Coastal Processes and Conservation, Poole Harbour' (1993) and the Draft CIRIA (1998) report.

Geomorphological History and Natural Evolution

Poole Harbour is a microtidal estuary formed by marine transgression over the last 5000-6000 years when a postglacial rise in sea level submerged Poole Basin to form a large shallow harbour. Sediment carried into the Harbour primarily by the rivers Frome, Piddle, Sherford and Corfe is derived from alluvial deposits and from outcrops of Bracklesham Beds. Tidal flushing is poor due to the narrow 350m wide opening to the sea combined with the phenomenon of double high water and due to the fact that Poole Harbour is an almost enclosed body of water, limited exposure to wave action from the English Channel takes place within it.

Approximately 80% of the Harbour is intertidal mud and sandflats. Saltmarshes have developed in the upper reaches of the Harbour where low energy conditions allow the deposition of fine sediment. Keysworth Marsh is an example that represents the largest continuous marsh in the Harbour, covering an area of 45 ha. There are also several sandy and gravel beaches in the Harbour. The Harbour mouth is bound by two spits, Studland to the south which has recently accreted and Sandbanks to the north which is a narrow spit subject to erosion.

Following sea level inundation during the Holocene, much of the estuary basin has experienced extensive sedimentation, combined with invasion of *Spartina*. This rapidly increased the build up of vegetated marshlands early on in the century, though much of the *Spartina* died back in the 1930's (BoP pers com). The original configuration of the Harbour has been substantially modified by erosion and accretion processes and is still being modified by the dynamic natural processes of waves and tides as well as human impacts.

Cliffs of varying vertical relief exist throughout the Harbour, which have mostly formed at the edge of the Bagshot outcrop. These are indicative of relatively high wave energies. Gravel capped Bagshot Beds are exposed as cliffs on parts of the Harbour shore (eg. Ham Common) and the northside of Arne Peninsula between Hydes Quay and Russell Quay. They are currently being eroded at the toe and the cliff top is receding at approximately 0.35m a^{-1} (Table 2.4.1). The cliffed southern coast of Brownsea Island is also eroding at approximately the same rate and in Brands Bay cliffs up to 4m high exist. The cliffs to the south at Shipstal Point are no longer being eroded at the toe due to saltmarsh growth in Middlebere Lake. On the Goathorn Peninsula in the south of the Harbour, there are cliffs up to 10m high. Bray *et al* (1991a) suggest that they are probably not part of the contemporary cliff line as they are now protected by Brownsea, Furzey and Green Islands.

One of the earliest maps covering the area was by Richard Popinjay in 1587 (one year before the Armada). Reference is made to Poole being "2.5 fathoms at the bar". However, the lack of clarity on the map reduces any role it may have in enlightening our knowledge on shoreline evolution in the area.

Anthropogenic Intervention

Land Reclamation

The inter-tidal area of Poole Harbour has been progressively reduced by land claim since 1411 when a sea wall was built around Poole Town. During the 18th and early 19th centuries, many wharves, piers and walls were also built. This practice increased during the late 19th and 20th centuries with the construction of railway causeways across Lythcett Bay (1845-7), Parkstone Bay (1874) and Holes Bay (1893) (May, 1969), Poole Power Station (over 30 acres), Poole Gas Works (over 60 acres) and Turlin Moor where over 25 acres of marsh has been claimed for a housing estate and playing fields (May, 1969). Other land reclamation events have taken place at Whitecliffe, Baiter, the port development and the Wareham River Banks. The combination of natural and human induced Harbour infilling amounts to 20-25% or ca 1000ha of the original surface area (6000BP) of the Harbour as measured at HWST.

There is a marked contrast between the northeast and the southwest shores of Poole Harbour, the former is extensively urbanised, primarily backed by seawalls, and has undergone large scale land claim for a variety of uses including agriculture. In contrast the southern shores are mainly mudflats and saltmarsh with areas of land claimed for agricultural purposes instead of urbanisation.

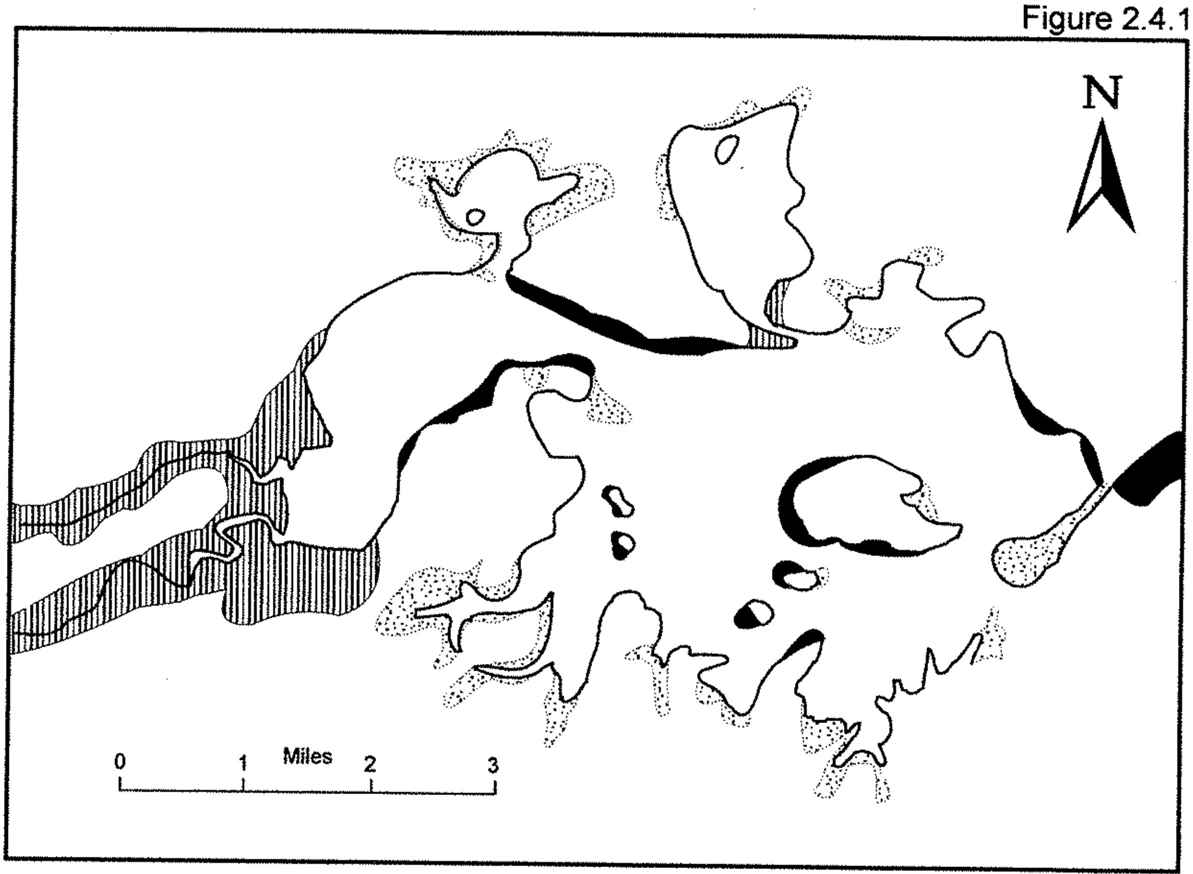
The area of Poole Harbour has been progressively reduced by land claim, primarily of marshland, but also of subtidal areas (May, 1969). The construction of embankments enclosing marshland, is most characteristic of the western shores of the Harbour although the eastern marsh of Brownsea Island was also enclosed in the 1840s. It is of note that most Harbour loss has occurred due to land reclamation adjacent to the Wareham River Banks.

Table 2.4.1 outlines the areal changes to Poole Harbour from 6000 BP to 1998AD, (see Figure 2.4.1).

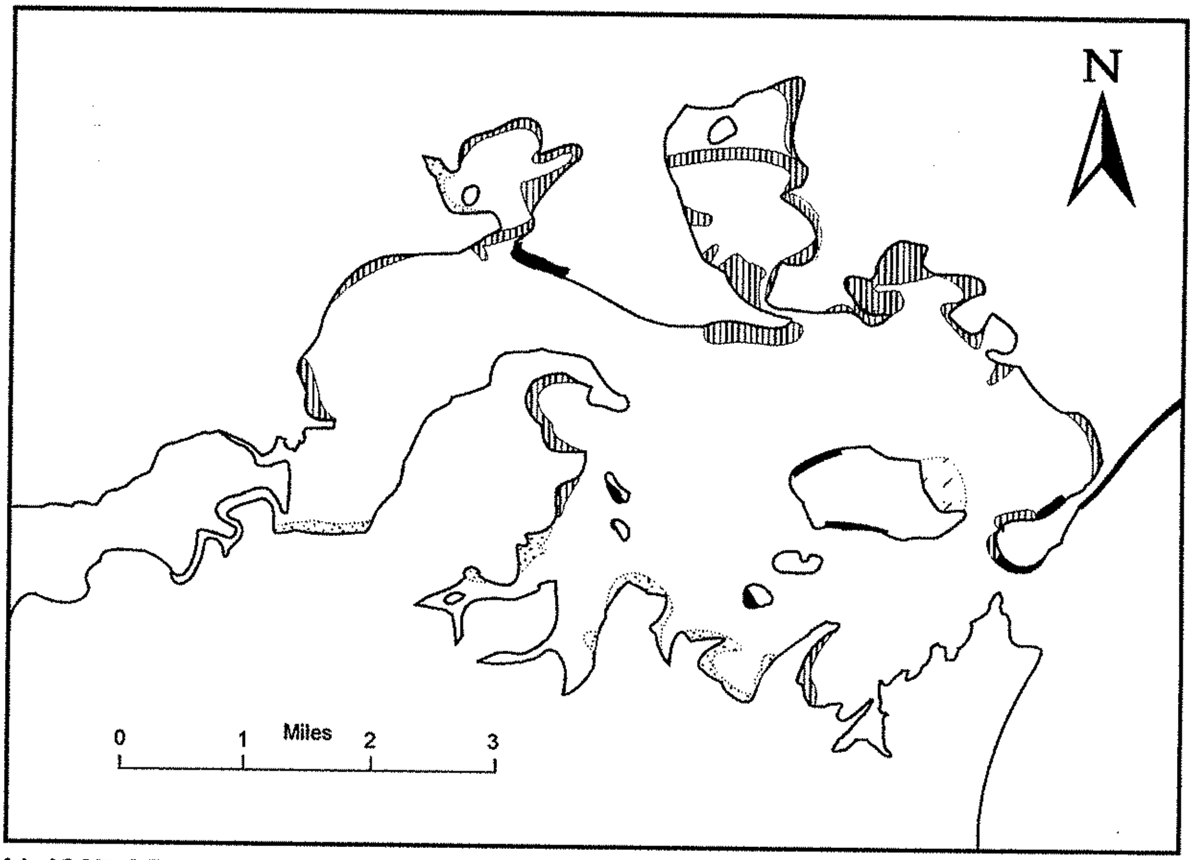
As well as reducing the area of marsh, land claim has both straightened and shortened the shoreline within the Harbour. In the last 200 years, the greatest reductions in the marsh area of the Harbour have been along the shoreline between Parkstone and Lytchett Bay. May (1969) has calculated that since 6000 BP, the area of Poole Harbour decreased at a rate of approximately 0.13 ha a^{-1}. This rate of Harbour infilling by a combination of natural and artificial processes, amounts to 20-25% or approximately 1000 ha of the original surface area of the Harbour as measured at HWST. May (1969) attributes this accelerating loss to:

- the extension of wharves and quays onto the mudflats around Poole Town during the late 18th and 19th centuries;
- Wareham river/agriculture reclamation
- the stabilisation and building up of the mudflats following the invasion of *Spartina townsendii*; (this is now, however, believed to be dying back);
- the land claim of large areas of mudflats for major works such as the former Power station, gas works, Turlin Moors and the piecemeal dumping of rubble and refuse on the marshland to extend waterfront premises.

Figure 2.4.1



a) 6000 BC - 1807 AD



b) 1807 AD - 1998 AD

Erosion

Reclamation

Accretion, under natural influences

Areas reclaimed and subsequently re-inundated

THE DEVELOPMENT OF POOLE HARBOUR
(adapted from May 1969)

GRAPHICS\VV\VVBMTH06WP\10.08.98

TABLE 2.4.1 Area changes in Poole Harbour 6000BP to 1966AD (after May, 1969).

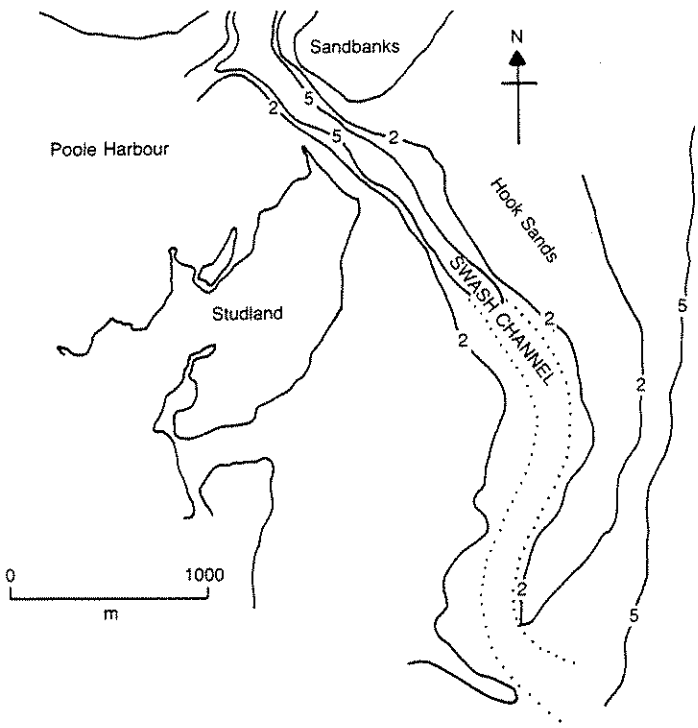
	Area claimed (ha)		
	Human influences	Natural agencies	TOTAL
6000BP to 1807AD			
Wareham & Keysworth	422	24	446
Lytchett Bay		101	101
Southern Shores		207	207
Brownsea & Islands		10	10
Holes Bay		49	49
Poole (Town)	19		19
TOTAL	441	391	832
Cliff Erosion		-28	-28
Net changes	441	363	804
1807 to 1966			
Wareham & Keysworth		30	30
Lytchett Bay	17	18	35
Southern Shores		71	71
Brownsea & Islands	(28)		(28)
Holes Bay	27	12	40
Poole (Town)	41		41
Parkstone & Eastern Shores	7		7
TOTAL	92	127	220
Cliff Erosion		-13	-13
Net Changes	92	115	207

NB: Baiter and Whitecliffe are omitted from the above due to no statistics being available

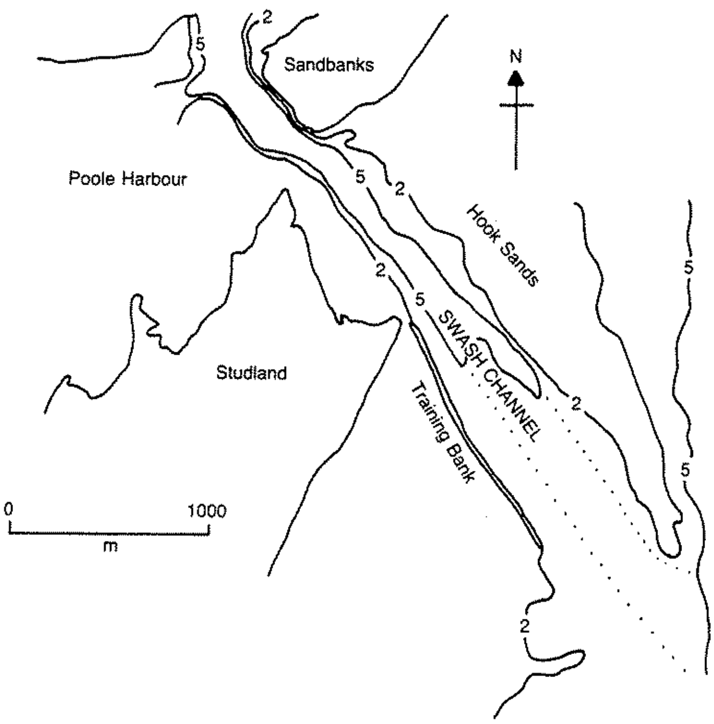
Dredging and Sand Extraction

Under Section 22 of the Poole Harbour Act 1914, Poole Harbour Commissioners (PHC) have the power to dredge for the purpose of maintaining and improving navigation, removing obstructions and cleansing or scouring the Harbour, (see Table 2.4.2). Access to Poole Port by shipping requires regular maintenance of the navigation channels particularly the Main (or 'North') and Middle (or 'Middle Ship') Channels. This is an important issue and one that needs to be stressed in the SMP. Changes in the relative positions of banks and shoals has caused some displacement of channels, although they have been general stable since the first reliable and detailed hydrographic survey in 1785.

Figure 2.4.2



SWASH CHANNEL, 1849



SWASH CHANNEL, 1973

(from Dredging of Swash Channel, Poole, 1991, Appleton)

Figure 2.4.2 shows the natural channel outside the entrance of Poole Harbour in 1849 that existed before any improvements had been carried out. Details of the history off this area has been presented in Section 2.3.1.

The increase in dredged quantities recorded substantially reflects the programme of capital dredging over this time period. This has involved the removal of some previously stable sediment and underlying substrate. The main capital dredging project in recent years has been the deepening of the Middle Ship Channel to accommodate the cross-channel vessel M V Barfleur. Shipping bound for Poole Port that used to navigate the North Channel now uses the straighter Middle Ship Channel. Associated with this work has been the deepening of the roll-on/roll-off berth. Sediment has been dredged from Fisherman's Dock, Poole Harbour Commissioner's Quays, the RNLI site, Cobbs Quay, Parkstone Marina and the Royal Marines Slipway and Chapman's Peak, though the latter shoal had returned only three months after dredging (Appleton, 1994).

At present, dredging is confined to the commercial shipping channels and amounts to approximately 60,000m^3. Of this volume 30-34,000m^3/yr is dredged regularly from the North and Middle Channels (to maintain their depths at 3.6m and 6.0m below chart datum respectively (CD = 1.4m below OD. There is also a requirement to dredge in the vicinity of the existing boatyards and marinas but the quantities are generally small. All of the material is removed to an approved, licensed dredge spoil dumping site offshore of Old Harry.

Patterns and Rates of Erosion and Accretion

The original configuration of the Harbour has been substantially modified by erosion and accretion processes. Erosion has been most obvious at a number of places on the cliffs exposed to wave attack from the south west. Wave height and period is limited by fetch in the Harbour. Erosion is significant locally but rates are generally lower than in Poole Bay (May, 1969). Table 2.4.3. outlines the annual average rates of cliff erosion in the Harbour. The highest rates that were previously experienced were at Whitecliffe and Lilliput in the northeast section of the Harbour. These sites are now fully protected (ie: land reclamation at Baiter).

Within Poole Harbour, the creation of extensive mudflats has resulted from accretion aided by the colonisation and stabilisation of saltmarsh vegetation. This process has been particularly effective in the past century due to the rapid invasion of *Spartina*. However since the 1930s, its areal extent has been reduced. This decline and associated erosion has released quantities of mud and increased the levels of sediment in other areas, shallowing some upper parts of the major channels.

TABLE 2.4.2: Volume of Dredged Material (m3) - Poole Harbour, 1969 -1998

Date	Main Channel	Middle Channel	Other	Total
1969/70	11,720	3,858	3,216	18,794
1970/71	9,646	-	6,678	16,324
1971/72	14,608	1,673	1,662	17,943
1972/73	8,269	-	30,338	38,607
1973/74	17,792	-	9,069	26,861
1974/75	10,788	2,215	7,086	20,089
1975/76	21,277	8,077	6,173	35,527
1976/77	11,892	6,992	2,008	20,892
1977/78	23,970	307	10,940	35,217
1978/79	9,582	192	30,627	40,401
1979/80	29,318	-	1,136	30,454
1980/81	34,540	9,171	484	44,195
1981/82	46,706	1,981	2,767	51,454
1982/83	33,539	1,751	10,477	45,767
1983/84	24,069	1,229	20,519	45,817
Avg	20,514	2,496	9,545	32,556
Date	Capital Dredging	Maintenance Dredging	-	Total
1984/85	23,735	48,808	-	72,543
1985/86	302,518	56,178	-	358,696
1986/87	65,639	46,086	-	111,725
1987/88	-	61,943	-	61,943
1988/89	739,422	56,745	-	796,167
1989/90	542,000	73,493	-	615,493
1990/91	-	88,845	-	88,845
1991/92	780,000	56,799	-	836,799
1992/93	-	66,687	-	66,687
1993/94	-	83,000	-	83,000
1994/95	-	30,600	-	30,600
1995/96	-	158,310	-	158,310
1996/97	-	60,505	-	60,505
1997/98	-	206,590	-	206,590
Avg	272,590	121,621	-	394,211

TABLE 2.4.3 Average Annual Rates of Cliff Erosion in Poole Harbour 1870 – 1952

	Survey Date	Cliff Top Erosion (m)	Rate (m/yr)
Hamworthy	1886-1952	18	0.3
Whitecliffe	1886-1952	36	0.5
Lilliput	1886-1952	43	0.6
West Brownsea	1886-1952	24	0.4
Arne	1886-1952	24	0.4

The Environmental Assessment of Poole Harbour Town Quay (Ecological Planning and Research – Poole Harbour Town Quay Boat Haven, Environmental Assessment Stage 1 Preliminary Ecological Appraisal and Identification of Issues 1991) noted that as a result of the enhanced tidal volumes and scouring in the Harbour (due to the die-back of *Spartina)*, the seaward ends of the major channels have actually deepened. As previously noted, the basic pattern of the major channels has remained relatively stable since 1785 but the hydrographic surveys reveal changes in the plan form of the banks and channels over the last 150 years. Green (1940) noted the tendency for the Main Channel to migrate eastwards between 1829 and 1934.

The only area of recent beach accretion in Poole Harbour is in Newtons Bay and the west coast of Goathorn Peninsula (Gray, 1985). Many of the sandy beaches are undergoing erosion, including the steeply shelving sandy beaches on the western and central sector of Arne Peninsula and the gravel beach on the south shore of Brownsea Island.

McMullen (1979) outlines the major changes in the Harbour over the last 125 years. Section 2.8 outlines the findings of his work with reference to Poole Harbour. The trends outlined by him are generally supported by the Poole Harbour Commissioners study (1982, 1985) which concluded that the major changes over the last 50 years were:

- deepening of the Middle Mud area, thus reducing the ebb flow in the main channel;
- some eastward and northeastward migration and narrowing of the North Channel;
- shallowing of the entrance channel between North Haven and Saltern's Beacon;
- largest area of land reclamation has been around the Wareham River;
- stability of the shape and depth of the upper Wytch channel.

Bray *et al* (1991a) note that the extensive shallowing of the Upper Wareham channel between 1934 and 1954, caused as a result of the release of sediment by the decline in *Spartina*, appeared to have ceased by the 1960's.

Other coastal configuration changes have also been simultaneously occurring. The areas south of Wareham Channel, east of Arne and over Middle Ground have been deepening. This has not increased the area of the Harbour at HWST but it has added to the reservoir over the tidal cycle (PHC, 1982). In 1982, the area of the Harbour covered at high water was 3564 ha, with a reduction to 1000ha at low water. This represents an increase of approximately 328 hectares over the area covered at HWST in 1784, about 243 hectares of which are in the Middle Mud and Middle ground areas.

Saltmarsh Erosion

Land claim is believed to be the major factor for loss of saltmarsh habitat in the majority of the estuaries in Britain and is a practice that dates from Roman times. The consequence of land claim, (described in some detail previously) is that it reduces the width of the intertidal area and hence reduces the ability of the remaining marsh to dissipate wave energy. Also, land claim can result in the hinterland being at a lower elevation than the foreshore. In addition, the presence of an embankment can provide a focus for wave energy at high tide and can create areas of erosion immediately adjacent to the structure. This can enable a pond to be created and the process will be self perpetuating often resulting in the development of a channel at the top of the marsh. This channel can facilitate higher wave energies to be directed onto the defence structure, and also the loss of protective saltmarsh at the toe will affect the integrity of the structure itself.

Dredging of navigation channels is likely to affect saltmarsh appearance through issues such as changes in the channel morphology, potential erosion of the saltmarsh, increases in wave energy, or the dumping of dredged material are all equally significant.

Finally, saltmarshes may be influenced by natural die back. This may be due to a number of interacting circumstances, some natural and some anthropogenically induced. This situation is likely to be exacerbated with the onset of sea level rise. In their natural state, saltmarshes will respond to relative changes in sea level by migrating inland when sea levels rise and migrating seawards when sea levels fall. The presence of a sea wall or embankment constrains the landward margin of the saltmarsh and thus prevents any natural readjustment to rises in sea level. In this situation, however, the seaward margin will migrate landward causing the width of the saltmarsh to be reduced, again reducing the buffering effect of the marsh.

The implications of this in terms of future defence option selection is detailed in Volume 1 of the SMP ("The Strategy Document").

2.5 Area 5F-5 South Haven Point To Handfast Point (STU)

2.5.1 Review of Existing Information

Information on the historic development and coastline recession within this Process Unit was derived from two key sources. Portsmouth Polytechnics 'Coastal Sediment Transport Study – Volume 4' (1991) report provided an overview of the unit and the Glasgow University Coastal Research Group report 'Estuaries Management Plan, Coastal Processes and Conservation, Poole Harbour' (1993) provided details on the development of the Studland/South Haven Peninsula.

Geomorphological History and Natural Evolution

In recent times, the north-eastern and central areas fronting Studland Bay have accreted most rapidly with maximum rates of 1.4mpa for 1880-1930 (Diver 1933) and 3.0-4.0mpa for 1933-70 (Carr 1971a). Recent accretion has built a new dune ridge over the period 1933-70 and it appears that growth of the northern and central parts is an ongoing process (Carr 1971a). The source of sand is generally regarded as onshore feed from the shallow sandy Studland Bay (Carr 1971a).

The following describes evolutionary trends for various sites within this Process Unit (south to north).

- South Haven Peninsula

For a summary of the development of the South Haven Peninsula and the Sandbanks spit at the tidal mouth of Poole Harbour see Section 2.3.1.

- Shell Bay

Map comparisons indicated rapid erosion of up to 3.3mpa over the period 1880-1930 (Diver 1933). Erosion was shown to continue during the period 1933-1970, but a reduced rate of 0.5mpa (Carr 1971a). It is possible that construction of the training bank structure extending 350m south-east from the eastern point of Shell Bay in 1876 and lengthened to 1500m in 1925-27 (Glover 1972) may have contributed in two ways: Firstly, the configuration of the Swash Channel was altered so as to cause increased scour in Shell Bay. Secondly, the training bank intercepts littoral drift from Studland Bay thereby reducing natural replenishment of Shell Bay.

- Studland Beach

Historic maps and chart comparisons indicate that the southern end of Studland Bay immediately north of Studland village has been subject to an eroding trend since 1721 (Diver 1933, Baden-Powell 1942). Analysis of maps and air photos covering the period 1933-70 revealed a maximum recession rate of 0.7mpa (Carr 1971a). Much of this area is low-lying and erosion probably only supplies small quantities of blown sand and gravelly sands. Quantities released are unlikely to be of the same order of magnitude as the accretion occurring further north along the bay.

- Redend Point

Erosion along this segment supplies small quantities of predominantly clay and sands but volumetric formation is not available; only parts of this cliffline are eroded by wave attack, as evidenced by the vegetation screen with tree growth in front of inactive cliffs. No historical map assessment has been made for this exact location.

2.6 Area 5F-6 Handfast Point to Peveril Point (SWA)

2.6.1 Review of Existing Information

Information on the historic development and coastline recession within this Process Unit was derived from two key sources. Portsmouth Polytechnics 'Coastal Sediment Transport Study – Volume 4' (1991) report provided an overview of the unit and the Hydraulics Research report 'Swanage Flood Alleviation Scheme' (1991) provided details of the development of Swanage Bay.

Geomorphological History and Natural Evolution

Substantial evidence of active coastal erosion of the chalk outcrop exists for the area from Handfast Point to Ballard Down. May (1971, 1977) has mapped coastal retreat from OS maps between 1882 and 1962 producing an retreat rate of 0.23mpa. Cliff recession and erosion is also substantial by comparison of the present state of the stacks at The Foreland with 19th Century descriptions and early photographs and by descriptions of collapse of a rock arch 1920-21 and a stack in 1899. Collapse of a cave in October 1976 is also reported. On the south side of Ballard Point, erosion is limited because of wave refraction, the dip of the Chalk rocks and a change in its lithological composition.

The geology of the northern end of Swanage Bay in particular is complex and influences present day cliff processes and the spatial distribution of mass movements. Falls and slips occur annually in the cliffs between Ballard Point and Ulwell Stream Outfall, including the area to south of the Pines Hotel, where there is a promenade and seawall at the base of the cliffs. Several attempts have been made to protect these cliffs but groundwater levels and drainage pose a particular ongoing problem. Up to 8m of cliff recession has taken place since the promenade was built in the early 1920s (Bray, Carter and Hooke, 1991).

Over the years there is reported to have been a general lowering of beach levels in the northern part of Swanage Bay, where the natural beach protecting the cliff has dropped by over 2 metres. Erosion has been so severe in some places that the Wealdon Clays below the beach have been exposed and eroded during the winter season.

Although the toe of the cliffs is protected by a steep shingle beach, it continues to erode as a result of a combination of wave attack and ground water flow. The shingle beach protecting the base of the cliffs can be washed away during storms.

Anthropogenic Intervention

The following describes events that have taken place at various sites within this Process Unit that have influenced shoreline evolution (south to north).

- Peveril Point to Swanage Pier

The foreshore in this area comprises rocky outcrops, overlain with a thin layer of cobbles, with a number of short stone groyne structures. The properties on Peveril Point are at risk in the longer term due to erosion of the Durlston cliffs to the south (ie: Process unit 5F-7). An undated photograph taken at the slipways shows a small, sand, beach and a series of rock groynes. The stone groynes were in place in 1888 and, although no evidence is available, it appears that they have been in place for a couple of hundred years.

To the south and east of the Mowlem Theatre, a series of walls and jetties intrude into the intertidal zone and hence the high water mark coincides with these structures. A small fillet of beach material has accreted immediately to the east of the Pier.

- Swanage Pier to Ulwell Stream Outfall

The foreshore between the Pier and the Mowlem is comprised of sand with a large number of rock outcrops, some with short stone groyne structures. The width of beach increases towards the east. East of the Stone Quay a small sand beach has accreted.

A photograph from 1890 shows the beach along the main part of Swanage Bay. Despite the lack of groynes, the beach does not appear dissimilar to the current beach. A groyne system was constructed between the Mowlem Theatre and The Ulwell Stream Outfall in the late 1920s and early 1930s, covering the main town frontage. There was a seaward advance of the high water line as a result of these groynes, however, the seaward advance of the low water line was less significant and resulted in a steepening of the beach. Although the groyne system stabilised the beach between the late 1920s and 1973, historical map comparisons between 1887 and 1973 indicate no significant intertidal change between these survey dates.

In the early 1960s the groyne system was extended towards Ballard Point, along a mainly private frontage, the foreshore north of the Ulwell Stream Outfall became quite narrow at high tide.

In 1993, the Outfall Jetty was constructed, seaward of Victoria Avenue, as part of the Swanage Flood Alleviation Scheme. Purbeck DC stated that beach levels to the south of the Outfall Jetty had built up quickly and have been stable over the last 2 years. Following an inspection of the beach in March 1998, it was noted that the groynes to the south of the Outfall Jetty were buried and the beach extended to the top of the seawall. The groynes to the north, however, projected some 0.5m above the beach whereas at the toe of the seawall, the beach was some 1.5m below its crest height. Thus, the Outfall Jetty appears to be obstructing the transport of sediment from south to north.

Purbeck DC state that the beach in March 1998 was in a better condition than the previous year, when beach levels were lower and the clay bedrock was exposed at the northern end of the Bay around Sheps Hollow.

- Ulwell Stream Outfall to Pines Hotel

A number of beach huts and shops on the promenade are protected by a series of small seawalls which follow an erratic line along the toe of the cliffs which were built in the early 1920s. Due to their geological composition, the cliffs in this area are unstable and material falls annually onto the promenade. In places, up to 8m of cliff recession has occurred since the promenade was built. Several attempts have been made to protect the cliffs but groundwater levels and drainage pose a particular problem.

- Pines Hotel to Sheps Hollow

A series of timber groynes (but no seawall) were constructed along this section in the early 1960s in an effort to maintain the beach and to prevent further erosion of the cliffs. These cliffs continue to erode, and recently at Sheps Hollow, a section slipped destroying the landward end of the most northerly groyne.

- North of Sheps Hollow

No man made structures exist along this stretch and so anthropogenic interference on the shoreline evolution of the area has been minimal.

2.7 Area 5F-7 Peveril Point To Durlston Head (DUR)

2.7.1 Review of Existing Information

Information on the historic development and coastline recession within this Process Unit was derived from a number of reports that exist, mainly because of the potential impact of cliff erosion on coastal properties and the problems of coastal management caused by the mass movements.

Geomorphological History and Natural Evolution

The interest in the geological structure of this process Unit is related to the presence of three faults in the Lower Purbeck and Middle Purbeck Beds. The deterioration of the cliffs in Durlston Bay is partly related to these structural features, but also to the fact that the lower three quarters of the cliff is composed of marls which are subject to rapid weathering and the effects of water. Therefore, the cliffs have naturally been deteriorating by physical weathering (wind, rain, freeze thaw processes etc), ground water percolation as well as from direct attack from the sea. The attack from the sea, in places, is mitigated by stone scree which has fallen from the top of the cliff.

Rotational slides of marl have been witnessed in these cliffs when the cliffs become undermined by sea action and the friable material above become weakened by weathering processes. Recession back to a known fault line is likely to see an increase in average recession rates in the area.

Investigations by Trevor Crocker and Partners (1986) showed that over the past 32 years, the cliff edge has been receding at an average rate of 0.44mpa (Trevor Crocker and Partners, 1986), though it is recognised that movement has not been continuous during that period. Marine erosion at the base of the cliffs quickly removes all the fine material, leaving boulder arcs marking the position of debris slides and mudflows.

In a subsequent report (Crocker 1988) it was calculated that a further 12m of recession has taken place since 1988 and that erosion rates appear to be accelerating to those originally predicted in 1986.

Anthropogenic Intervention

The cliff stabilisation scheme, constructed in 1989, will aim to protect this section of the cliffs from erosion into the future. Volume 3 covering Coastal Defences details this aspect more fully. However, due to the conservation status, the cliffs along this Process Unit will be allowed to erode in order to allow the continued exposure of the unique geological formations.

In summary, coastal defence schemes have not had a significant impact on the shoreline evolution of Durlston Bay to date.

2.8 Bathymetric Changes

Over recent years, it has become clear that knowledge of active processes at a given site is not in itself sufficient to answer wider coastal issues. Such information forms only a part of understanding the "system" as a whole. This is certainly the case for the Poole and Christchurch Bays SMP. Recent attempts have been made by Shoreline Management Plans (SMP) to divide the coast into "management units", however, these show little recognition of offshore issues in adjacent units that may be influencial upon the immediate area of interest. Thus to develop a regional understanding, the definition of local processes must be set in the context of wider "systems" that are related to the evolution of Poole and Christchurch Bays. This is the approach adopted by Halcrow for this SMP.

Knowledge of past bathymetric change is an important element in seeking to understand the dominant coastal processes that operate and are influential upon the evolution of Poole and Christchurch Bays. By using a sound understanding of past changes, it becomes possible to identify areas which are experiencing similar types of change, or have common sensitivities to future change.

To understand the evolution of the shoreline fronting the subcell shoreline, the relationship between form and process along this study area on temporal and spatial scales needs to be considered. Assessing and understanding the selective movement of varying sediment size fractions in different directions is important as this concept is integral to the development of offshore morphological form in the area.

The main objective here was to obtain reliable measurements covering as long a period as possible to discern historical bathymetric trends. It was decided, however, that those Admiralty Charts published prior to the 1931edition would not be used in the analysis (eg:1867) on the grounds of accuracy. These older Charts were, nevertheless, used for basic overlaying and general comparative purposes to elucidate trends. This issue of data accuracy is developed further in the following sub-section. The recent contemporary changes (past 15 years) that can be relied upon are especially important as it is envisaged that they should represent processes operating within prevailing management regimes. Consequently, the detailed appraisal exercise outlined in the following sections essentially refers to recent change in offshore bathymetry derived from existing published sources or from new work carried out for this SMP.

2.8.1 Limitations of Offshore Evolution Analysis

The accuracy of the offshore analysis carried out depends to some considerable extent upon the accuracy of the surveys to be compared. This may be somewhat variable, during the period of the surveys used in this study. The method and accuracy of each survey is not consistent, consequently it is difficult to assess the degree of confidence in the results presented.

The problem of accuracy is less likely to be of significance on relatively flat areas of seabed (eg: Poole and Christchurch Bays in general) than on steep ones or transient offshore banks (Shingles Bank). A small difference in the horizontal positioning of the sounding may result in a very large difference in sounding on a steep slope. Unfortunately, the areas of most interest are those with relatively steep slopes.

The Admiralty Charts are the key source of hydrographic survey data for the whole area, though Poole Harbour Commissioners possess very good coverage of bathymetric change in Poole Harbour and its entrance. They are primarily designed as navigation aids, as opposed to precise sea bed surveys used for calculating historic or volumetric change. The survey accuracy is somewhat limited in the earlier surveys, particularly when having to establish true geographic position. Position fixing still presents a problem even with more modern sophisticated survey methods. The frequency of bed soundings also limits the accuracy of the surveys. Where soundings are widely spaced, as they appear to be on many of the earlier surveys, the bed shape may not be described sufficiently accurately to allow quantification of bed changes to take place. This has also caused problems when using contouring software packages as part of this study.

It is because of these uncertainties that a basic temporal overlay of chart editions has been carried out as opposed to a more analytical digital terrain model approach. Although the latter presents perhaps the best method of comparing surveys, identifying trends in the development of the sea bed and offshore bank formation, analysis of volumetric changes should be viewed with caution if there is any uncertainty over survey accuracy. For the purposes of this study, therefore, a visual comparison of surveys has been carried out to identify broad areas of change outlining key erosion / accretion trends or development of new features.

Details relating to Poole Harbour are not covered here as they have been well described in Section 2.4.

2.8.2 Summary of Findings

Comparison of bathymetric charts between 1979 and 1990 identified the principal areas of change in bed levels (Velegrakis, 1994). The overall impression is that the seafloor in the area appears to be eroding, with the erosion most severe in Christchurch Bay. Extensive areas of seafloor erosion can be identified, namely;

- In the shallow waters offshore of Poole Bay, where changes of up to 2m have occurred; offshore of Milford on Sea and Hurst Spit (Christchurch Bay)
- The northern flanks of Dolphin Bank and Sand, together with the western flank of the Shingles Bank; the area to the east of Christchurch Ledge (Christchurch Bay)
- Around Shingles bank, the northern part of the North Channel is eroding and deepening in response to the landward migration of Hurst Spit (Bradbury 1992)
- The Hurst Narrows channel is eroding deeper due to tidal scour action. Also the crest of Shingles bank is moving from west to east, causing erosion on the west side and accretion on the east. (Bradbury 1992)
- The area to the east of Handfast Point (Poole Bay)
- The Swash Channel area within the Poole Harbour ebb-tidal delta. A review of historic data from charts and more recent bathymetric surveys identified that the shallow nearshore East Looe channel has gradually deepened since 1785. This deepening has accelerated in recent times and has also moved inshore. This in turn has increased the nearshore tidal currents (measured at 3 knots maximum during high spring tides) which prevent the accretion of sand on the

foreshore. If the East Looe channel was ever allowed to continue to migrate onshore at its present rate of 6m/yr, which is now improbable due to the construction of rock groynes as training walls to stop this movement, the beach will steepen which will destabilise the channel further, leading to higher tidal velocities closer to the shore. Ultimately this will undermine the existing structures and erode the remains of the sand dunes. An extensive bank, the Hook Sand, flanks the north-eastern side of the Swash Channel and some of this material is probably carried landward during periods of onshore winds. Initially the sand was derived from the erosion of the cliffs of Poole Bay before this natural sediment supply was terminated to reduce erosion rates.

Parts of the seabed that show accretion are limited to;

- Along the southern flanks of the Dolphin Bank and Sand
- The eastern flank of Shingles Bank and the North Head Shoal (offshore from Hurts Spit)
- The area offshore of Hordle Cliff (Christchurch Bay)
- Limited areas within the central part of Poole Bay
- Bradbury (1992) records a net increase in the sediment volume of Shingles Bank between 1882 and 1988.

Generally the major bathymetric changes identified are concentrated over, or lie close to, some of the major geomorphological features of the area (Poole Harbour and West Solent tidal inlets and the Dolphin sandbanks). Between 1891 and 1988 the Dolphin sandbanks have remained relatively stable in shape although there has been an overall shift in position towards the south, which has accelerated during recent years (Velegrakis, 1994).

With reference specifically to Poole Harbour, the Upper and Lower Wareham Channels have undergone considerable shallowing. This is in contrast to a deepening that has occurred over a large area of mudflat from Patchins Point to south of Little Channel. In the central area of the Harbour, the North Channel has tended to migrate northward and eastward, possibly linked to considerable reclamation events that have taken place in and to the north of Parkstone Bay and Middle Ground. In recent years considerable shallowing has taken place in the Middle Channel especially immediately north of the eastern end of the Wytch Channel. Changes to the Wytch Channel and minor channels include general shallowing with the exception of the eastern part of the Wytch Channel, the Swash Channel and Harbour entrance which has remained relatively stable.

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