Christchurch Bay and Harbour Flood and Coastal Erosion Risk Management Study

Technical Annex 5: Coastal Processes

Prepared by

New Forest District Council and Halcrow Group Ltd

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Prepared by

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Contents

1 Introduction

This Technical Annex provides a summary of past coastal evolution, an overview of coastal processes acting within Christchurch Bay and predictions of the future evolution of Christchurch Bay. The information within this Annex has been extracted from the Poole and Christchurch Bays Shoreline Management Plan (Halcrow, 1999) and Futurecoast (Halcrow, 2002). The Futurecoast study was lead by Halcrow's coastal scientists to provide analysis and predictions of shoreline evolution tendencies over the next century which will be used to underpin the development of long term coast defence policy throughout England and Wales.

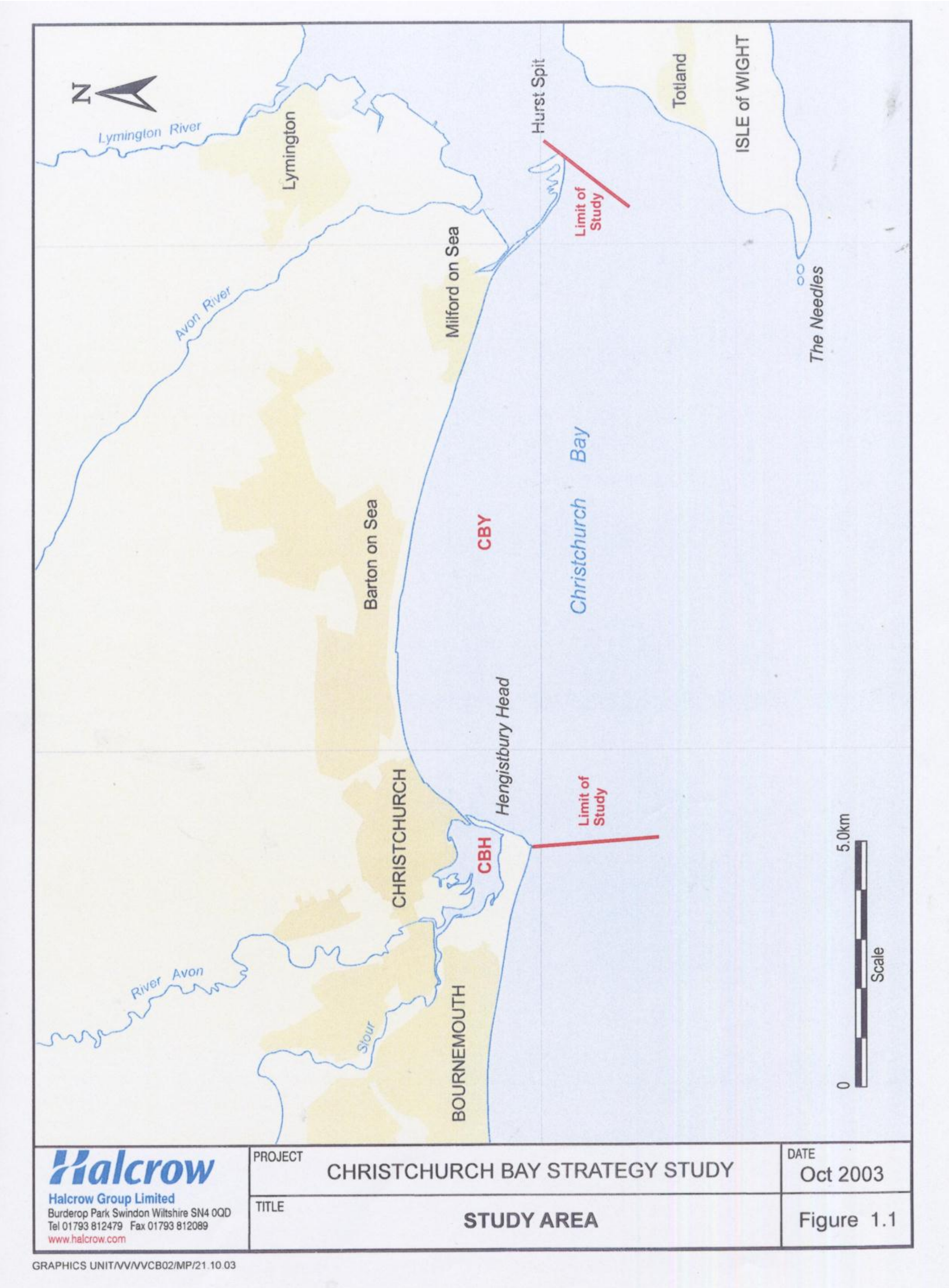
Christchurch Bay is bounded by Hengistbury Head in the west to Hurst Spit in the east and comprises three principal frontages, each representing different geomorphological features:

- The low-lying Christchurch Harbour with associated spits at its mouth;
- The soft Tertiary sea cliffs, capped with plateau gravels, dominating the shallow embayment of Christchurch Bay; and
- The gravel spit named Hurst Spit that extends across the entrance to the western Solent.

Christchurch Harbour is considered separately in Technical Annex 4 since it is predominantly controlled by estuarine processes, however the nature of the Harbour and its influences on the open coast are considered within this Technical Annex.

Within Christchurch Bay the coastal process units defined in the Shoreline Management Plan, see Figure 1.1, are:

- Christchurch Bay – Process Unit CBY;
- Christchurch Harbour – Process Unit CHB.


N
Lymington River
Lymington
Avon River
Milford on Sea
Hurst Spit
Limit of Study
Totland
ISLE of WIGHT
The Needles
Barton on Sea
CBY
Christchurch Bay
Hengistbury Head
CHRISTCHURCH
CBH
Limit of Study
River Avon
Stour
BOURNEMOUTH
0
5.0km
Scale
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TITLE
STUDY AREA
Figure 1.1
GRAPHICS UNIT/VV/VVCB02/MP/21.10.03

Figure 1.1

2 Past Coastal Evolution

2.1 Holocene Evolution

Formerly, the Solent River ran from Poole Harbour eastwards across Poole and Christchurch Bays, draining into the present-day Solent. Its course was constrained to the south by a near-continuous Chalk ridge that once extended from Ballard Down (on the Isle of Purbeck) to The Needles (on the Isle of Wight). This ridge is believed to have occupied a relatively low and narrow profile and was dissected by initially small southward-orientated drainage channels. These channels progressively became exploited by rising sea level after the last glaciation, resulting in the breaching of the Chalk ridge and the preferential southward flow of Rivers Frome and Piddle through the ridge rather than eastwards into the present Solent. This led to erosion and the eventual removal of the Chalk ridge approximately 7,000 to 8,000 years ago, a change which, combined with sea level rise, resulted in:

- separation of the Isle of Wight from the mainland;
- tidal inundation of the river basin that backed the former Chalk ridge, leading to the creation of the present-day Poole and Christchurch Harbours;
- the combing-up of coarse sand and gravel from the seabed to form barriers that subsequently have continued to migrate landward in response to continuing sea level rise; and
- rapid erosion of soft material deposits of the Hampshire Basin to form the present-day embayed coastline of Poole and Christchurch Bays.

2.2 Recent Historic Evolution

The present plan-form configuration of the coastline within the Study Area is principally due to diffraction of waves from the predominant south-west sector around Hengistbury Head, the headland at the western end of Christchurch Bay. This headland has been created by the presence of ironstone nodules within its otherwise generally soft geological structure. These locally have provided it with an increased degree of resistance against marine erosion when compared with the adjoining sea cliffs of Poole and Christchurch Bays. They were, however, actively mined from coastal exposures and an inland quarry on Hengistbury Head during the 19th Century, resulting in accelerated erosion of the headland and its landward recession to its present position. This significantly altered the control that the headland exerted on wave diffraction, causing accelerating erosion of the shoreline to its east.

The accelerated erosion in the vicinity of Hengistbury Head led to an increase in the volume of material transported by longshore drift eastwards into Christchurch Bay, enabling Mudeford Spit to grow progressively across the mouth of Christchurch Harbour. Indeed, Mudeford Spit has undergone as many as five cycles of bay-mouth bar building and subsequent breaching over the hundred years preceding its last breach in 1935. It is now stabilised by defence structures.

Due to the presence of interbedded clay and sand lithologies, the sea cliffs of Christchurch Bay yield easily to marine forcing and are highly sensitive to landsliding behaviour, promoted not only by marine action but also by groundwater conditions. High rates of erosion of these cliffs have prompted management intervention activities (including cliff drainage, vegetated swards, seawalls, groynes and replenishment) from the mid-1800s to the present day in several locations, most notably at Highcliffe, Barton-on-Sea and Milford. In turn, this management intervention has initiated classic downdrift erosion problems by reducing sediment input from the cliffs to the foreshore, or by intercepting sediment drifting alongshore and thereby causing fragmentation of the natural coastal process system.

3 Coastal Processes

The Shoreline Management Plan identified the principal sediment transport pathways within Christchurch Bay. A summary of existing understanding is provided in Figure 3.1 which highlights key coastal process information for this area, including locations most at risk from sea level rise, sediment sources and sinks and contemporary sediment drift directions.Christchurch Bay is a headland-controlled embayment, with material released from cliff erosion moving eastward along the shoreline to be deposited in the sink of Hurst Castle Spit and ultimately the offshore bank, Shingles Bank. The plan-form configuration of Christchurch Bay is dependent upon Hengistbury Head and the Isle of Wight. The occurrence of two smaller log-spiral embayments extending between the Isle of Purbeck and Hurst Spit, rather than one larger continuous embayment, is due to the presence of Hengistbury Head acting as a secondary headland control.

Hengistbury Head exists as a headland although it is potentially a ‘soft’ control since its resistance against marine erosion is attributed to the localised presence of ironstone nodules within an otherwise highly erodible structure, as opposed to a large mass of resistant geology. Its natural control on shoreline evolution is enhanced artificially by the presence of the Hengistbury Head Long Groyne.

Christchurch Ledge is a nearshore feature protruding into the sea, representing a formerly more seaward position of Hengistbury Head. The remnant Ledge comprises resistant ironstone nodules and consequently influences and partially dissipates larger waves passing over it into Christchurch Bay

Wave and tidal action create the dominant sediment transport mechanisms in Christchurch Bay. The prevailing offshore wave direction is from the south-west, coinciding with the greatest fetch. This results in net eastward transport of sediment along the Christchurch Bay frontage.

The western sections of the Isle of Wight afford shelter to Christchurch Bay, particularly its eastern section, against less frequently occurring southerly, south-easterly or easterly storms. This is also influential upon the development and stability of Hurst Castle Spit, which is a depositional area for available sand and shingle. This spit also is a major control on the evolution of the frontage further to the east as it shelters the western Solent area from south-westerly storm events.

A series of offshore banks, part of the tidal delta system of the Western Solent, play an important role in refracting waves and dissipating their energy as they approach Hurst Spit from the south-west. There is a clockwise circulatory sediment transport system operating within Christchurch Bay that historically has been sustained by coast erosion. This is described further below in terms of sediment inputs, transport pathways and outputs.

3.1 Sediment Inputs

The main sediment inputs identified in the SMP are as follows:

- Christchurch Bay is supplied with some sand and shingle from Poole Bay due to natural bypassing of the Hengistbury Head Long Groyne, although this input is relatively moderate in volume.
- The Bay is relatively lacking in contemporary sediment supply because much of the available beach sediment was derived from the sea bed and transported onshore during Holocene sea level rise. This supply from the sea bed has now largely been exhausted.
- Additionally, the continued erosion of sediment-supplying cliffs has largely been reduced through the construction of coastal defences and other cliff stabilisation works, thereby reducing contemporary supply from sea cliff recession to low levels.
- Those sections of cliff that remain unprotected are eroding at high rates. Despite this, they now supply less shingle to the beaches than historically because the layer of gravel in the cliffs was formerly considerably thicker than those presently exposed.

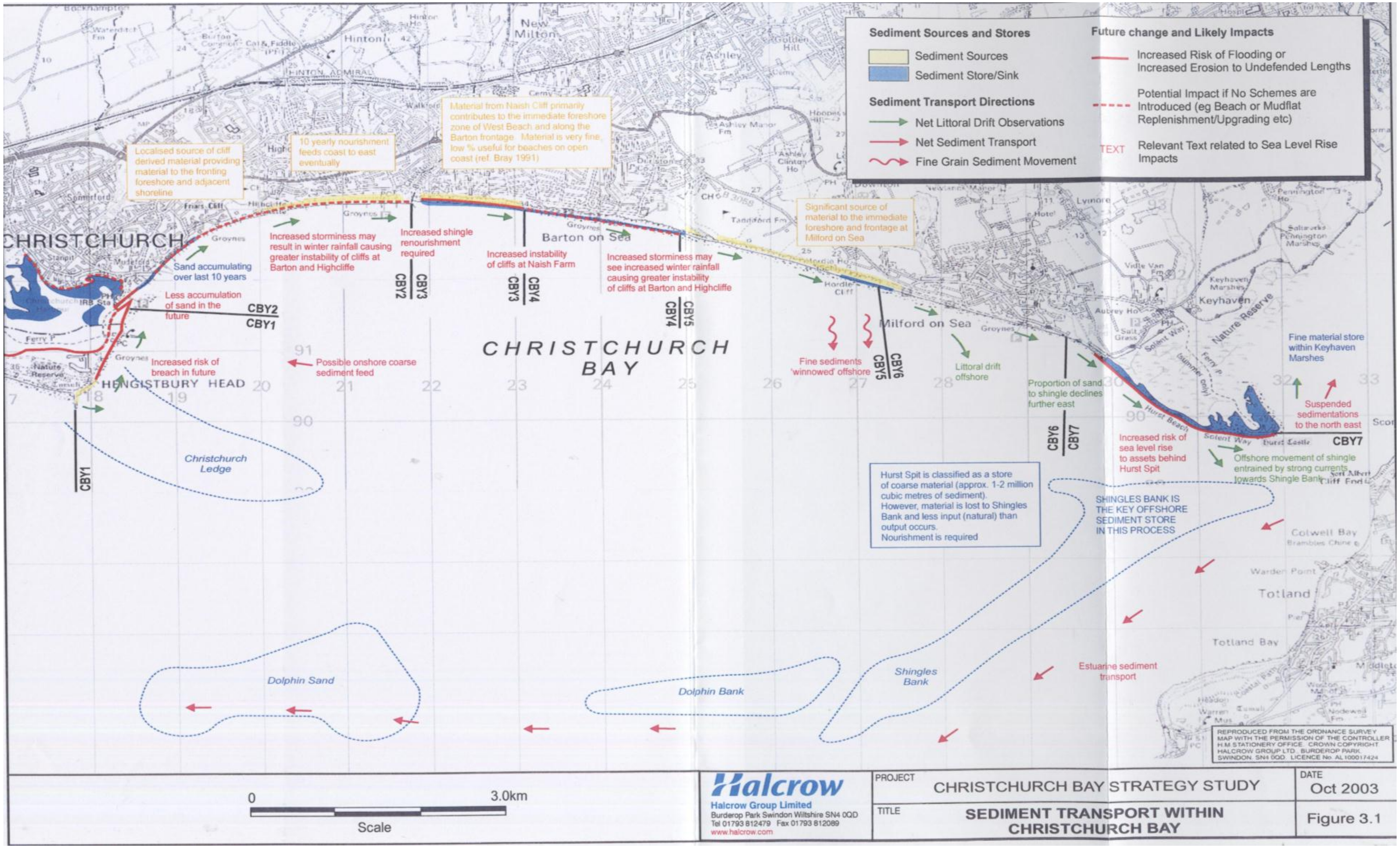
3.2 Sediment Transport Pathways

The main sediment pathways identified in the SMP are as follows:

- There exists a general eastward transport of sand and shingle along the foreshore of the Bay.
- Fine-grained sediments supplied from eroding sea cliffs are progressively winnowed from the foreshore and transported offshore.
- Coarser material remaining on the foreshore is transported alongshore by littoral drift and deposited at Hurst Spit.
- Some of the material drifting along Hurst Spit is lost offshore, entrained by strong tidal currents in the Hurst Narrows. This sediment is preferentially transported seaward to the Shingles Bank: an ebb-tide delta of the Western Solent that represents a shingle sink to this coastal process system.
- There exists a general westward transport of sediment from the Shingles Bank to Dolphin Bank and then to Dolphin Sand, located approximately 4km offshore from Hengistbury Head.

3.3 ***Sediment Outputs***

There is some loss of sediment from Christchurch Bay into the Western Solent. However the main sediment output is from Hurst Spit to Shingles Bank, where it is stored or moved through the succession of offshore banks.



Sediment Sources and Stores
Sediment Sources
Sediment Store/Sink
Sediment Transport Directions
Net Littoral Drift Observations
Net Sediment Transport
Fine Grain Sediment Movement
Future change and Likely Impacts
Increased Risk of Flooding or Increased Erosion to Undefended Lengths
Potential Impact if No Schemes are Introduced (eg Beach or Mudflat Replenishment/Upgrading etc)
TEXT
Relevant Text related to Sea Level Rise Impacts
Localised source of cliff derived material providing material to the fronting foreshore and adjacent shoreline
10 yearly nourishment feeds coast to east eventually
Material from Naish Cliff primarily contributes to the immediate foreshore zone of West Beach and along the Barton frontage. Material is very fine, low % useful for beaches on open coast (ref. Bray 1991)
Significant source of material to the immediate foreshore and frontage at Milford on Sea
CHRISTCHURCH
Sand accumulating over last 10 years
Less accumulation of sand in the future
Increased risk of breach in future
HENGISTBURY HEAD
Increased storminess may result in winter rainfall causing greater instability of cliffs at Barton and Highcliffe
Increased shingle renourishment required
Increased instability of cliffs at Naish Farm
Barton on Sea
Increased storminess may see increased winter rainfall causing greater instability of cliffs at Barton and Highcliffe
CBY1
CBY2
CBY3
CBY4
CBY5
CBY6
CBY7
Possible onshore coarse sediment feed
CHRISTCHURCH BAY
Christchurch Ledge
Fine sediments 'winnowed' offshore
Milford on Sea
Littoral drift offshore
Proportion of sand to shingle declines further east
Keyhaven
Nature Reserve
Fine material store within Keyhaven Marshes
Suspended sedimentations to the north east
Increased risk of sea level rise to assets behind Hurst Spit
Hurst Beach
Offshore movement of shingle entrained by strong currents towards Shingle Bank
Hurst Spit is classified as a store of coarse material (approx. 1-2 million cubic metres of sediment). However, material is lost to Shingles Bank and less input (natural) than output occurs. Nourishment is required
SHINGLES BANK IS THE KEY OFFSHORE SEDIMENT STORE IN THIS PROCESS
Colwell Bay
Totland
Totland Bay
Estuarine sediment transport
Shingles Bank
Dolphin Sand
Dolphin Bank
REPRODUCED FROM THE ORDNANCE SURVEY MAP WITH THE PERMISSION OF THE CONTROLLER H.M STATIONERY OFFICE. CROWN COPYRIGHT HALCROW GROUP LTD., BURDEROP PARK, SWINDON. SN4 0QD. LICENCE No. AL 100017424
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3.0km
Scale
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TITLE
SEDIMENT TRANSPORT WITHIN CHRISTCHURCH BAY
DATE
Oct 2003
Figure 3.1

Figure 3.1

4 Future Evolution

Output from a national research and development programme named Futurecoast (Halcrow, 2002) provided the following predictions for the Study Area for the unconstrained scenario over the next century.

It is believed that because Christchurch Bay is relatively young in geological terms, it is still adjusting in response to breaching of the former Chalk ridge extending between the Isle of Purbeck and the Isle of Wight. Consequently, there is a tendency for continued erosion within the bay towards a more mature plan form development. The rate of future plan form development depends principally on the future of Hengistbury Head, which acts as an important control on the development of Christchurch Bay.

As Hengistbury Head is not a static headland composed of resistant rock (common in many headlands elsewhere around the UK coast – e.g. the Isle of Purbeck), but instead is a softer headland control, Christchurch Bay may never fully develop an equilibrium form, but will continue to be re-adjusting. This is because the main headland control on wave diffraction and embayment formation will continually be changing location.

The presence of Christchurch Harbour has resulted in the creation of associated spits which form an important component of the sediment transport system and store volumes of material that may otherwise feed the shoreline. Mudeford Spit typically experiences cycles of growth and breaching.

The spit at Hurst historically has grown and rolled back with rising sea levels a process that still dominates its contemporary and future development. It is, however, unlikely to completely breakdown and disappear over the next century due to the potential for some continued sediment supply from replenishment activities near Hengistbury Head and in central Christchurch Bay, and eroding unprotected sea cliffs in Christchurch Bay. Instead the spit may breach locally resulting in the creation of a new tidal inlet.

Hurst Castle Spit, Central Christchurch Bay, Christchurch Harbour Mouth and Christchurch Harbour are discussed in further detail in the following sections that have been extracted from Futurecoast (Halcrow, 2002).

4.1 Hurst Castle Spit: Local Scale Shoreline Response

4.1.1 Components

This frontage contains a large shingle spit overlying a bench of clay, projecting from Milford-on-Sea into the Western Solent. The spit fronts low lying tidal flats and marshes.

The central section of the spit is swash-aligned, being normal to the predominant south-westerly waves. Although the spit experiences only modest net transport along its length, there is some transport of sand and shingle by strong tidal currents in the Hurst Narrows from the spit to the Shingles Bank, from where it is subsequently re-distributed to other offshore banks and shoals.

4.1.2 Present Management Practices

The spit has been subject to frequent re-profiling, experienced major replenishment in 1996 with shingle dredged from the Shingles Bank and has been armoured with rock at its neck.

4.1.3 Historic Trends

The shingle comprising the spit was derived from erosion of plateau gravels capping the sea cliffs in central Christchurch Bay and through the onshore migration of Solent River valley deposits from the sea bed during the Holocene. Over recent centuries, the spit has further been fed by shingle and coarse sand derived from Tertiary cliff erosion within central Poole and Christchurch Bays and transported eastwards by longshore drift. This led to the elongation of the spit, as marked by a series of recurves towards its distal end, in combination with its rollback across the low-lying backshore in response to changes in sea level.

As sediment input from sea cliff erosion in Poole and Christchurch Bays became significantly lower due to the progression of coastal protection works, so the spit started to become denuded of sand and shingle. This resulted in accelerated landward migration and the onset of breaching in 1954, whereas breaches had not been recorded historically. Temporary breaches in the spit began to occur with increasing frequency, and present management intervention has not completely stopped this natural process

4.1.4 Wider Scale Interactions

The spit is sheltered against waves approaching from southern to eastern sectors by the Isle of Wight. Exposure to the predominant south-westerly waves is reduced by the offshore banks and shoals named Dolphin Bank, Shingles Bank and North Head Shoal. The spit also shelters the tidal flats and marshes of the western Solent.

4.1.5 Future Evolution: Potential Tendency (Unconstrained)

The spit would be fed by material released from erosion of the cliffs to its west. With sea level rise, the spit would continue to roll back across the low-lying hinterland, exposing existing tidal flats and marshes as it does so. A permanent breach of Hurst may not be likely in the short- to mid-term so long as it received sufficient sediment from updrift. In the longer-term breaching remains a possibility; the resulting wave penetration into the western Solent would have serious implications for the tidal flats and marshes at Keyhaven and would leave Hurst Castle exposed as an island.

4.1.6 Future Evolution: Predicted Behaviour with Present Management Practices

Present management activities attempt to maintain a fixed position of the spit in the light of both a diminishing sediment stock and a tendency to migrate landward with rising sea level. Sections immediately downdrift of the existing rock revetment will be susceptible to accelerated erosion and will be highly vulnerable to breaching, unless shingle losses continue to be replaced by periodic recharge and/or recycling. Under this scenario, the shelter that the spit provides to the tidal flats and marshes of the western Solent will remain.

4.1.7 Future Evolution: Uncertainty Classification

Potential tendency for unconstrained scenario: medium uncertainty.
Predicted behaviour with present management practices: low uncertainty.

4.2 Central Christchurch Bay: Local Scale Shoreline Response

4.2.1 Components

This frontage contains a shingle foreshore fronting sea cliffs. The cliffs are intersected by the Walkford Brook at Chewton Bunny and comprise soft and highly erodible Tertiary materials.

4.2.2 Present Management Practices

Although there are long lengths of presently undefended cliff (Steamer Point, Friars Cliff, Naish Cliffs between Chewton Bunny and west Barton-on-Sea, and Hordle Cliff), the remainder has been heavily defended to prevent historic erosion. Cliff management intervention had involved a variety of techniques including toe revetments, re-grading, cliff-face drainage, vegetated swards, rock walls to reduce slip plane activity, diaphragm walls and drains near the cliff top. Rock and timber groynes have also been used to trap drifting foreshore sediment. Some of the foreshore has also been replenished with shingle. At Barton, several cliff re-activations have occurred in spite of the stabilisation schemes.

4.2.3 Historic Trends

Historically, this frontage has been highly erosive since the former Chalk ridge extending between the Isle of Purbeck and the Isle of Wight was eroded during the Holocene. More recently, the rate of erosion increased as coastal defence measures were introduced in Poole Bay, including the Hengistbury Head Long Groyne. This cut off a large volume of sediment that would otherwise have fed the foreshore in Christchurch Bay.

At the west of the frontage, erosion of the cliffs at Highcliffe accelerated as the Mudeford Spit, formerly much greater in length, reduced in size to attain its present position. This exposed the backing sea cliffs to increased marine action.

This frontage exhibits classic examples of downdrift erosion problems as coastal defence works have been progressed and beaches downdrift have been starved of sediments. The principal erosion mechanism is mass movement due to the high content of clay within the cliff. Much work has been undertaken to design and install cliff drainage and walls to reduce the propensity for slipping

Cliff recession has reduced significantly at Hordle where an accreting foreshore of shingle has protected cliff toes over the past century.

4.2.4 Wider Scale Interactions

This frontage is fed by material from as far afield as Poole Bay and contributes sediment to storage zones at Hurst Castle Spit and in offshore banks of North Head Shoal, Shingles Bank, Dolphin Bank and Dolphin Sand.

4.2.5 Future Evolution: Potential Tendency (Unconstrained)

The sea cliffs throughout the frontage would continue to erode through mass movement events at a rapid rate. The sediment released to the foreshore through such recession would initially form talus slopes, but this would relatively rapidly be removed and fed alongshore (shingle and sand) and offshore (fine sand and clays). This progressive clearance of the debris material would leave the cliffs susceptible to further mass movements events.

4.2.6 Future Evolution: Predicted Behaviour with Present Management Practices

The focus of management intervention is on reducing both the marine-induced erosion at the cliff toe (through revetments for example) and reducing the groundwater conditions leading to instability (through cliff drainage measures). Such efforts consequently attempt to maintain a fixed plan-form position of the shoreline. As a consequence, the foreshore sediment will become increasingly denuded and the cliffs will become increasingly difficult to maintain in their present position. Differential erosion of presently protected and unprotected cliffs will lead, over time, to localised embayments between defended hard points.

4.2.7 Future Evolution: Uncertainty Classification

Potential tendency for unconstrained scenario: low uncertainty.
Predicted behaviour with present management practices: low uncertainty.

4.3 Christchurch Harbour Mouth: Local Scale Shoreline Response

4.3.1 Components

This frontage is dominated by the double spits at the entrance to Christchurch Harbour. Mudeford Sandbank Spit on the southern side extends from cliffs at Hengistbury Head. It fronts low-lying tidal flats and marshes and contains some blown sand. Mudeford Quay (or Haven House Spit) on the northern side extends south-south-west from the cliffs at Mudeford across the entrance to Christchurch Harbour.

4.3.2 Present Management Practices

Groynes and rock revetments exist along the seaward face of the spit. Shingle replenishment was undertaken in 1980. Sheet piling is used to stabilise the present inlet position.

4.3.3 Historic Trends

The southern spit has experienced the most change over the past two hundred years. Between the date of the first recorded map in 1785 and 1880, the spit grew considerably and extended across Christchurch Harbour entrance as far as Highcliffe Castle. By 1886, however, a breach had occurred in the spit close to the present harbour entrance. This breach naturally sealed by 1905, re-creating a continuous spit that extended towards Highcliffe. A further breach, in 1924 formed the foundations for the present entrance, leaving the sediment contained within the isolated section to be dispersed by longshore processes and onshore migration, contributing a pulse of sediment to the foreshore stock. In total, the spit went through as many as five cycles of bay-mouth bar building and breaching in the hundred years leading up to 1938. The last breach of the spit occurred in 1935, followed by a few years of elongation.

4.3.4 Wider Scale Interactions

The spits of the harbour mouth are fed by sand and shingle from adjacent frontages and provide important natural protection to Christchurch Harbour. When Mudeford Spit extended across to just south of Highcliffe Castle, it also provided protection to the backing sea cliffs.

4.3.5 Future Evolution: Potential Tendency (Unconstrained)

The supply of sand and shingle from Poole Bay would enable the elongation of the southern spit across Christchurch Harbour, deflecting the entrance to the north-east. In addition to this, the spit would simultaneously attempt to rollback across the low-lying hinterland in response to rising sea levels. The past tendency of the spit to exhibit cycles of breaching and sealing may not re-occur within the timescale of a century due to the relatively large supply of sediment that would be provided from Poole Bay. Instead, spit growth would dominate the next century, providing a degree of natural protection to the cliffs in the vicinity of Highcliffe. Spit breaching would, however, occur over longer timescales, ultimately allowing greater wave penetration into Christchurch Harbour and reducing the natural protection to Highcliffe.

4.3.6 Future Evolution: Predicted Behaviour with Present Management Practices
Present management intervention attempts to maintain a fixed plan-form position of the spit and thereby prevents both its elongation and landward transgression.

4.3.7 Future Evolution: Uncertainty Classification
Potential tendency for unconstrained scenario: medium uncertainty.
Predicted behaviour with present management practices: medium uncertainty.

4.4 Christchurch Harbour

This Type 3a Estuary appears to be rather anomalous in many characteristics. It is the estuary of the rivers Stour and Avon. It has spits at the mouth composed of both sand and gravel that enclose a wide shallow lagoon. The two spits overlap, with that from the west being predominant. The mouth has a very narrow, controlled entrance with jetties and groynes. There is a history of spit growth from the west terminating in breakthrough during times of flood river discharge, and release of sand for littoral drift. There are extensive mudflats and salt marshes. The upper parts of the river valleys have been reclaimed, which provides large flood plains, and limits the tidal volume. The estuary is largely natural, apart from the mouth.

The estuary volume and the cross sectional area are both small, but it appears that they are in reasonable equilibrium. The intertidal area ratio is very low at 0.51, and there should be capacity for further deposition. However, the maximum flow ratio is very high. This suggests that a plume is likely to be formed at all stages of the tide at maximum river flow, and that would tend to keep the estuary clear of sediment. The estuary is ebb dominant, which would also resist deposition.

It is likely that the estuary would be a strong source of fine sediment, and a weak source for coarser sediment. The spit growth interrupts the littoral transport, but little coarse material enters the estuary. The main future problem will be the development of the estuary if the narrow and low lying land west of Hengistbury Head becomes breached. The mouth of the estuary may then try to re-locate.

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