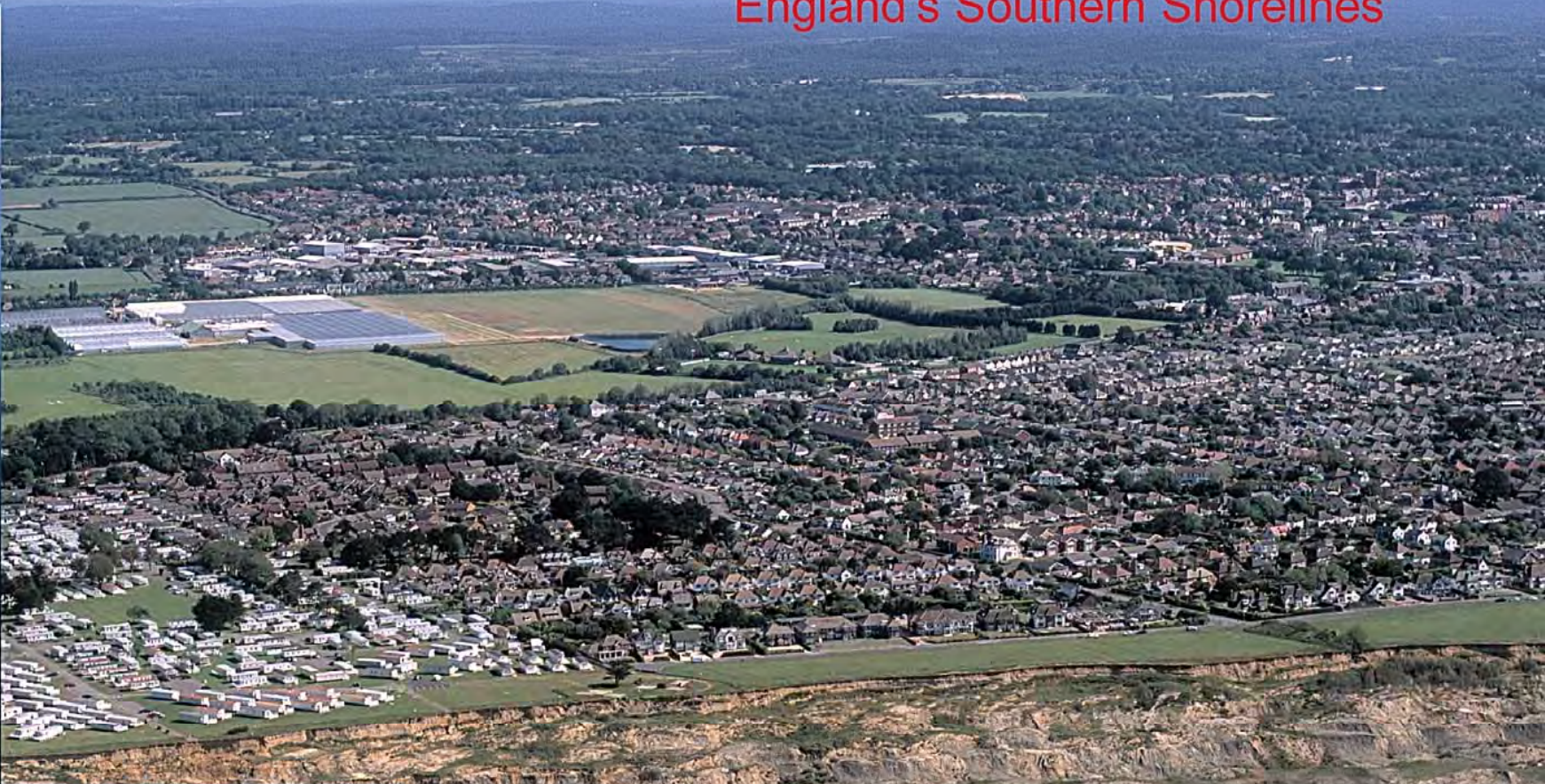


ACCESS

'Adapting to Coastal Change along
England's Southern Shorelines'



Adapting to Coastal Change along England's Southern Shorelines

SCOPAC 'ACCESS' Study





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Figure I.1: Entrance to Portsmouth Harbour

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Figure 1.2: Part of the town of Ventnor and the village of Bonchurch, at the eastern end of the 12km Isle of Wight Undercliff urban landslide complex - the largest in north-western Europe (Case Study D). The Undercliff has been subject to detailed geomorphological investigations, which have not only suggested a preferred approach to risk reduction but have also offered advice and good practice for similar problems internationally.

Executive Summary

The Standing Conference on Problems Associated with the Coastline (SCOPAC) is an influential network of local authorities and other key organisations with an interest in coastal risk management. Established in 1986, SCOPAC's role has been to assist local authorities and others along the central south coast of England in developing a more co-ordinated approach in this field, and, by commissioning research and sharing information, ensuring that a more sustainable approach is developed to coastal risk management. In order to better inform its constituent members and stakeholders SCOPAC has promoted a long-term research programme, which has totalled over £1.2 million in value over the last twenty-five years.

Coastal communities along the south coast of England are on the front line in terms of climate change impacts. Assessments of assets at risk from erosion and instability along the SCOPAC coastline over the last ten years, together with the research into the predicted impacts of climate change, have highlighted the need for more refined assessments to be made of coastal erosion risk, the value of assets currently and potentially at risk and the opportunities for adaptation to the impacts of climate change, looking ahead over the next one hundred years. SCOPAC believes that with this additional information the Operating Authorities and related interests will be significantly better informed in terms of planning and managing coastal risks and, as a result, more capable of addressing the resulting demands in the future.

This research project takes forward recommendations arising from an earlier SCOPAC review of methodologies for appraisal of assets at risk together with the findings of the European Union LIFE Environment project 'Response' (Responding to the risks from climate change) 2003-2006 and the conclusions of the International Conference on 'Landslides and Climate Change - Challenges and Solutions' held on the Isle of Wight in May 2007. Furthermore, this study has been undertaken alongside the completion of the second round of Shoreline Management Plans (SMPs), National Coastal Erosion Risk Mapping (NCERM) and data from the South-East of England Strategic Coastal Monitoring Programme. The SCOPAC 'ACCESS' study, drawing on case study findings, recommends actions to be implemented to address future assessments of 'coastal risk hotspots' along the south coast, supported by recommendations for a more equitable system for valuing assets at risk from coastal erosion and land instability. The study highlights those locations which face particular challenges in terms of coastal risk management, looking ahead over the next century drawing on the best available coastal research.

Councillor Roger Elkins
Chairman
SCOPAC



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Figure I.3: Hurst Spit, Hampshire (Case Study F) provides protection to the village of Keyhaven, the town of Lymington and, more widely, the western Solent shorelines.



Figure I.4: Barton-on-sea, Hampshire and the adjacent Naish Farm frontage (Case Study G) comprise soft rock cliffs affected by toe erosion and landsliding. The site is regularly monitored and of significant concern with respect to the medium and longer term impacts of coastal change.

Introduction

Background to the 'ACCESS' Research Project

The central south coast of England, facing the English Channel, is impacted upon by Atlantic storm waves from the south-west, as well as from waves generated within the Channel itself. This coastline has, historically, experienced rapid rates of coastal erosion, resulting in coastal instability problems, breaching and sea flooding (McInnes *et al*, 2006). England's central south coast supports a high population density, with major cities, towns and smaller settlements as well as important infrastructure located in vulnerable locations.

As a result of climate-induced coastal change including sea level rise, some frontages are already experiencing worsening conditions, particularly more rapid erosion rates and the reactivation of coastal landslides (Moore *et al*, 2010; Halcrow, 2010a). However, the relationship between future sea level rise and the rate of cliff recession is currently less well understood and further research in this area is needed.

As part of the European Union LIFE Environment project 'Response' (Responding to the risks from climate change on the coast) (McInnes *et al*, 2006) a regional-scale assessment was made of the impacts of climate change on the SCOPAC coastal frontage looking ahead to the year 2100. The results indicated that of the total length of the SCOPAC coastline, amounting to 375 km:

- Losses of over 100 m of hinterland are possible over the next one hundred years along 120 km of the frontage;
- 22 km of the frontage are currently experiencing regular inundation by tidal and fluvial flooding;
- 12 km of the coastline and hinterland are currently formed of unstable, unprotected coastal slopes;
- 35 km of coastline are currently susceptible to flooding and erosion hazard;
- 60 km are currently protected by defences but with potential for coastal erosion losses of up to 100m of hinterland possible if defences are not maintained;
- 56 km of low-lying land are currently protected from regular flooding by defences; these frontages have the potential for inundation over the next hundred years due to climate change and loss of defences.
- 8 km of coastline are currently formed by unstable coastal slopes which have some defences and protection measures. Occasional small landslides and localised settlements may take place whilst complete reactivation of landslide complexes and losses of over 500 m of hinterland are possible under various climate change scenarios.
- Approximately 200 km of the frontage are affected by potential flooding and coastal erosion hazard.

The 'ACCESS' study has investigated these increasing problems through an assessment of a number of important research projects (listed below) as well as by examining selected case study sites, representing the range of natural hazards occurring across the SCOPAC region (see Figure 2.1). A further component of this research project has involved investigation of how assets at risk from coastal erosion are currently valued. The current system does not take full account of the wide range of assets at risk; recommendations for improving the risk assessment and valuation, looking ahead for the next 100 years have been proposed.

Research background

Historically, national appraisals of assets at risk from flooding and coastal erosion, including assessments of the potential impacts of climate change, have been undertaken to provide advice and guidance to the Department for Environment, Food and Rural Affairs (Defra) in terms of developing flood and coastal erosion risk management policy and programming (Halcrow, 2001; Halcrow 2004). The results of these studies took account of the best available data at that time. However, it was recognised by the authors that the availability of information, particularly relating to coastal erosion, had, in the past, been limited on account of a lack of both reliable data, and detailed information to support the evaluation of assets at risk over time.

Defra sought to provide improved information on long-term coastal change in support of coastal risk management through funding of a range of further research including the 'Futurecoast' study (Halcrow, 2002), Shoreline Management Plans (Round Two), the on-going Coastal Defence Strategy Study programmes (Defra, 2007), and the 'Risk Assessment of Coastal Erosion' research (RACE; Halcrow, 2006). More recently the Environment Agency has overseen the development of the 'National Coastal Erosion Risk Maps' (NCERM) (Halcrow, 2010b).

Studies commissioned by SCOPAC and the former South Downs Coastal Group (McInnes, 2007), had highlighted the need for a more detailed appraisal of those assets at risk along the central south coast of England as SCOPAC was concerned that some assets and infrastructure were not being included in economic valuations. As a result, the benefit-cost analyses for coast protection schemes sometimes fell far short of reflecting the true value of assets at risk and, as a result, were unable to benefit from grant aid from Defra. The objective of this new study has, therefore, been to provide those involved in coastal risk management, both practitioners and politicians, with succinct advice and guidance on potential erosion and instability risks looking ahead over the next one hundred years, together with ways of encouraging the introduction of improved practices for the identification and valuation of coastal assets over time.

The ACCESS study has been informed by a number of important research projects commissioned in recent years. These have helped advance methodologies for predicting coastal erosion rates, improving the classification of different types of cliff and shoreline behaviour as well as the use of probabilistic approaches to addressing the uncertainty inherent in the coastal erosion process. The key studies have included:

- **'THE INVESTIGATION AND MANAGEMENT OF SOFT ROCK CLIFFS'**: Prediction of recession rates and erosion control techniques (MAFF Research & Development Programme, 1994-2001). The objectives of the research programme included the development of analytical methods of predicting cliff erosion rates for the wide variety of differing situations around the coast (Lee & Clark, 2002).
- **'PREPARING FOR THE IMPACTS OF CLIMATE CHANGE'** (SCOPAC Research Programme, 2000-2001); This landmark project developed a broad-scale approach to evaluating the potential impacts of climate change and relative sea level rise on the levels of risk along the south coast of England. The approach involved identifying and characterising shoreline behaviour models which provide the basis for assessing changes in hazard and risk (Hosking & Moore, 2001).
- **'FUTURECOAST'** (Defra R&D, 2000-2002); This was a regional-scale study of the whole coast of England and Wales designed to inform the approach used in the second round of Shoreline Management Plans (SMPs). FutureCoast provided a robust geomorphological framework for conceptualising coastal evolution. It included a 'cliff erosion database', which defined 'cliff behaviour units' and provided projections of potential erosion rates with or without coast protection measures in place (Halcrow, 2002).

- **'SCOPAC SEDIMENT TRANSPORT STUDY'** (SCOPAC Research & Development Programme, 2003-2005): This project was undertaken by the University of Portsmouth and updated the original SCOPAC study carried out in 1990-91. The Sediment Transport Study provided fundamental information on sedimentary processes, sediment sources, transport mechanisms and deposition around the whole of the SCOPAC coastline (Carter *et al*, 2004).
- **EUROPEAN UNION (EU) LIFE ENVIRONMENT PROJECT 'RESPONSE':** 'Responding to the risks from climate change on the coast' (Isle of Wight Centre for the Coastal Environment and partners, 2003-2006). The objective of this project was to develop sustainable strategies for local authorities and other stakeholders across the European Union to manage natural hazards in the coastal zone through demonstration of an innovative regional-scale methodology for coastal evolution studies and risk mapping, taking account of the impacts of climate change. Sustainable strategies for managing coastal and natural hazards inform land use development and planning by ensuring decisions are compatible with specific local coastal conditions and also future challenges (McInnes *et al*, 2006).
- **'RISK ASSESSMENT OF COASTAL EROSION'** (Defra Research & Development Programme, 2005-2008): The aim of the RACE project was to develop, test and disseminate a robust and consistent probabilistic method for assessing the hazard and risk of coastal erosion. The approach was supported by data and information from the FutureCoast cliff erosion database, monitoring programmes and risk-based inspections. The outputs represent hazard and risk in a manner comparable with the RASP (Risk Assessment of flood and coastal defence for Strategic Planning) method used for flood risk assessment (Halcrow, 2006).
- **'NATIONAL COASTAL EROSION RISK MAPPING'** (Halcrow, 2008-ongoing): NCERM maps erosion/instability around the coastline of England and Wales, taking account of the influence of current coastal defences and management policies. A key aspect of the work is capturing local knowledge and expert opinion using web-based mapping techniques to allow local operating authorities to verify, interrogate and amend input data and provide a live visualisation of the outputs generated. When it is completed, the project will complement NaFRA to provide a complete representation of flood and erosion risks along the coastlines of England and Wales.

Approach to the study

This study has aimed to help fill current information gaps on coastal risks, and their economic consequences, following the identification of some sixty 'hotspots' along the SCOPAC coastline (See Figure 2.1, page 19). A 'hotspot' is a location where more than 40 properties may be lost over the next 100 years under a 'No Active Intervention' scenario. Eleven of the sites, representing the range of coastal hazards, have been the subject of more detailed evaluation; each case study is presented in Chapter Two and the findings are discussed in Chapter Three.

The first chapter of this report explains the background to coastal change along the SCOPAC coastline before considering the hazards and risk to be addressed. Chapter Two introduces the case study sites, explaining why they have been selected before describing the eleven 'hotspots' in greater detail. The findings from the case study investigations and the wider research, including approaches to the valuation of assets at risk, are discussed in Chapter Three, whilst the conclusions and recommendations from the ACCESS study are set out in Chapter Four; an abbreviated Glossary of Terms is provided at the end of the report.

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Figure I.5: The town of Lyme Regis in Dorset was developed on an ancient coastal landslide complex. Over the last 20 years the nature of the problems have been understood following a holistic investigation and comprehensive monitoring programme. Major coast protection works together with cliff stabilisation and drainage have helped reduce landslide risk to the local community.



Chapter One

Understanding coastal change in central southern England

The central south coast of England is composed of a wide range of relatively soft rocks which have been deposited over the last 200 million years. Uplift of the sea floor during the Alpine mountain building phase together with folding, faulting, sea level changes, weathering and erosion have resulted in the present coastal scenery. Along the coast the most marked differences are often created through contrasts between those more resistant rocks, which form headlands and uplands, such as Portland Bill and The Needles, and the sands and clays which form the lowlands and soft cliffline coastal frontages, for example those of the Solent shorelines and the West Sussex coast.

Alongside the processes of weathering and erosion, coastal change is taking place continuously through the transport and deposition of sediment around the coastline, dictated by wave direction and currents. These transport systems may be interrupted by major coastal headlands and estuaries, creating sediment cells. Each sediment cell comprises sediment inputs (i.e. eroding cliffs), sediment throughputs in the form of "longshore drift," sediment stores (i.e. beaches and inter-tidal habitats) and sediment outputs (offshore sediment sinks) (Carter *et al*, 2004). Some famous examples of sedimentary stores include Hurst Spit (Case Study F) which provides some protection for the Western Solent and Chesil Beach (Case Study J) within the East Devon and Dorset World Heritage Site. However, management measures, implemented with good intention in the late 19th and early 20th centuries but constructed without understanding of the coastal system, have in some cases, led to adverse effects downdrift.

Measuring the scale and rate of coastal change

The factors which result in coastal change do not always operate at the same frequency, whilst some factors are more intense than others. Understanding the coastal response may be complex; particular changes in the rate of erosion, scale of landsliding or other factors may depend on certain thresholds being exceeded followed by periods of relative tranquillity until another threshold is exceeded. Some of the factors which lead to more dramatic coastal changes may have, therefore, been influenced by conditions in past decades. All this emphasises the need for particular care to be taken when examining coastal processes and the need to draw evidence from longer term experiences rather than making decisions based upon data derived from a short timeframe. An understanding of the processes at work around the coast is, therefore, fundamental to effective risk management (Hosking & Moore, 2001; Halcrow, 2002).

Research over the last decade has highlighted the increasing importance to considering long-term coastal change (Hosking & Moore, 2001; Halcrow, 2002). Understanding of change in the past through, for example, historical evidence (McInnes & Stubbings, 2011) and long-term coastal monitoring programmes (Bradbury *et al*, 2007) are key to predicting future changes.

Monitoring provides an invaluable data source for coastal scientists and engineers alike, and informs coastal risk management. It also provides a basis for the design and development of coastal protection and landslide remediation works as well as encouraging greater confidence in efficient design of civil engineering works. Future requirements for remediation works can be predicted using monitoring data, which may change the risk management philosophy from a reactive to a more pro-active one.

Quantifying hazards and risks along the SCOPAC coastline

The natural hazards of erosion, landsliding, breaching and flooding have significant impacts along the soft rock, low-lying SCOPAC coastline. The costs of emergency action, remediation and prevention can often represent a significant burden to the communities affected, local authorities with limited resources and for the government. It is now accepted that the impacts of climate change on the coast are real and that sea level rise, in particular, poses serious risks to coastal communities in terms of increased rates of coastal erosion, an increased frequency of landsliding as a result of a wetter climate, accelerated toe erosion and increased flooding.

When these hazards interact with society, coastal risks arise. Risk-based decision-making is seen to provide the means of addressing the challenges put forward by climate change and sea level rise. Risk-based approaches allow an appreciation of the degree of risk reduction and the residual risk that must be borne by society or individuals after mitigation measures have been implemented (Lee & Moore, 2004). In order to identify the risks to assets along SCOPAC's coastline, it is necessary, first, to establish the current level of risk, and then to gain an understanding of the potential increase in frequency and magnitude of hazardous events as a result of coastal climate change.

Box 1.1

KEY TERMINOLOGY

HAZARD	A threatening event, or the probability of occurrence of a potentially damaging phenomenon within a given time period or area.
MITIGATION	Actions which reduce the potential cause of an event e.g. reducing greenhouse gas emissions to help reduce the extent of climate change.
RESIDUAL RISK	The remaining risk after coastal management has taken place, i.e. unexpected events and highly severe flooding.
RISK	Expected loss (of lives, persons injured, property damaged and economic activity disrupted) due to a particular hazard for a given area and reference period. Based on mathematical calculations, risk is the product of hazard and vulnerability. Risk = Hazard x Potential Worth of Loss

Coastal erosion risk

Coastal erosion is a natural process which has helped to create the different landforms we see along the central south coast of England. The erosion process leads to change over long periods of time but may also promote more major landslide events or cliff failures through wave-induced undercutting and beach lowering. A distinction is made between complex cliffs and non-complex cliffs, taking account of the various cliff behaviour types (Moore *et al*, 2010) the effects of toe erosion and groundwater, and the frequency and magnitude of the cliff recession process.

Sea level rise, as well as a predicted increase in frequency of extreme weather events, will have a significant impact on cliffs, slopes and beaches. The maintenance of beaches relies on the balance between the supply and removal of sediment. A rise in sea level, pushing the high water mark further up the beach, more aggressive stronger waves and unpredictable weather events will increase the risks arising from beach change.

Thus the hazard of coastal erosion will increase risks to coastal communities including:

- Risks to life, property, infrastructure and natural resources;
- Destruction of natural or man-made defences, which in turn may result in retrogressive landsliding or flooding of the hinterland.

The cost of reducing coastal erosion risk has, historically, relied almost entirely upon the national budget with funding rarely provided by the local community although some private frontagers do maintain their defences. This issue is of concern to the Government which is consulting on options for funding coastal risk management measures for the future (Defra, 2011). This highlights the importance of understanding the risks, identifying potential 'hotspots' and developing strategies that will inform land-use planning by ensuring decisions are compatible with specific local coastal conditions in the context of climate change.

Landslide risk

In recent decades there has been a significant increase in landslide activity along the south coast of England, comprising both first-time failures as well as the re-activation of dormant landslides. These events have been promoted as a result of increased landslide toe erosion coinciding with increasing amounts of winter rainfall. In these locations ground instability poses significant risks to land use and development; examples from the Hampshire coast (Case Study G: Barton-on-sea and Naish Farm) Dorset coast (Case Study K: Lyme Regis and Charmouth), the Isle of Wight (Case Study D: Ventnor) and elsewhere clearly illustrate its significance (Moore *et al*, 2010a). Over the last 40 years major landslide events have caused substantial damage and loss of property and assets. Problems have often arisen in the past because of the lack of co-ordination between land use planning and decisions over coastal defence and other strategies. Parts of the SCOPAC coast suffer from an inheritance of unplanned communities and developments built on eroding clifftops and in other unsustainable locations - often, but not always, a result of 19th century development, or mass speculative development in the early 20th century.

Whilst major landslide events inevitably lead to significant losses and damage to property in developed areas, minor, longer term failures can also have costly implications through disturbance of structures and damage. This again accentuates the importance of integrating natural hazard management into land-use development and planning policies, particularly as there are few mitigation measures that can be implemented to combat more major ground movement events that occur with little or no warning (Jones and Lee, 1994).

Low-lying coastal features at risk

Saltmarshes

Coastal saltmarshes form the upper vegetated parts of inter-tidal mudflats, creating a "living" buffer between land and sea and providing a valuable habitat for birds and invertebrate species. Saltmarshes are located in sheltered areas, regularly inundated by the sea between high water neap and high water spring tides. Saltmarsh systems are characterized by halophytic vegetation, showing distinct landward zonation from mudflat through to low or pioneer marsh, middle marsh, high or mature marsh and terrestrial vegetation. This succession is according to frequency of tidal inundation and species competition.

The Strategic Coastal Monitoring Programme reported approximately 1700 ha of saltmarsh across the SCOPAC region in 2008 (Figure 1.1), which forms a very important natural defence against storm attack and subsequent flooding or erosion. In addition, the saltmarsh systems

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across the SCOPAC region are heavily designated for their ecological importance at international, national and local level.

The systems have, however, been declining in area since the 1930's due to dieback of the hybrid cordgrass *Spartina anglica* and in more exposed locations such as Lymington, because of wave attack on the seaward edge of the marsh (see Case Study E: Lymington to Beaulieu and Case Study C: Langstone Harbour). This is cause for concern for nature conservation and coastal risk management reasons.

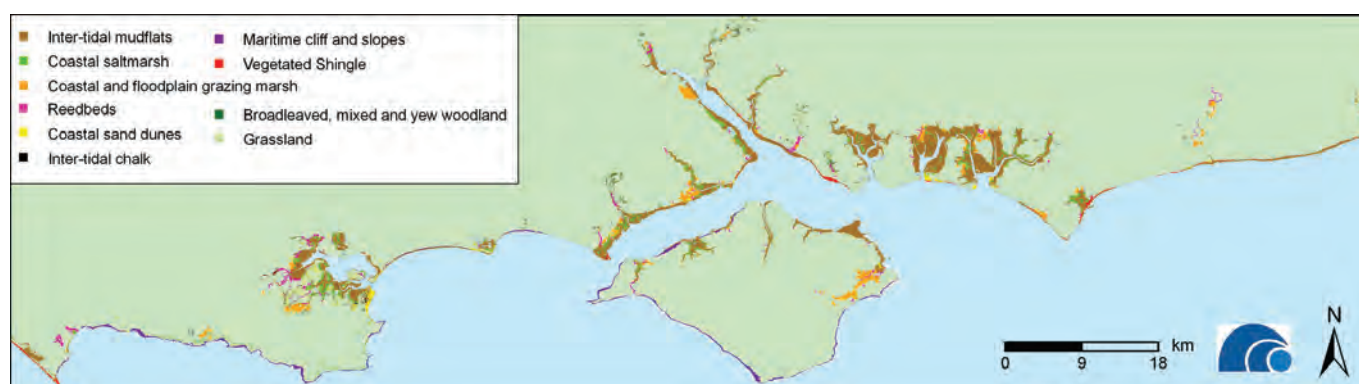


Figure 1.1: An example of coastal habitats from the SCOPAC region © CCO (2008).

Sand dunes

Sand dunes form in areas where dry inter-tidal sand is blown onshore with frequent, strong winds under a process known as saltation. The mobile sand gets trapped around small objects such as strandline material, which eventually becomes vegetated, forming embryo dunes. As the embryo dunes increase in size they are less frequently covered by the tides, allowing more vegetation to colonise and in turn secure the system further. Sand dunes can range from stable to shifting (mobile features); those in the SCOPAC region tend to be stable features (Figure 1.1), although both Studland Spit in Dorset (see Case Study H: Studland) and East Head Spit in Hampshire are undergoing some erosion.

The survival of sand dune systems is very much dependent on a steady supply of sand and the ability of the vegetation to maintain ground cover whilst migrating inland with sea level rise. In addition, fire, local wind acceleration and trampling must be kept to a minimum in order to maintain the vegetation and avoid, "blow outs" from occurring. The extent of frontal dune erosion may increase in the next century as a result of increased storminess and sea level rise, and this may have negative impacts on the extent of some dune habitats and the effectiveness of dune systems as flood defences (Pye *et al*, 2007). The most substantial dune system in the SCOPAC region is Studland sand dunes (see Case Study H: Studland).

Barrier beaches, spits and fringing barrier beaches

Barrier beaches in the SCOPAC region are linear shingle features, attached to the coastline and backed by lowland or lagoon. Conversely, spit features are comprised of either shingle or sand, are attached to the coastline at their proximal end and are free standing at their distal end (see Case Study F: Hurst Spit). Both systems offer a dissipative barrier against wave attack and often provide shelter to inter-tidal habitats (see Figure 2.1).

Barrier beaches and spits are dynamic features undergoing landward rollover through processes such as overtopping, overwashing, breaching and re-sealing. Where sediment input keeps pace

with sea level rise the barriers will migrate onshore through landward rollover and spits will continue accumulating sediment at their distal ends. Throughout the SCOPAC region, sediment input to these systems is restricted by hard engineering solutions resulting in barrier and spit breakdown and the risk of permanent breaching or complete overwashing and overstepping of the system (Cope 2004; Stripling *et al*, 2008).

There are limited examples of natural barrier beach and spit features in central southern England. Many features have been highly engineered with sea defences to provide flood protection to assets at risk in the hinterland (see Case Study A: Worthing) or have rolled onshore to meet rising ground.

A continuous barrier beach, starved of sediment will eventually be completely overwashed during a high storm or swell wave event or will breach to form two spits. Where sediment supply increases in time, these spits may re-seal to form a continuous barrier beach once again. This cycle has taken place over a 60 year period at Sowley (see Case Study E: Lymington to Beaulieu) and a similar scenario would possibly progress at Pagham Harbour, West Sussex if there was no human intervention.

Flooding risk

Coastal flooding, affecting villages, towns and cities along the SCOPAC coastline, can result from a combination of tide and surge levels that exceed the levels of sea walls but are more usually due to wave action in combination with high water levels. Close to the shore the maximum wave height is closely related to the water depth and the amount of wave run-up and overtopping is a function of the nature and configuration of the shoreline. Coastal defence infrastructure including sea walls, tidal barriers and related measures influence pathways and aim to control the impact that water flowing over defences or through breaches can have on the coastal floodplain. Sea walls often operate in combination with beach and foreshore management techniques such as beach recharge, groynes and breakwaters to control wave energy and improve the resilience of the coastal structures and limit wave overtopping.

Without suitable action it is expected that flood risk will increase to unacceptable levels affecting not just people and property but also businesses, hospitals and emergency services. The integration of flood risk into the planning and development process is one way of helping to reduce future costs for coastal communities in terms of economic, social and environmental losses.

Quantifying and mitigating risks

The risks resulting from natural hazards in coastal zones fall broadly into three categories: economic, social and environmental. The direct economic costs can be divided into two main categories:

- The costs of emergency provision and remediation in the occurrence of a hazardous event (most applicable to landsliding and flooding);
- The financial costs of mitigating against the risks associated with natural hazards.

Economic costs are the greatest in financial terms and are perhaps the most important from the perspective of local authorities and other organisations responsible for managing coastal risks. However, there are also other 'indirect costs' such as insurance costs, depreciation of property or land values and legal actions.

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The cost of an emergency response may include emergency coast protection works, evacuation, provision of temporary accommodation, mobilisation of emergency and relief services, cost of investigations, transport delays and other interruptions. Mitigation is also very costly and involves research into coastal evolution, hazards, and risks and the preparation of high level plans and strategies to support the formulation of planning policies; the cost of coast protection schemes including design and construction, as well as the cost of coastal monitoring.

The *social* costs of coastal hazards are largely intangible. Fatalities can be measured in real terms whilst health-related factors such as stress and depression, cannot be measured in the same way. Other factors that may impact upon the individual or society are largely related to inconvenience and are also difficult to measure.

Environmental costs are difficult to quantify and to date have been based on the cost of recreating the lost or damaged habitat (see Case Study C: Langstone Harbour). There are a wealth of ecologically important sites across the SCOPAC region (e.g. Special Protection Areas (SPAs), Special Areas of Conservation (SACs), Ramsar sites and Sites of Special Scientific Interest (SSSIs)) and legislation requires the protection of these sites from erosion or flooding in order that they are maintained in a favourable condition. Where a plan or project is likely to have a significant effect on a European designated habitat, an Appropriate Assessment is required which details area and location of habitat lost and any mitigation or compensation requirements (The Conservation of Habitats and Species Regulations 2010), resulting in significant additional costs for construction projects.

Costs arising from natural hazards can prove to be a significant burden for local taxpayers, particularly in terms of funding the emergency response. A changing climate will increase this burden as the events become more frequent and impacts more extensive. Emergency response plays a key role in minimising the potential costs of a hazardous event. Early warning and preparedness are primarily a means of reducing the social costs of hazardous events, particularly those of the type considered in this publication, enabling evacuation procedures to be effectively implemented and at-risk communities to seek refuge. To this end, early warning systems consist of three elements:

- Forecasting and prediction of impending events;
- Processing and dissemination of warnings to political authorities and the population;
- Undertaking appropriate reaction to warnings.

These measures enable the cost in human suffering and loss of life to be minimised but the economic losses of an inevitable event are more difficult to control, particularly in the case of property loss due to landsliding.

Implementing coastal risk management

The development of sustainable policies for risk reduction in coastal areas necessitates a strategic approach. The second round of Shoreline Management Plans (SMPs; Defra, 2006) provide a large-scale assessment of the risks associated with coastal processes and allows the development of a policy framework to reduce these risks to people and the developed, historical and natural environments in a sustainable manner. In doing so, these 'high level' documents form an important contribution to the national strategy for flood and coastal erosion risk management and aid the government to determine future national funding requirements. The second round of SMPs integrate with other types of coastal plans including Estuary Management Plans, Catchment Flood Management Plans and the over-arching Coastal Zone Management Plans, and inform key development plans including Regional Spatial Strategies and Local Development Frameworks.

A variety of responses are available to Coastal Protection Authorities in terms of managing coastal risks including:

- Avoiding inappropriate development in vulnerable areas through land-use planning or realignment of the coastline in a managed way;
- Reducing the likelihood of loss of life and property along the coast through effective shoreline management engineering techniques;
- The provision of suitable warning systems;
- Protection against damaging storm events through flood and coastal defence schemes or building modifications.

It is clear, therefore, that a key benefit of the second round SMP process is the 'joined-up thinking' which can be achieved through participation in Regional Coastal Groups, which bring together coastal engineers from adjacent local authorities, with the Environment Agency, County Councils, Natural England and other key stakeholders. Coastal Groups ideally contain a cross-section of flood and coastal erosion engineers, strategic planners and environmental and other interests. The need for close liaison between the coastal defence authorities and the local planning authorities cannot be over-emphasised. Throughout the development of both SMPs and local authority development plans there are strong links and interactions. For example, the development plan can provide information to assist the preparation of the SMP, and equally the adopted SMP will provide informal support and contribute to the development plan and its future reviews (Ballinger *et al*, 2004).

The SMP also informs the development control process by providing information on coastal evolution and coastal risks, and the suitability or otherwise for development of land adjacent to particular parts of the coastline. In summary, therefore, the second round SMPs support the planning system, firstly, at a sub-regional level by identifying those issues that need to be considered over a wider area than that of a single local authority, and, second, by informing the local planning authority of shoreline management issues and identifying areas at risk from flooding, coastal erosion and instability over the next 100 years (Moore *et al*, 2010b; Halcrow, 2010).

Adapting to coastal climate change

Climate change, with less predictable weather patterns and the risks from sea level rise, bring new challenges for coastal management in central southern England. If nothing is done to adapt, then many communities could see the level of risk increase each year; the second round SMPs are used, therefore, as high level strategic planning documents, providing a framework for effective coastal management.

The second round of SMPs reflect future risk and set out protection options, where possible, and necessary. There must be flexibility in the design and location of new coastal developments and some existing settlements may have to be moved to safer locations over time. Decision-making will be informed by the Environment Agency's coastal erosion risk maps and the new guidance on funding of coastal protection (Defra, 2011) as well as the outcomes from Defra's 'Coastal Pathfinder Programme' (Defra, 2010) and further research being undertaken with financial support from the European Union Interreg 2Mers Programme (European Commission, 2011).

Ongoing partnerships working between the Environment Agency, local authorities, Coastal Groups and SCOPAC will be essential to tackle increasing risks and to meet the challenge of creating a sustainable coast.

Coastal communities and local partners in coastal change hotspots will need to work together and to plan how to adapt to the effects of coastal change based on the sound science provided in the Shoreline Management Plans and Strategic Coastal Monitoring Programmes.

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Chapter Two

Introduction to SCOPAC 'Hotspots' and case studies

The following chapter introduces areas at risk of coastal erosion, cliff instability and coastal flooding across the SCOPAC region, termed "hotspots". Areas at risk of flooding were included for comparison, to provide a context for the hotspots associated with cliff instability and erosion. Case studies were selected from the hotspots to raise awareness of the hazard potential, for a range of geomorphology types.

In order to identify the generic risk across central southern England, the following datasets were collated and inserted into a Geographical Information System:

- Second generation Shoreline Management Plan shoreline erosion and cliff instability predictions;
- Environment Agency's 2008 (1:200 year) floodzone 3 mapping data;
- Environment Agency's 2009 Address-point data.

Under a "do nothing" scenario, where more than 40 properties were identified as being at risk from erosion, instability and/or flooding over the next 100 years, the SMP Management Unit was identified as a hotspot (Figure 2.1). Saltmarshes, barrier beaches, spits and sand dune features were also identified as hotspots where they assist in protecting over 40 properties at risk from erosion or flooding. The hotspots were cross checked with crunch sites identified in the "Adapting to Changing Coastlines and Rivers," Making Space for Water Strand SD2 paper (Taussik *et al*, 2006) and categorized into the following geomorphology and corresponding hazard types:

Geomorphology	Hazard
Barrier beaches or spits	Breaching followed by flooding
Fringing barriers	Erosion followed by flooding
Sand dunes	Erosion
Saltmarshes	Erosion
Lowland areas	Flooding
Simple cliffs	Erosion
Complex cliffs	Instability



Figure 2.1: Coastal change 'hotspots' across the SCOPAC region

The method applied in this study does not highlight smaller conurbations or privately owned land which may be at risk from erosion or flooding in the future. An example of this issue is highlighted in more detail in Case Study E: Lymington to Beaulieu.

Figure 2.2 depicts the number of properties at risk for each hotspot. The size of the symbol is dependent on the number of properties at risk from the hazard.

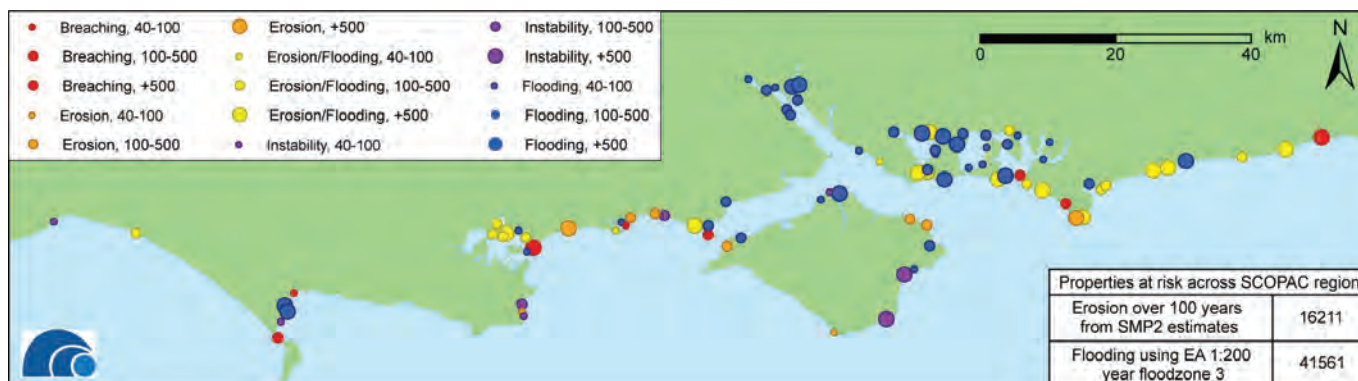


Figure 2.2: Number of properties at risk across the SCOPAC region

The ACCESS project is primarily interested in the process of cliff instability and erosion rather than flooding. Of particular interest are barrier beaches and spits, fringing barriers, sand dunes and saltmarshes as these geomorphological features and associated hazards have not been investigated in as much detail on a national basis. Figure 2.3 presents those case studies used to illustrate the issues associated with breaching, erosion, instability and erosion followed by flooding. The case studies demonstrate different methods of predicting erosion, site specific monitoring, management to prevent erosion and consequent flooding, and adaptation measures.

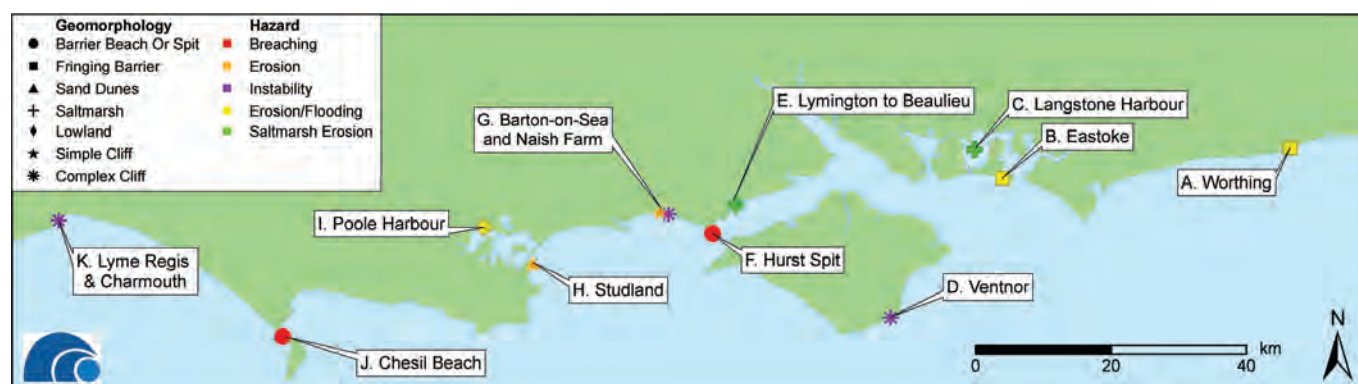


Figure 2.3: Case studies

The method used in this study to identify the numbers of properties at risk and the value of the assets at risk was based on a high level technique applied in the second round Shoreline Management Plans. The data used to identify the properties at risk and the average local authority property prices applied, result in a major underestimation of value (see Chapter 3). Therefore, the values of the properties at risk, as quoted in the case studies, are to be used with caution.

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CASE STUDY A: WORTHING

Location: The Worthing frontage is located between Bognor Regis to the west and Shoreham to the east, West Sussex (Figures a.1 and a.2).

Why was the study area chosen?

The Worthing frontage and the adjacent beaches between Selsey Bill and Brighton are examples of highly managed fringing barrier structures, replenished with shingle when necessary, particularly at east Worthing and Lancing, to prevent erosion and overtopping, thereby protecting the many residential properties from subsequent land loss and flooding under a "do nothing" scenario.

1. Overview

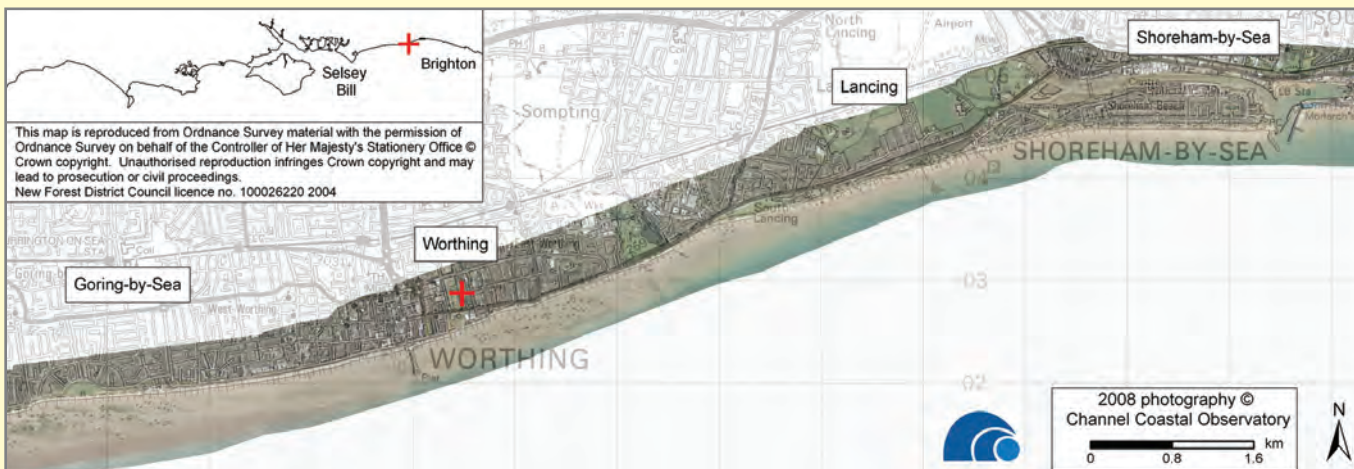


Figure a.1: Worthing, West Sussex

The Worthing frontage is representative of other relict barrier beach structures along the SCOPAC coastline, whereby sediment supply is now limited and the beach has lost many of its natural defence mechanisms against storm attack, thereby requiring pioneering coastal management techniques to prevent erosion and flood risk to the adjacent properties.

2. Geological and Geomorphological setting

The SCOPAC Sediment Transport Study (Carter *et al*, 2004) postulates that Worthing beach and the surrounding area is a product of a series of ancestral shingle barrier beaches located seaward of the present shoreline, combed up and driven landwards as sea levels rose throughout the early Holocene transgression. The beach consists of a predominantly steep and often narrow gravel backshore and low gradient wide sandy foreshore, being a product of inundation and erosion of the coastal plain over the past 15,000 years. There is still a continuing tendency for the beach to migrate landwards but like so many of the relict barrier beaches in the

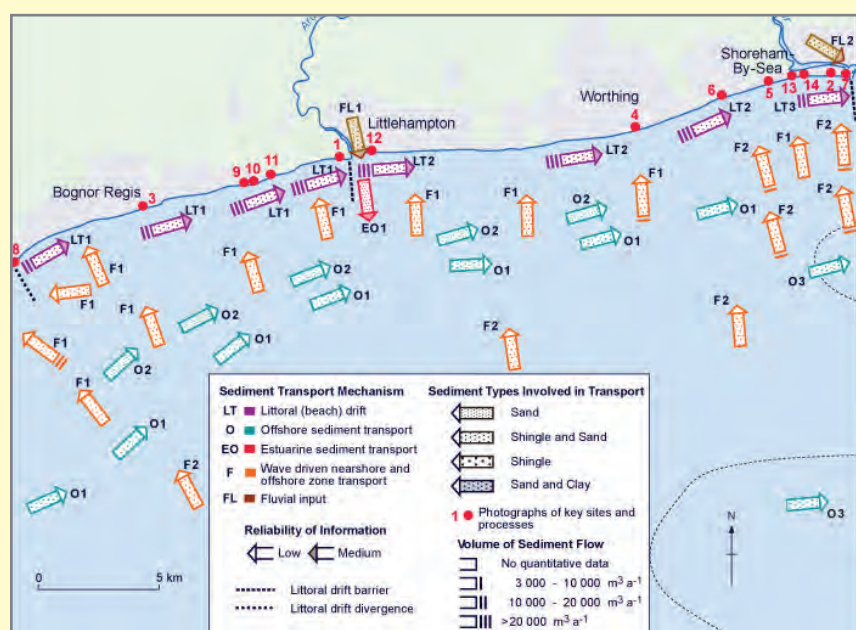


Figure a.2: Sediment transport for Worthing © SCOPAC Sediment Transport Study (Carter *et al*, 2004)

SCOPAC region which are highly managed, most of the original barrier beach characteristics, such as a low wide crest, seepage cans, overwash fans, natural sediment sorting and dissipative response to storm attack have been lost.

3. The nature of historical evolution and coastal risks

The SCOPAC Sediment Transport Study (Carter *et al*, 2004) notes that the fringing barrier beaches between Selsey and Brighton are almost completely defended by seawalls, revetments and groynes and are heavily managed following increasing urbanisation since the 19th Century. These hard defences, as well as the breakwaters and training structures stabilizing the mouths of the rivers, have significantly reduced the net drift of the shingle, but have only partially affected transport of sands on the lower foreshore. This has resulted in downdrift shingle deficits with natural sources of shingle supply reduced. As a consequence, beach renourishment has been undertaken since 1989. In addition, the Environment Agency placed approximately 170,000 m³ between Lancing and Shoreham between 1991-1998. The hinterland of Lancing, east Worthing and Goring-on-Sea are below maximum high water and have been subject to repeated flooding during storm events (Figure a.1).

4. Current Situation and Approach

- **Investigation and monitoring**

Since 2002, the South-east Strategic Regional Coastal Monitoring Programme (SSRCMP) has monitored beach changes on an annual basis. Monitoring and research of the surrounding area is important for the Goring-by-sea, Worthing and Shoreham frontage in order to identify sources of suitable material for extraction and recycling. Aerial photography is flown every year and Lidar is flown for the frontage every 5 years. In addition, sea defences are regularly monitored by Worthing Borough Council, to ensure they are operating at optimum efficiency.

- **Methods used to predict the Hazard and Risk Potential at Worthing**

The problem with quantifying erosion risk for frontages such as Worthing is that defences of some form were constructed by the mid-1940's, meaning historical aerial photography becomes a redundant method of measuring change (see Case Study E: Lymington to Beaulieu). Historical maps may provide some evidence of change but cannot be used with any great certainty given the error associated with them. Worthing Borough Council investigated historical maps, dating from 1699, to identify coastal change and found the average annual erosion rate to be in the region of 1.5m to 2.5m per annum. Abrupt changes in coastal orientation, such as the event between 1700 and 1820 when 180-275m of land was washed away in front of Worthing, may well be indicative of an overwashing and breaching event when the ancestral barrier spit, terminating at Shoreham was not backed by hard sea defences. Not being able to determine a robust erosion rate results in disparities between local and national predictions of risk.

- **Current status and actions: how are we adapting to coastal climate change in this location?**

Between the late 1980's and early 1990's, the low lying hinterland around Goring suffered approximately 12 flooding events, all of which were attributed to seepage through the barrier (except one event), indicating a well sorted, dissipative barrier. An alleviation scheme was proposed in the Rivers Arun to Adur Coastal Defence Strategy (Scott Wilson Kirkpatrick, 1999) to construct an impermeable wall within the existing shingle bank, which would stop any

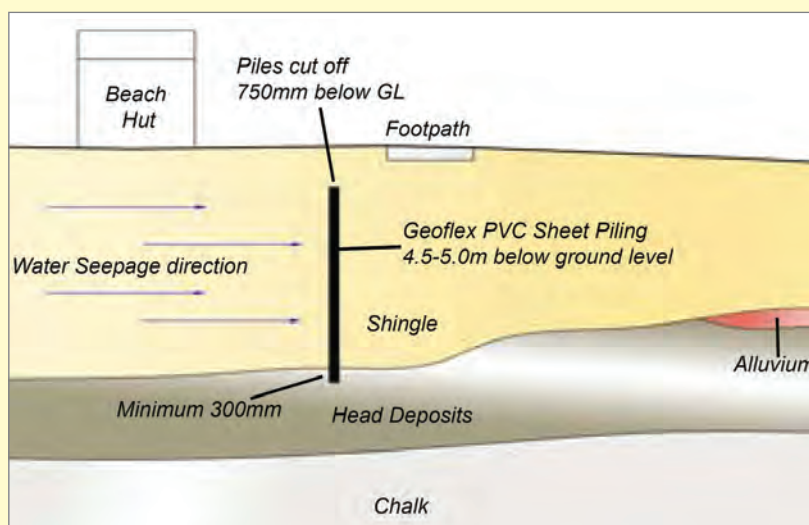


Figure a.3: Cross section through beach © WBC, scheme K (Worthing Borough Council, 2006)

sea water penetrating through the bank and flooding the land behind (Worthing Borough Council (WBC), scheme K, 2006). By March 2006 a 5mm thick 197mm wide PVC Geoflex sheet piling was inserted through the shingle bank into Head Deposit material which was located approximately 5m below ground (Figure a.3). The Head Deposits are a less impermeable material than that of shingle and would allow the piling to form an impermeable barrier and stop the water from passing through the bank (Figure a.3). The scheme has been successful in alleviating percolation of water through the barrier beach.

In terms of recent sediment losses and gains along the Goring-by-sea to Lancing frontage, between 2003 and 2008, the net loss was 233,454m³ (Figure a.1). Erosion was consistent along the beach but was focused on the lower foreshore. The net loss takes into consideration the 107,683m³ of material placed at Lancing during the Shoreham to Lancing Renourishment Scheme in 2005 and a further 9,800m³ of material, originating from the beach further east placed in this area in November 2007 during the Emergency Replenishment Scheme (Worthing Borough Council, 2009). In contrast, the Lancing to Shoreham frontage (Figure a.1) accreted with a gain of 348,942m³, although 274,664m³ of material gain was imported during the 2003 to late 2005 Shoreham to Lancing Renourishment Scheme. In addition, 59,793m³ material was moved to the east side of Shoreham and as already mentioned, 9,800m³ of material was removed for replenishment at Lancing. Therefore the net gain of material on this frontage was 143,871m³ (Worthing Borough Council, 2009).

Given the built up nature of the Goring-by-sea, Worthing and Shoreham frontage and the tourist and heretige value of the area, it was given a Hold The Line policy for 100 years in the Beachy Head to Selsey Bill Shoreline Management Plan (Halcrow, 2006). Continued renourishment works and defence upgrade and renewal were suggested as ways of holding the line, although the plan acknowledged that the beaches may reduce in volume towards the end of the 100 years.

5. Key issues: What can we learn from this site to inform coastal risk management and adaptive planning?

It should be noted that a barrier beach feature will perform better under storm attack when it can naturally roll onshore through the processes of overtopping and overwashing, producing a highly dissipative bank through natural sediment sorting and seepage cans (Cope, 2004). Still, the Worthing frontage and adjacent beaches are a good example of heavily developed hinterlands which do not have the capacity or space to "roll back" and, therefore, have to take a more hard engineering, preventative approach to coastal Management given that the only solution is to manage the risk. Scheme K is a good example of pioneering engineering works necessary to prevent seepage, erosion and flooding of these fringing barrier features once alternative soft engineering works are no longer an option (Figure a.3).

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CASE STUDY B: EASTOKE

Location:

Eastoke, Hampshire is located on the eastern southern shore of Hayling Island.

Why was this study

The frontage is replenished with shingle on an annual basis to prevent beach erosion and overtopping and to protect the many residential properties from subsequent flooding. The site is a good example of a fringing barrier beach that is susceptible to erosion followed by flooding under a "do nothing" scenario.

1. Overview

Eastoke peninsula is the most eastern point of Hayling Island located in the east Solent region (Figure b.1 and b.2). There is a drift divide to the west of the Eastoke peninsula (Figure b.2); sediment entering the system from offshore is either transported in an easterly direction along the Eastoke frontage, around Eastoke Point into the mouth of Chichester Harbour, terminating at Black Point spit or is transported in a westerly direction before reaching another drift divide at Gunner Point (Figure b.2). There is a large conurbation of residential properties situated at Eastoke, protected by a groyined beach, seawall and annual beach



Figure b.1: Eastoke, Hayling Island

nourishment schemes. If it wasn't for the intense management of the site, there would be rapid erosion of up to 2m per year.

2. Geological and Geomorphological setting

It is thought that Eastoke was once part of a "super" barrier extending from Selsey Bill to Portsmouth, combed up from fluvially deposited gravels as sea levels rose throughout the early Holocene transgression (Figure b.3). The super barrier would have been relatively stable as it rolled onshore due to an abundance of sediment supply in relation to sea level rise. Relict barrier islands named the Mixon Shoal and Owers, situated offshore from Selsey Bill indicate that the barrier continued to migrate inland 2,000 to 3,000 years B.P. (Wallace, 1996) (Figure b.3). The beach consists of a predominantly steep and

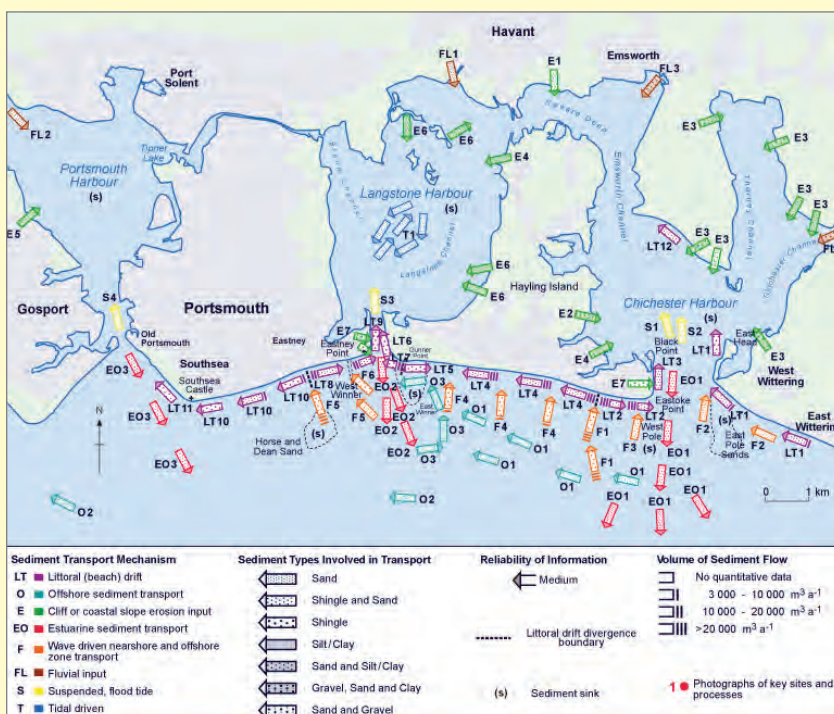
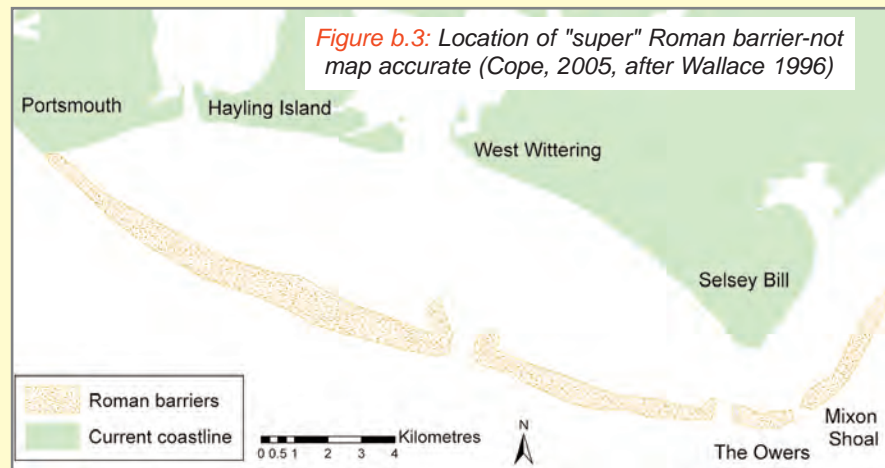


Figure b.2: Sediment transport around Portsmouth to Chichester Harbour entrance © SCOPAC Sediment Transport Study (Carter et al, 2004)

often narrow gravel backshore and low gradient wide sandy foreshore, being a product of inundation and erosion of the coastal plain over the past 15,000 years.

3. The nature of historical evolution and coastal risks

Havant Borough Council report that, since the early 1920's the Eastoke Peninsula was increasingly developed as a residential area. Natural erosion of the foreshore made it necessary to build defences to protect these properties. By 1974, extension of the seawall to the east and west of the frontage (2.6 kilometres) was exacerbating erosion as the fringing barrier tried to re-align further inland to its natural position. By 1985 the frontage was regularly overtopped and flooded; as a result a Beach Replenishment Scheme was implemented which imported half a million cubic metres of shingle from the Owers Bank (Figure b.3) and placed it on the beach over a length of 2.2 kilometres. This alleviated further incidents, although by 1987 timber groynes were built to try and halt the rapid transport of material along the frontage and in 1990 a rock groyne was constructed to further reduce loss of material around Eastoke Point. Following the success of the 1992 Beach Management Plan, the council approved recommendations to defend the frontage against a 1 in 200 year storm event by undertaking annual beach recycling and periodic beach nourishment, which is still in operation.



4. Current Situation and Approach

- Investigation and monitoring**

Since 2002, the South-east Strategic Regional Coastal Monitoring Programme (SSRCMP) has monitored beach profile changes on an annual basis using kinematic GPS. Monitoring and research of the surrounding area is important for the Eastoke frontage in order to identify sources of suitable material for extraction and recycling to the Eastoke promenade area. Aerial photography is also flown every year and Lidar is flown for the frontage every 2 years (www.channelcoast.org). In addition, groynes and revetments are regularly monitored by Havant Borough Council, to ensure they are operating at optimum efficiency.

- Methods used to predict the Hazard and Risk Potential at Eastoke**

The North Solent Shoreline Management Plan (SMP) (New Forest District Council, 2010) predicted what would happen to the shoreline if all coastal management ceased, otherwise known as a, "No Active Intervention" scenario. Figure b.4 depicts this scenario which was devised using erosion rates provided by Havant Borough Council (HBC). The No Active Intervention scenario anticipates that in the next 20 years the Eastoke coastline to the east of the drift divide would recede by up to 42m if recharge operations ceased and defences failed. There are no properties predicted to be in the erosion zone for the 0-20 year epoch at Eastoke, although £218m worth of property is at risk within the EA flood zone 3 area due to its low lying topography. If the defences were to completely fail, erosion would be rapid as the beach attempts to reach equilibrium. Over 170m of retreat from the present day between Eastoke and the Chichester Harbour Entrance is predicted, which would cause loss of £169m worth of properties in total over 100 years. The existing flood risk zone will extend further north impacting on £332m worth of properties in 100 years time (Figure b.4). The assets at risk will be much higher following more detailed methods of assessment and property values applied at Strategy level. Being a high level document, the SMP did not attempt to predict coastal evolution for the stretch of coastline between Eastoke and Black Point Spit as the coastal processes in operation are extremely complex.

• **Current status and actions: how are we adapting to coastal climate change in this location?**

In order to raise the Eastoke beach to the recommended 1 in 200 year Standard or Protection, HBC successfully completed a Beach Nourishment scheme which involved placing 25,000m³ of material on the frontage of Eastoke in 2008 and a further 65,000m³ of material in 2009 (Havant Borough Council). The Eastoke frontage has a Hold The Line policy for the next 100 years in the recent North Solent SMP (New Forest District Council, 2010). This does not guarantee public funding for new works but does provide an indication of the intended broad scale, long term management of the site. Plans for the immediate future involve continuing with the Hold The Line policy by improving the existing rock structures and strengthening the groyne field.

The predicted effects of climate change and sea level rise present a significant challenge for future coastal management of the site. HBC note the key pressures are as follows:

- Increased problems of overtopping of existing defence structures due to sea level rise.
- Increased beach volatility and increasing sea levels, resulting in beach recharge schemes requiring greater material volumes.
- Diminishing beaches reducing both support and protection of structures.
- Higher sea levels resulting in greater wave heights at the shoreline and increased wave forces on structures.
- Potential changes in patterns of long-shore drift resulting in altered patterns of erosion and deposition.
- Increased potential for 'flash flooding' of low-lying areas by intense rainfall events.

5. Key issues: What can we learn from this site to inform coastal risk management and adaptive planning?

Eastoke is representative of many sites across the SCOPAC region that are dependent on annual beach recycling and maintenance of hard structures to protect the many assets from erosion followed by subsequent flooding. Continued strategic coastal monitoring and ongoing research undertaken by HBC and the South-east Strategic Coastal Monitoring Programme will contribute to the understanding of the dynamic coastal processes in operation along this stretch of coastline, which in turn will form the basis of future coastal management for the southern Hayling Island frontage.

Further Reading

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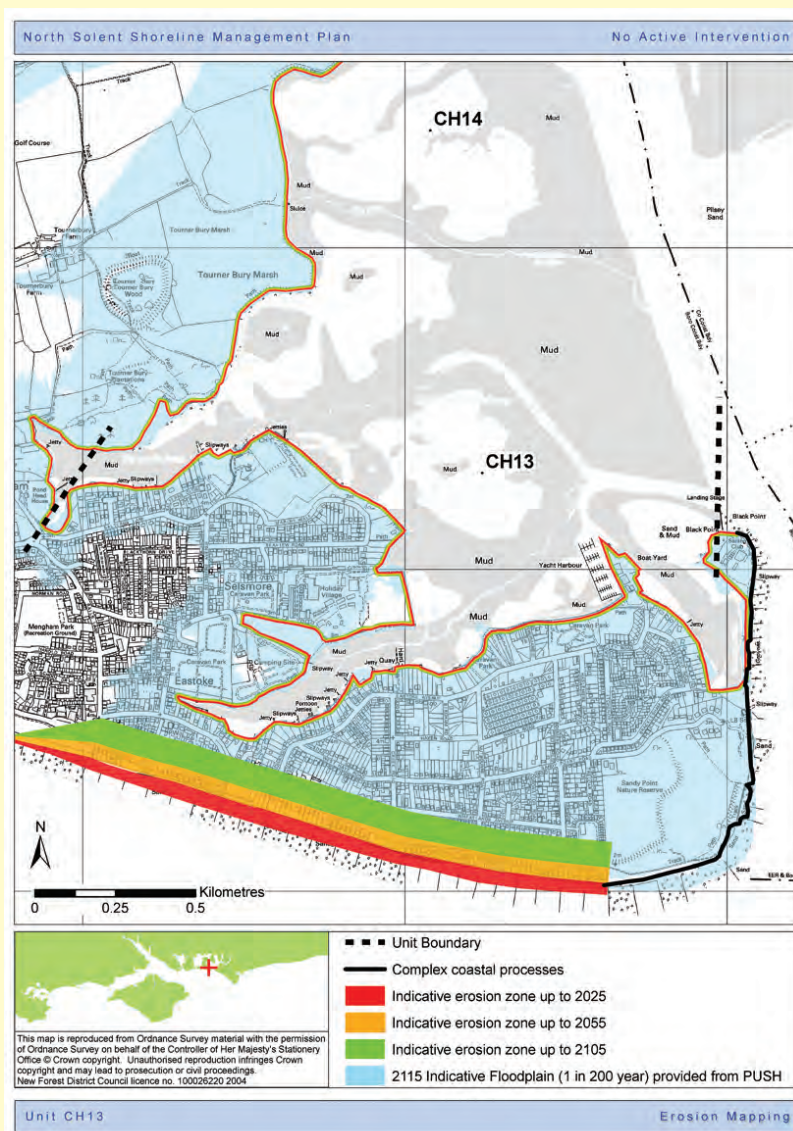


Figure b.4: Erosion under a No Active Intervention scenario
 © North Solent SMP (New Forest District Council, 2010)

CASE STUDY C: LANGSTONE HARBOUR

Location:

Langstone Harbour, Hampshire is located between Portsmouth Harbour to the west and Chichester Harbour to the east (Figure c.1).

Why was this study area chosen?

The rapid decline of saltmarsh habitat in Langstone Harbour since circa 1930 is representative of all saltmarsh sites across the SCOPAC region but in particular, the north Solent region. This is cause for concern in terms

of coastal management where the saltmarsh acts as a primary defence or is coupled with hard defences, and nature conservation, given that the majority of SCOPAC's saltmarsh habitat is designated as part of the European Natura 2000 network and requires replacement habitat under human induced losses. This case study will focus on Farlington Marshes as an example of nature conservation requirements under climate change.

1. Overview

Langstone Harbour is one of three interconnecting harbours situated in the north Solent region; Portsmouth, Langstone and Chichester Harbour are characterized by European designated mudflat and saltmarsh habitats, with grazing marsh habitats positioned on higher land or behind coastal defences. All three harbours are heavily defended by a combination of seawalls, revetments and natural embankments which inhibit natural migration of inter-tidal habitat, resulting in coastal squeeze. The majority of the defences are nearing the end of their residual life in the next 20 years and any upgrade will require replacement inter-tidal



Figure c.1: Historical loss of saltmarsh in Langstone Harbour

habitat to offset that predicted to be squeezed out over the lifetime of any scheme under the Conservation of Habitats and Species Regulations 2010. Natural England advise that any replacement inter-tidal habitat should be as close to the damaged European site as possible which is a challenge given the built up nature of the hinterland and the fact the majority of potential inter-tidal habitat creation sites are already designated for their bird function.

2. Geological and Geomorphological setting

The SCOPAC Sediment Transport Study (2004) notes that, Portsmouth, Langstone and Chichester Harbours are shallow tidal basins, created after sea levels approached their present levels approximately 5,500 years ago, thereby flooding a sequence of low lying valleys that were draining the coastal plain. Marine transgression has contributed up to 3.5 m of sediments that largely conceal a late Pleistocene and Holocene sediment sequence overlying Eocene sands and clays.

3. The nature of historical saltmarsh evolution and coastal risks

The saltmarshes of Langstone Harbour and indeed the whole SCOPAC region underwent rapid growth in area and elevation between the 1880s and late 1920s due to the invasion of the fertile hybrid cord grass *Spartina anglica*. The fully fertile *S. anglica* was rapid at colonizing low level mud and quickly invaded every estuary across the SCOPAC region, reaching its maximum extent in the 1920s, thereby securing sediment in situ and providing a natural wave buffer to the shore. Since then, there has been continuous and substantial saltmarsh erosion and loss (Solent CHaMP - Bray & Cottle, 2004; SDCP - Cope *et al*, 2008) (see Figure c.1).

Under rising sea levels, saltmarshes would naturally migrate inland assuming low-lying, gently sloping land. This is often prevented due to the presence of defence structures, such as sea walls and revetments, and the proximity of urban and coastal developments. This process termed coastal squeeze, results in the rapid erosion of these natural flood defences and increases the risk of flooding and coastal erosion as the defences become increasingly exposed to wave attack during storm events. Given that the majority of inter-tidal habitats across the SCOPAC region are designated European sites, any coastal squeeze as a result of coastal management works requires replacement habitat. The Solent Dynamic Coast Project (Cope *et al*, 2008) and the Poole and Christchurch Harbours Dynamic Coast Project (Cope *et al*, 2010) predicted that if all current sea defences are held across the north Solent region and in Poole and Christchurch Harbours, over the next 100 years, approximately 700-800 ha of designated inter-tidal habitat will require replacement habitat as a result of coastal squeeze. More specifically, the Langstone and Chichester Harbour European site requires 220 ha of replacement mudflat and saltmarsh (the majority of which is saltmarsh) if all defences are held.

4. Current Situation and Approach

- **Investigation and monitoring**

Analysis of saltmarsh loss using Historical Photography Interpretation (HPI) was undertaken by the Solent CHaMP (Bray & Cottle, 2004) and the dataset added to by the SDCP (Cope *et al*, 2008) (see Figure c.1). Since 2002, the South-east Strategic Regional Coastal Monitoring Programme (SSRCMP) has monitored the extent of coastal Biodiversity Action Plan habitats (i.e. mudflat, saltmarsh, coastal grazing marsh, saline lagoons, vegetated shingle, reedbeds, sand dunes and maritime cliffs and slopes) on a rolling basis using digital aerial photography and Light Detection and Ranging (Lidar) data. In addition, Hampshire and Isle of Wight Wildlife Trust have produced a Solent Waders and Brent Goose Strategy (King, 2010) which provides invaluable information on the usage of European sites by Brent Geese and Waders.

- **Methods used to predict the Hazard and Risk Potential in Langstone Harbour**

In terms of coastal change, the HPI indicates that the saltmarshes in Langstone Harbour have decreased by 83% from 438 ha to 73 ha between 1946 and 2002 and that this loss is slowing down (Bray & Cottle, 2003; Cope *et al*, 2008). These losses were extrapolated to provide an estimate of future saltmarsh loss in Langstone Harbour over the next 100 years. Flooding of digital terrain models in a GIS was another method employed by the SDCP (Cope *et al*, 2008) to predict and visually represent future inter-tidal evolution, both existing and potential habitat, over the next 100 years (Cope *et al*, 2007).

- **Current status and actions: how are we adapting to coastal climate change in this location?**

The saltmarsh loss in Langstone Harbour appears to be levelling out according to HPI and topographic modelling from the SDCP (Cope *et al*, 2008) still continued BAP habitat monitoring is required to confirm this. In terms of coastal management, the saltmarsh habitat no longer provides significant protection to the majority of the harbour, apart from Farlington Marshes where the Binness Islands to the east and the saltmarsh to the west of the peninsula, provide some protection; instead, mudflat has replaced the saltmarsh areas.

Farlington Marshes is a good example of other sites across the SCOPAC region, where the topography is ideal to support re-creation of inter-tidal habitat to offset coastal squeeze in the Langstone and Chichester European site but the site is, however, designated as a European Special Protection Area (SPA) and Ramsar site for the birds which means that any re-alignment requires replacement grazing marsh and roost habitat. Recent Environment Agency guidance suggests re-creation of inter-tidal habitats costs £75,000 per ha and takes approximately 10 years to establish, whilst re-creation of grazing marsh habitats costs £35,000 per ha and takes 20-50 years to establish (Natural England advice, 2010). Any re-alignments over grazing marsh must be planned 20-50 years in advance to provide enough time for the Environment Agency's Regional Habitat Creation Programme to start creating the replacement habitat.

5. Key issues: What can we learn from this site to inform coastal risk management and adaptive planning?

There is a requirement to replace any European designated habitat which is adversely affected by a coastal management scheme, whether that be through holding the line and causing inter-tidal coastal squeeze or re-aligning and losing coastal grazing marsh and bird roost function. The problem across the SCOPAC area, but particularly in the north Solent region, is that the majority of the coastline is defended and the habitats either side of the seawalls are designated, eg. Farlington Marshes. This results in a high proportion of inter-tidal coastal squeeze that will need to be offset to enable schemes to proceed but in order for these inter-tidal habitat creation sites to be realised, the replacement grazing marsh habitat will also have to be re-created 20-50 years in advance where any re-alignment schemes impact on European designated grazing marsh habitat. The question of whether coastal grazing marsh should be sacrificed to re-create inter-tidal habitat is site specific and comes down to the most technically and economically sustainable decision (Burn & Collins, 2006). If re-aligning over these landward SPA and Ramsar sites' is the most sustainable option, then replacement habitat should be recreated as close to the adversely affected European site as possible to maintain the network of bird feeding and roost sites. Farlington Marshes was identified as a potential managed re-alignment site in the North Solent Shoreline Management Plan but until further studies confirm the impacts of losing this valuable European roost and feeding site the area will sustain a Hold the Line policy. Any form of habitat creation is not an easy task, particularly in the north Solent region where the majority of these sites are privately owned and competing pressures on the coast result in few opportunities. Lessons learned from sites like Farlington Marshes is that it is essential to:

- have as much information as possible on the importance of the site in terms of the wider European network and impacts on birds and plant species if the site is to be re-aligned over
- take a strategic approach across a wide area when determining the best management option for a European site
- have a joined up approach between different organizations to maximize habitat creation opportunities.

The strategic SMP-wide approach to meeting the Conservation of Habitats and Species Regulations 2010 is essential in order to maximize habitat creation opportunities. These opportunities will be delivered throughout the SCOPAC region through the Environment Agency's Southern and South-west Regional Habitat Creation Programmes.

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CASE STUDY D: VENTNOR

Location:

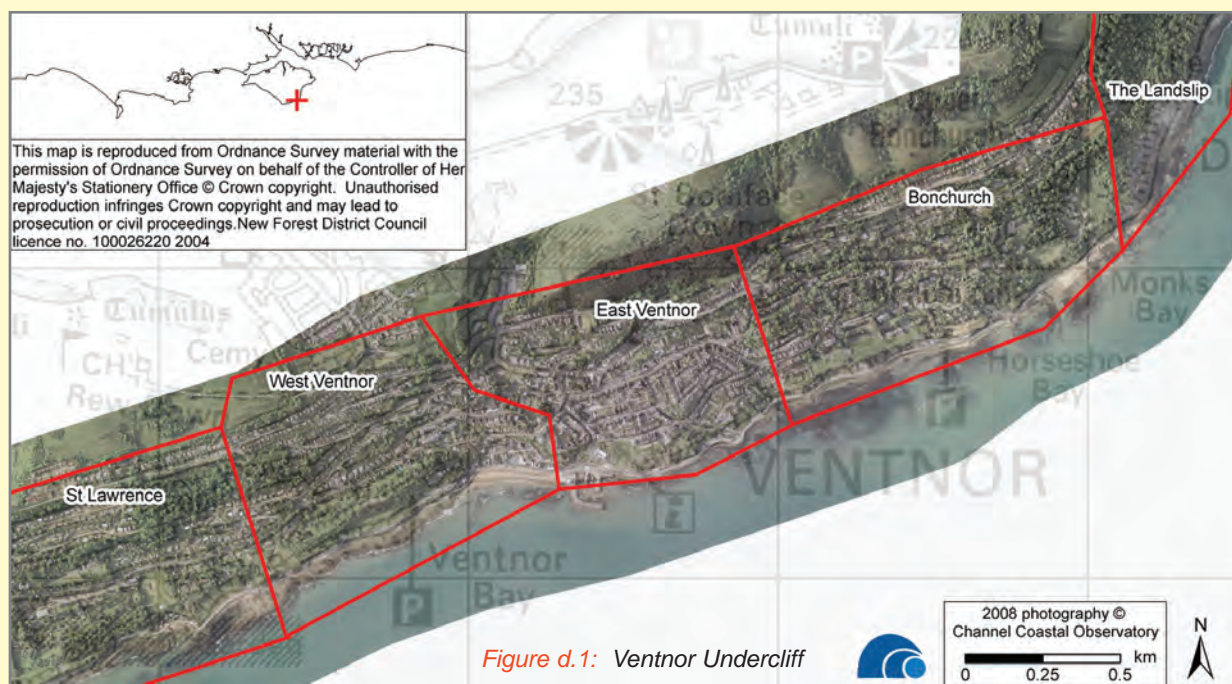
Ventnor Undercliff, Isle of Wight, UK.

Why was this study study are chosen?

The Ventnor Undercliff is an extensive coastal cliff and landslide complex that poses a significant risk to a large number of properties, services and other assets.

1. Overview

The Undercliff is a 12km-wide coastal cliff and landslide complex between Luccombe and Blackgang on the south coast of the Isle of Wight. The cliffs were formed as a result of deep-seated mass movements that occurred many thousands of years ago dating back to past glacial periods. The remnants of these ancient landslides extend a significant distance offshore and up to 700m inland of the shoreline where they comprise steep slopes and terraces up to 120m high. The Undercliff is regarded as one of the most unstable developed geological settings in the UK; the complex cliffs are formed in weak rocks that are sensitive to the effects of toe erosion and groundwater. The main area of interest for this case study concerns the section of Undercliff between Bonchurch and Ventnor (Figure d.1). The impact of ground instability and toe erosion in this densely populated area has been considerable in the past resulting in widespread damage to property and services. Coastal defences and local cliff stabilisation measures were built between Bonchurch and Ventnor Esplanade in 1987, and a rock armour revetment was built along the Western Cliffs at Ventnor to Steephill Cove in 1993.



The Undercliff provides a rare opportunity to test methods for deep-seated landslide behaviour prediction based on continuous real-time ground monitoring data, and extensive research and site investigations carried out since the mid-1980s. The results of this work inform the nature of the landslide ground model, failure mechanisms and causes, quantitative risk analysis and review of engineering stabilisation options. The patterns and rates of ground movement and their relationships with erosion, rainfall and groundwater provide valuable insight about the deformation potential of large complex landslides. The results also prompt consideration of whether rapid accelerations of ground movement are likely under future predicted climate change scenarios.

2. Geological and geomorphological setting

The coastal cliffs of the Isle of Wight Undercliff are formed within the Lower Cretaceous sequence of sedimentary rocks comprising Chalk, Upper Greensand, Carstone and Sandrock. The sequence of

strata is strongly bedded with a 2° dip seaward which pre-disposes the succession to large-scale landslides. The sea cliffs forming the present-day 'toe' of the Undercliff are mostly cut into landslide debris, and erosion rates are typically 0.3m per year. In situ soft sandstones (Sandrock) form the high sea cliffs at the east and west ends of the Undercliff at Luccombe and Blackgang where toe erosion rates are much higher between 1-3m per year. The Undercliff has experienced a relative increase in sea level and winter rainfall over the historical period promoting toe erosion and excess groundwater levels both of which have an adverse impact on stability.

3. Impact of historical cliff instability and erosion

Ground movement in the Undercliff generally takes the form of very slow and intermittent creep of the ground, the cumulative effects of which, over many years, has caused significant damage to property, businesses, other assets and services. Occasional rapid ground movements occur, for example at Blackgang in 1994, at Bonchurch in 2000, at Niton in 2001, and at Ventnor in 1960 when some residents had to be evacuated. Over the last 100 years, some 60 properties have had to be demolished in Ventnor due to the impacts of ground movement whilst others have sustained significant damage. The most notable impacts of ground movement can be observed in Upper Ventnor at a feature known as the 'Lowtherville graben' which extends some 500m in length, 20m across, and has subsided vertically by up to 4m. The B3327 Newport Road and other services located across the graben and are continually subject to damage due to ground movement. The A3055 Undercliff Drive is routed through Niton, St Lawrence, upper Bonchurch and Ventnor and provides a strategic road network linking the coastal towns, communities and businesses across the southern and south-west coast of the Isle of Wight. The present value annual risk of damage caused by ground movement at Ventnor has been estimated to be £4.64m (Lee & Moore, 2007).

4. Current situation and management approach

- **Study site hazard and risk potential**

The Undercliff is sensitive to toe erosion and deep-seated ground movement due to the inherent geology and exposure of weak rocks to weathering, excess groundwater and coastal erosion. There is concern that increases in relative sea level and winter rainfall will result in accelerated ground movement rates and more frequent landslide events over the next 100 years. The impact of these events is expected to be limited to the current extent of the Undercliff and is unlikely to involve significant recession of the headscarp; the SMP estimates a total of 2,485 properties (worth £511m) are at risk from landslip in Ventnor and Bonchurch and combined with estimates of replacement value of other assets including highways, footpaths and services the total value of assets at risk is estimated to exceed £600m. These estimates are consistent between the SMP, NCERM and Ventnor Landslide Quantitative Risk Assessment (QRA). At Bonchurch there is concern that ongoing instability of the Landslip (Figure d.1) will result in retrogression of the Undercliff headscarp putting at risk up to 63 properties (worth £13m) and the A3055 road linking Shanklin with Ventnor; the SMP does not consider recession of The Landslip (Figure d.1) whereas NCERM does (Figure 3.4 in Chapter 3). Given the significant value of property and infrastructure at risk of land instability and cliff recession at Ventnor and Bonchurch the benefits of coast protection and landslide stabilisation will be an important consideration in mitigating the risk.

- **Investigation and monitoring**

A central element of the local authority landslide management strategy at Ventnor has involved the installation, maintenance and recording of an extensive network of



Figure d.2: High aerial view of Ventnor, Isle of Wight

survey markers and automatic or manually-read slope monitoring devices. These include a weather station, crackmeters and settlement cells, and groundwater piezometers and movement inclinometers installed in deep boreholes across the town (Figure d.2). The Channel Coast Observatory also undertakes aerial surveys of the Undercliff comprising LiDAR and photography surveys.

- **Current status and actions: how are we adapting to coastal climate change in this location?**

The local authority implemented a landslide management strategy in the Undercliff in 1992. The main purpose of the strategy has been to engage key stakeholders and the community to raise awareness of the issues and promote best practice for managing ground instability through a range of practical measures and improved planning and building control. However, a quantitative risk assessment of coastal instability and erosion at Ventnor completed in 2006 demonstrated that whilst these measures were beneficial, active civil engineering intervention would be necessary to avert the increasing risks of major ground instability due the effects of climate change and rising sea level; further, the study identified a positive benefit to cost ratio for stabilisation in the form of deep drainage and improved coastal protection measures.

5. Key issues: what can we learn from this site to inform coastal risk management and adaptive planning?

Climate change poses a significant challenge to the future stability and management of the Undercliff and other similarly marginally stable coastal landslides in southern Britain. The value of site investigation, continuous monitoring of weather, groundwater levels and ground movement rates is clearly demonstrated in this case study. The relationships and understanding derived from analysis of these data provide the basis for design of robust early warning and response strategies and engineering stabilisation works; thereby providing opportunity for mitigation of ground movement and landslides in developed areas, reducing the potential adverse impacts and consequences of such events. Reliable assessment of the hazards and risk of large pre-existing coastal landslide complexes can only be achieved through detailed site investigations which are needed to inform effective planning, management and stabilisation.



Figure d.3: Bath Road Landslide Damage 1961



Figure d.4: Lowtherville graben 2005

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- Chandler, M.P. (1984) *'The Coastal Landslides forming the Undercliff of the Isle of Wight'*, PhD thesis, University of London.
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CASE STUDY E: LYMINGTON TO BEAULIEU, WEST SOLENT

Location: The Lymington River to Beaulieu River stretch of shoreline is located in the West Solent region. The area is relatively sheltered from south-westerly wave attack by Hurst Spit to the west and the Isle of Wight to the south, thereby providing a suitable environment for inter-tidal habitats to establish and survive (Figure e.1).

Why was this study area chosen

The rapid decline of saltmarsh habitat in the West Solent since circa 1930 is representative of all saltmarsh sites across the SCOPAC region but in particular, the north Solent region. This is cause for concern in terms of coastal management and nature conservation. This case study focuses on the coastal management implications of saltmarsh loss and the effect on smaller settlements, reliant on saltmarsh as a form of natural sea defence.

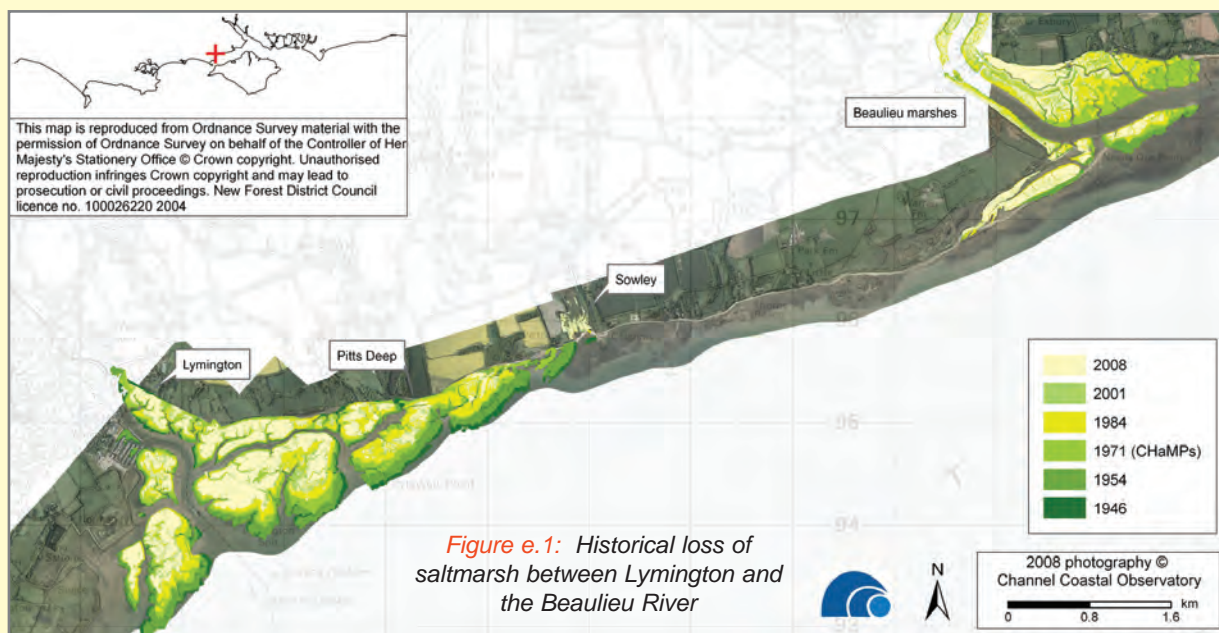


Figure e.1: Historical loss of saltmarsh between Lymington and the Beaulieu River

1. Overview

The Lymington River to Beaulieu River stretch of shoreline is characterised by European designated mudflat and saltmarsh habitats, with grazing marsh habitats and grade 2 agricultural land positioned on higher ground or behind discontinuous privately owned coastal defences, which vary in condition and residual life, protecting individual or small numbers of properties. The saltmarsh provides a first line of natural defence by dissipating incoming wave energy. With a reduction in saltmarsh extent, the shoreline is increasingly susceptible to increasing risk of overtopping of sea defences, flooding and erosion. The focus of the SCOPAC ACCESS project has been on hotspots of over 40 properties at risk of erosion and/or flooding, however, this stretch of coastline provides a good example of the importance of saltmarsh as a primary defence and highlights those smaller settlements requiring a strategic, community approach to defending their land against increasing future erosion and flooding risks.

2. Geological and Geomorphological setting

The SCOPAC Sediment Transport Study (Carter *et al*, 2004) notes that this frontage comprises a section of the northern flank of the ancient Solent River valley that became inundated by rising sea-levels some 7,000 to 8,000 years ago following breaching of a barrier beach, or narrow isthmus of land at the eastern end of Christchurch Bay. This led to a supply of clays, sands and gravels into a permanent tidal channel at Hurst Narrows from Christchurch Bay, thereby linking the West Solent to Christchurch Bay.

3. The nature of historical saltmarsh evolution and coastal risks

The saltmarshes between Lymington and Beaulieu and indeed the whole SCOPAC region underwent rapid growth in area and elevation between the 1880s and late 1920s due to the invasion of the fertile

hybrid cord grass *Spartina anglica*. The fully fertile *Spartina anglica* rapidly colonized low level mudflats and quickly invaded every estuary across the SCOPAC region, reaching its maximum extent in the 1920s, thereby securing sediment in situ and providing a natural wave buffer to the shore. Since then, there has been continuous and substantial saltmarsh erosion and loss (Bray & Cottle, 2003; Cope *et al*, 2008) (See Figure e.1).

Under rising sea levels, saltmarshes would naturally migrate inland assuming low-lying, gently sloping land. This is often prevented due to the presence of defence structures, such as sea walls and revetments, and the proximity of urban and coastal developments. This process termed coastal squeeze, contributes to the erosion of these natural flood defences and increases the risk of flooding and coastal erosion as the sea defences become increasingly exposed to overtopping and wave attack during storm events.

4. Current Situation and Approach

- Investigation and monitoring

Historical Photography Interpretation (HPI) was used as a tool to determine the historical extent of saltmarsh habitat for the West Solent area. Historical aerial photography spanning 50 years was collated and geo-rectified to make it map accurate (Figure e.2). It was then inserted into a Geographical Information System (GIS) where the extent of the saltmarsh was digitized for the various years. Analysis of saltmarsh loss using (HPI) was undertaken by the Solent CHaMP (Bray & Cottle, 2003), West Solent Coastal Defence Strategy Study (New Forest District Council, 2005) and the dataset added to by the SDCP (Cope *et al*, 2008) (see Figure e.1). The shoreline between Lymington and Beaulieu will be increasingly exposed to erosion and flooding in the future with the decline of the protective inter-tidal habitats and the area therefore provides an analogue for other nearby locations experiencing rapid saltmarsh loss.

Analysis of historical aerial photography in Figure e.2 shows that the shoreline became more exposed to south-westerly wave attack by the 1950's as the fronting saltmarshes eroded. As a consequence, the beach at Sowley was permanently breached during a storm in 1955 and the small lagoon, which then formed, was at a sufficient elevation in relation to tidal inundation to permit saltmarsh colonization. At the same time, erosion of the Pitts Deep shoreline released sediment into the system which was transported eastwards, feeding the western Sowley spit.

Since 2002, the South-east Strategic Regional Coastal Monitoring Programme has monitored the extent of coastal Biodiversity Action Plan habitats (i.e. mudflat, saltmarsh, coastal grazing marsh, saline lagoons, vegetated shingle, reedbeds, sand dunes and maritime cliffs and slopes) on a rolling basis using digital aerial photography and Light Detection and Ranging (Lidar) data.

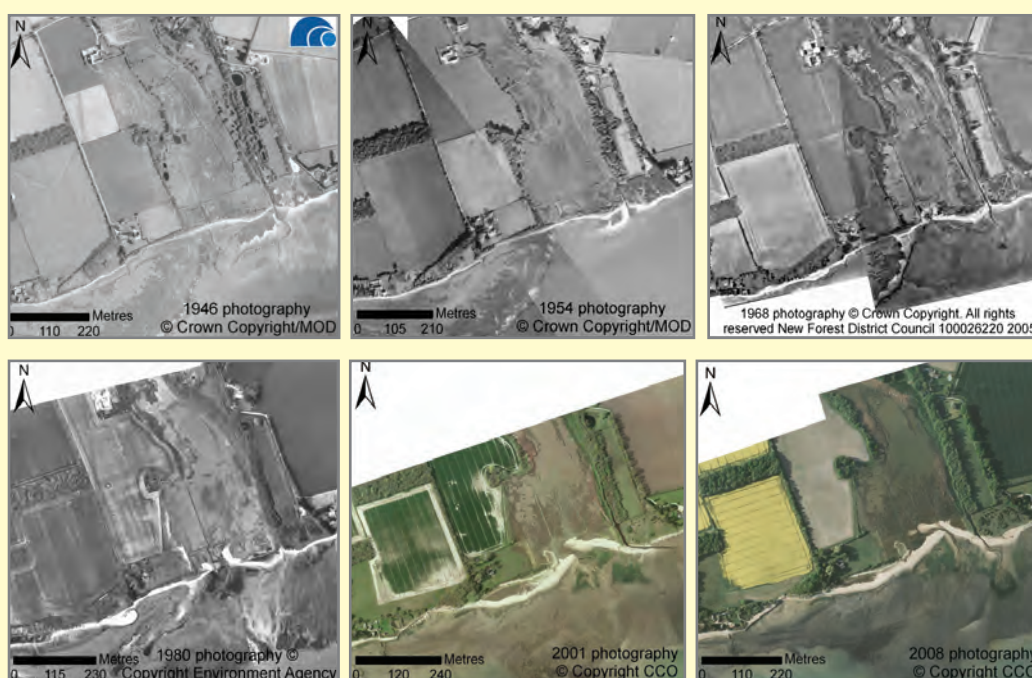


Figure e.2:
Evolution of Sowley
lagoon, West Solent
(see Figure e.1
for location)

- **Methods used to predict the Hazard and Risk Potential**

In terms of coastal change, the HPI indicates that the saltmarshes at Lymington have decreased by 58% from 266 ha to 111 ha between 1946 and 2001, the saltmarshes at Pitts Deep have decreased by 83% from 39 ha to 7 ha between 1946 and 2001 and the saltmarshes at Beaulieu River have decreased by 53% from 150 ha to 71 ha between 1954 and 2001. Flooding of digital terrain models in a GIS was another method employed by the SDCP (Cope *et al*, 2008) to predict and visually represent future inter-tidal evolution over the next 100 years (Cope *et al*, 2007).

The risk of overtopping to the Pennington seawall under different extreme wave and water level conditions and saltmarsh extents was undertaken by the West Solent Coastal Defence Strategy Study (New Forest District Council, 2005). Findings highlighted the significant role of the saltmarshes in dissipating wave attack and acting as a buffer to prevent overtopping when coupled with the seawall.

- **Current status and actions/How are we adapting to coastal climate change in this location?**

Continued BAP habitat monitoring is required to confirm if the saltmarsh loss trend continues to be linear. In terms of coastal management, the saltmarsh habitat is ceasing to provide significant protection to the frontage; instead, mudflat has replaced the saltmarsh areas. Regardless of the rate of saltmarsh loss, the multiple landowners will soon require a strategic community approach to managing their assets and adapting to climate change. With respect to privately owned and maintained defences, the North Solent SMP (New Forest District Council, 2010) has highlighted the concerns associated with the perception and implications of the current SMP policy definitions and the requirement to seek clarification on how privately owned defences are considered in Defra's Flood and Coastal Erosion Risk Management framework approach. Closer liaison between landowners and regulators and a community approach will be required to achieve effective management of defences and flood and erosion risk.

5. Key issues: What can we learn from this site to inform coastal risk management and adaptive planning?

A number of frontages within the SCOPAC region, including sections of the shoreline in the West Solent, were assigned a No Active Intervention SMP policy. In terms of national economic criteria, the defence works required to protect the settlements or isolated properties along these frontages from increasing flood and coastal erosion risk as a result of climate change and saltmarsh erosion are not considered economically viable to warrant public funding. However, the landowners want to continue to maintain and fund the maintenance of their defences and have certain permissive development rights to do so, that remain irrespective of the SMP policy. In order to achieve adaptive, achievable and effective management of the flood and erosion risks, a community approach in partnership with operating authorities and clear guidance from the local planning authorities is required.

The North Solent SMP (New Forest District Council, 2010) produced an information note for landowners and planners clarifying any implications of the SMP policies and permissive rights of landowners, but further guidance from Defra is necessary that resolves planning and legislative issues.

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CASE STUDY F: HURST SPIT

Location:

Hurst Spit is a shingle structure with varied sediment sorting, extending 2.5 km from the end of Milford beach across the entrance to the western Solent.

Why was this study area chosen?

Hurst Spit is a crucial control feature for the west Solent as it forms a primary flood defence against south-westerly wave attack and provides shelter to inter-tidal habitats in its lee. The spit and inter-tidal habitats help dissipate wave energy, thereby reducing the standard of protection required to defend residential properties throughout the west Solent. It is a good example of a shingle spit, which, without careful management would be frequently overwashed and breached, particularly with climate change.

1. Overview

Hurst Spit is a relict of the Holocene transgression when sediment supply was abundant in Christchurch Bay from offshore sources. With sediment starvation updrift, the barrier spit became increasingly prone to overwashing, causing a temporary tidal breach in 1989. In 1996 a major engineering scheme was undertaken to increase the cross-sectional area of the spit and increase the standard of protection. Since 1996 sediment has been recycled approximately every three years both from build ups along the spit and the tip of the recurve spit (North Point). Monitoring of the beach shows that the spit has performed better than predicted since the 1996 recharge scheme, ensuring that the next recharge is only undertaken when necessary. Subject to government funding and beach

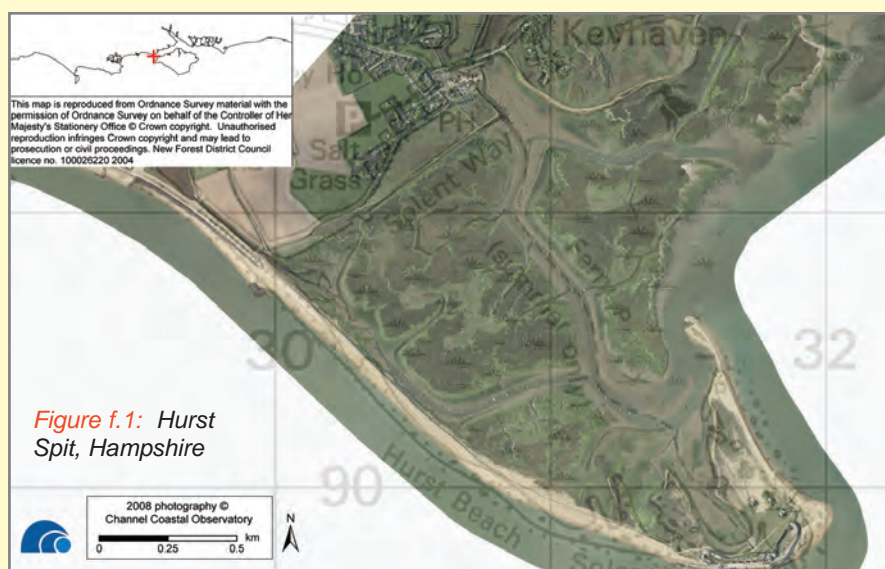


Figure f.1: Hurst Spit, Hampshire

performance, the next major recharge scheme will be in 2013.

2. Geological and Geomorphological setting

The SCOPAC Sediment Transport Study (Carter *et al*, 2004) notes that Hurst Spit is composed of sub-angular to sub-rounded flint pebbles and sand, all of which are of Pleistocene fluvial origin that were incorporated into the spit system throughout the Holocene transgression (Nicholls, 1985). It is postulated that in the latter 5,000 yrs B.P., the spit would have had a plentiful supply of sediment not only from offshore sources but eroding cliff line sources from the west (Bray, 1996). The beach was supplemented with 300,000m³ of recharge material in 1996.

Figure f.2 demonstrates that Hurst Spit is dependent on an updrift supply of shingle from areas to the west (Bray, 1996). Most of the sand that is eroded from the cliffs to the

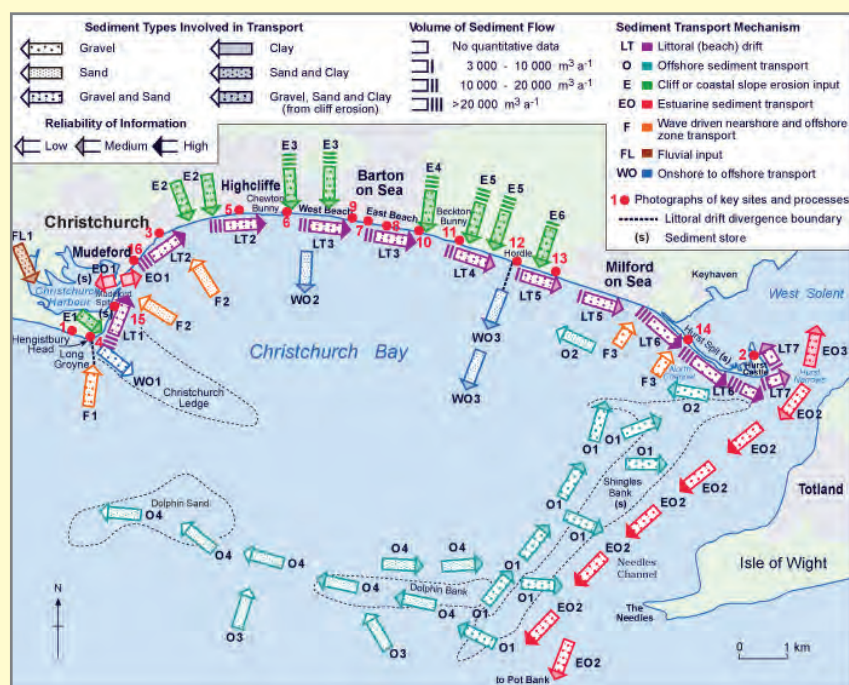


Figure f.2: Christchurch Bay sediment transport © SCOPAC Sediment Transport Study © SCOPAC Sediment Transport Study (Carter *et al*, 2004)

west does not reach the spit, indicating that it is carried offshore (Nicholls and Webber, 1987). Any fine material that does reach the spit is transported round the Castle to North Point, which aids further protection of the Keyhaven marshes, particularly from south-easterly and easterly waves. Coarser sediment is carried offshore to the Shingles Bank where it is estimated that 42 million m³ is stored, and therefore acts as a good wave dissipater (Bradbury *et al*, 2003).

3. The nature of historical evolution and coastal risks

Management practices operating along Hurst Spit are a consequence of human intervention further west. A series of defences implemented after 1944 at Mudeford, Highcliffe, Barton and Milford have reduced sediment supply to the beach (Bradbury, 1998). Longshore drift feeding Hurst Spit was severely disrupted by extensive works at Highcliffe and Barton between 1964 - 1969 and reinforcement of the Becton Bunny sewage outfall in 1970. In 1969, rock armour was placed along a 600 m frontage of Hurst Spit which was effective in providing local protection, though was prone to being outflanked. Following the complete overwashing and breaching of Hurst Spit in 1989, the standard of service against overwashing was calculated to occur under the conditions arising from a 1:1 year storm event, during a south-westerly storm and tidal surge of 0.5 m above mean high water springs. The spit became part of a long-term 50 year Beach Management Plan site in 1996, run by the New Forest District Council (Bradbury *et al*, 2003). In 1996 a rock revetment and offshore breakwater, which acts as a headland structure, were constructed, positioned at the most vulnerable section of the spit (proximal, north-west section).

4. Current Situation and Approach

- **Investigation and monitoring**

Since 2002, the South-east Strategic Regional Coastal Monitoring Programme (SSRCMP) has monitored beach profile changes on an annual basis; these continue the records that date back to 1987. Aerial photography is flown every year and Lidar is flown for the frontage every 2 years. In addition, the sea defences are regularly monitored by the New Forest District Council to ensure they are operating at optimum efficiency. Monitoring is important to ensure the beach is performing as predicted and will be used to update when the next recharge is necessary (Figure f.3).

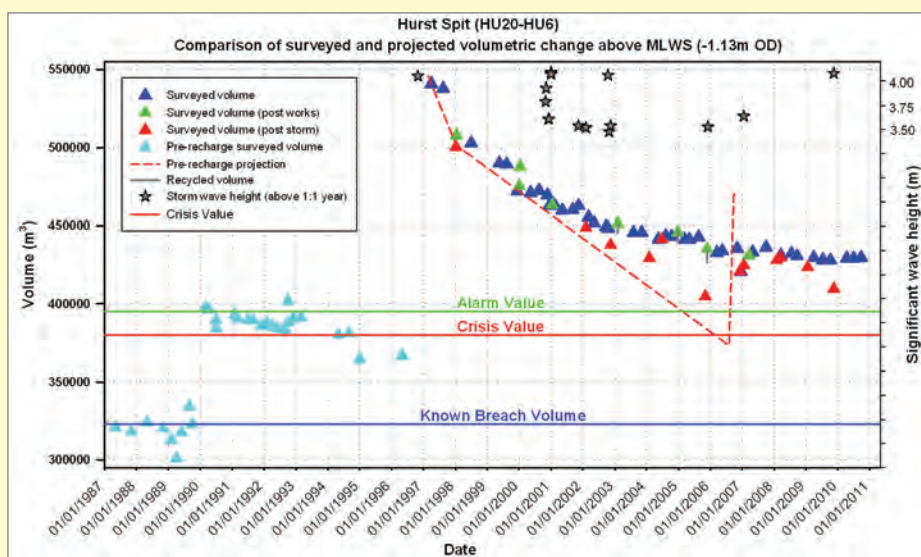
- **Methods used to predict the Hazard and Risk Potential at Hurst Spit**

Figure f.3 shows the difference between design and performance of the 1996 Hurst Spit scheme. The dashed red line shows the forecasted beach recharge performance whilst the triangles, circles and squares show actual surveyed volume. Monitoring data demonstrates that the beach is performing better than predicted. Analysis of the Milford wave buoy data suggests measured wave periods are lower than typically expected for storm events by earlier models (Bradbury *et al*, 2007). The beach has not reached the predicted alarm volume which will trigger an interim beach recharge of 100,000 m³ to avoid breaching but is expected to do so in a few years time.

In addition to monitoring beach performance, the future risk to Hurst Spit from different sequences of storm events and water levels can be predicted by applying Bradbury's (1998) overwashing model.

Figure f.4 shows application of the model for a Mean High Water Spring (MHWS) and MHWS + 1.0m storm surge scenario. The coloured profile lines indicate the storm return period that is predicted to cause overwashing for the specified water level.

Figure f.3: Surveyed and projected volumetric change at Hurst Spit above MLWS © After Bradbury et al, (2007)



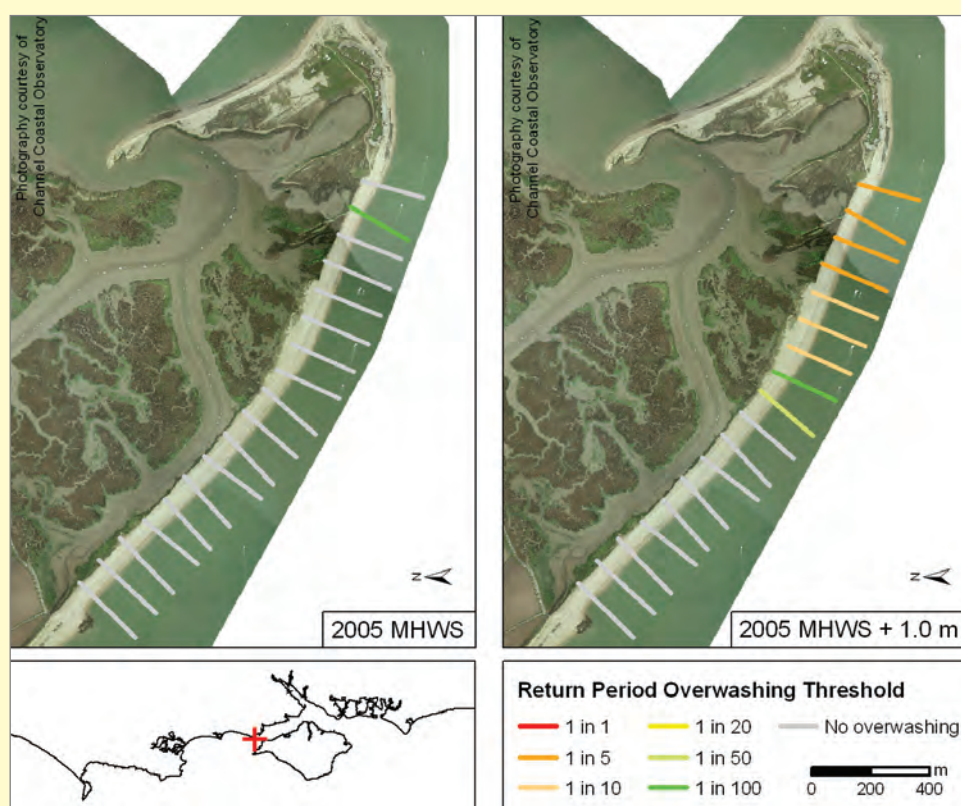


Figure f.4: Overwashing return period thresholds for Hurst Spit based on 2005 survey © Bradbury et al (2005)

this natural sediment supply, careful monitoring is required to ensure sediment recharge is implemented before the beach reaches a crucial level, vulnerable to overwashing and breaching incidences. In addition, understanding the hydrodynamic conditions under which the spit overwashes and breaches is essential to future management. Research shows that building a low and wide cross sectional area is better for barrier beaches and spits, as well as using native sediment for beach recharge where possible to ensure the sediment sorting is maintained. A naturally sorted beach performs better under storm attack by efficiently dissipating wave energy. The value of monitoring beach plan shape change is demonstrated in improved management efficiency. Similarly the long term monitoring offers opportunities for improved expenditure planning and risk assessment.

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• Current status and actions: how are we adapting to coastal climate change in this location?

The long term policy for Hurst Spit in the Poole and Christchurch Bays Shoreline Management Plan is to Hold the Line. This means that future recharge schemes will be necessary to maintain the cross-sectional area of the spit to ensure the West Solent is protected from south-westerly wave attack with the expected consequences of future climate change.

5. Key issues: What can we learn from this site to inform coastal risk management and adaptive planning?

Hurst Spit is representative of other spit features across the SCOPAC region, being dependent on an updrift sediment supply to maintain the cross-sectional area. Without

CASE STUDY G: BARTON-ON-SEA AND NAISH FARM

Location: Barton-on-Sea and Naish Farm, Hampshire, UK.

Why was this study area chosen? The coastal cliffs at Barton illustrate a variety of cliff types subject to erosion and landslides that pose a hazard and risk to the public, cliff top property, services and other assets.

1. Overview

The 2km cliff section between Becton Bunny and Naish Farm (Figure g.1) is characterised by an 'Undercliff' of steep slopes and terraces up to 33m high and 120m from crest to toe. The cliffs are formed of weak rocks that are susceptible to toe erosion and the effects of groundwater. The impact of past cliff instability and erosion includes the loss of cliff top property and businesses at Barton Court and Naish Farm. Coast protection and cliff stabilisation measures have been constructed in various stages along the frontage since the late 1950s to prevent toe erosion and landslides, respectively.



Figure g.1: Barton cliff frontage

The relationships between cliff recession rate, the causes and mechanisms of toe erosion and landslides, the sensitivity to climate change and sea level, and the effectiveness of coast protection and stabilisation measures, provides a rare opportunity to assess these factors. This understanding can be used to inform prediction of cliff instability and recession and the adverse impacts and risk these pose to the public and cliff top assets in future.

2. Geological and geomorphological setting

The cliffs are formed of overconsolidated Eocene clays, sands and sandy clays that are overlain by Quaternary sands and gravels. The strata are strongly bedded and dip 1° ENE. The sequence of interbedded clays, sands and gravels make the Barton cliffs very susceptible to coastal erosion and mass movement processes which has resulted in some of the highest rates of coastal cliff recession on the south coast of England.

3. Impact of historical cliff instability and erosion

Cliff-top properties, businesses and services are located along the Barton frontage; the cliffs are also open access to the public providing panoramic views of Christchurch Bay and the Isle of Wight. Major landslides and cliff recession occurred in 1974 and 1987 at Barton Court (resulting in damage and loss of cliff-top property) and in 1993, 1996 and 2001 at the Cliff House Hotel (resulting in significant cliff-top retreat). Naish Farm has been continuously affected by high rates of toe erosion and cliff recession over many years necessitating the relocation (roll-back) of holiday chalets further landward.

The first coastal defences were built in the late 1950s comprising timber groynes. During the late 1960s, the cliffs at Barton Court and Marine Parade were stabilised with deep drainage, piling and slope profiling. Further works were undertaken in the 1990s comprising construction of the rock armour groynes and revetment seen today and installation of cut-off drains. Cliff instability and recession has continued at the western and eastern ends of the protected cliff section (Becton Bunny and Naish Farm) causing outflanking and failure of defences.

A detailed cliff behaviour assessment and analysis of historical aerial photographs (1940-2001) was carried out for the frontage in 2002, to define cliff extents of similar physical characteristics and failure mechanisms, and historical cliff behaviour (erosion and landsliding).

The freely degrading cliffs at Naish Farm and Becton Bunny are subject to active toe erosion and the measured long-term historical cliff recession rate since 1940 is 1.03m/yr (Figure g.2). The stabilised cliffs at Marine Drive and Barton Court are characterised by complex cliff behaviour, involving cliff top degradation and deep-seated landsliding. The historical data for the stabilised cliffs indicates cliff-top recession events of between 2-5m occur every 5-13 years, confirming they are marginally stable. The cliffs at Barton have been exposed to a relative increase in sea-level and winter rainfall over the historical period.

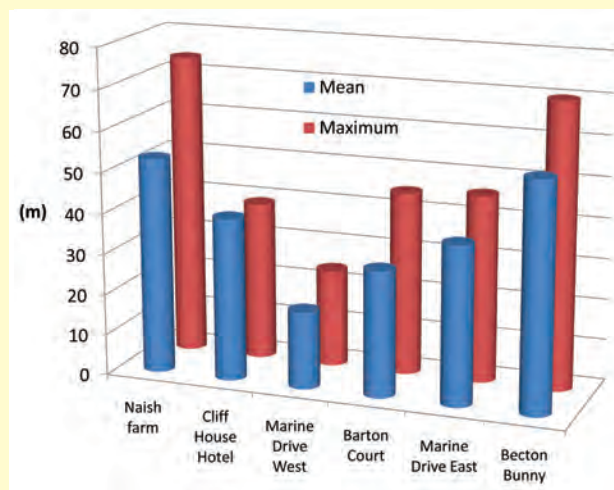


Figure g.2: Cliff top recession at Barton (1940-2001)

4. Current situation and management approach

- **Study site hazard and risk potential**

Cliff instability and erosion along the Barton frontage poses a number of significant hazards and risk to the community particularly in the context of predicted climate change and sea level rise. Over the next 20 years, ongoing failure of the cliff stabilisation and coast protection measures at Barton Court, Marine Drive West and Cliff House Hotel will pose a significant hazard and risk to the public due to ground disruption and unravelling of existing engineering works. The SMP average projections of future losses across the frontage indicate that up to 1 property (worth £260k) is at risk over the next 20 years; 7 properties (worth £1.82m) are at risk between 20 to 50 years, and 316 properties (worth £82.21m) are at risk between 50 to 100 years. These average projections do not explicitly account for the effects of future climate change and sea level rise, and as such the number of properties at risk could be greater than estimated here; also, it is noted that the NCERM projections for this frontage differ from those of the SMP, most likely a result of the different data inputs and projection methodologies employed. Notwithstanding this, mitigation of the coastal instability and erosion risk will require investment in cliff stabilisation and coastal protection works.

- **Site investigation and monitoring**

New Forest District Council undertakes site investigation and monitoring of the frontage. In the past this has included major ground investigations of the landslides to inform the design of cliff stabilisation and coast protection measures and regular monitoring of ground movement and groundwater levels. Regular beach surveys have also been conducted over a 20 year period, and since 2002 the Channel Coast Observatory has been undertaking aerial LiDAR and photography surveys, and terrestrial GPS surveys of ground markers.



Figure g.3: Cliff House Hotel Frontage

- **Current status and actions: how are we adapting to coastal climate change in this location?**

There is concern over the stability of the cliff behaviour units west of Barton Court, which have been subject to significant landslip since 1993, with large tension cracks evident in the adjacent roadway, distortion of the steel sheet

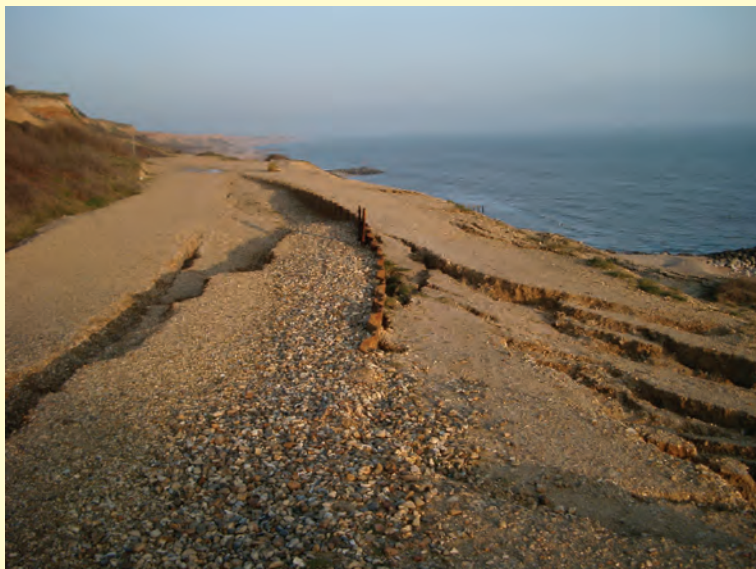


Figure g.4: Marine Drive West frontage

piled wall, and failure of the cliff top (Figures g.3 and g.4). The impacts of climate change and sea level rise are likely to lead to more frequent landslide events, higher rates of toe erosion and cliff top recession over the next 100 years.

In their natural freely degrading state, the Barton cliffs are sensitive to coastal erosion and landslides due to the weak sediments forming the cliffs which offer little resistance to weathering, surface erosion, excess groundwater and toe undercutting. Where the cliffs have been stabilised, these will be sensitive to the effects of climate change and peak groundwater levels, and the reduced effectiveness of stabilisation works with time. Consequently, the potential cliff recession rates and landslide event

frequency under a scenario of rising sea-level and increased winter rainfall and groundwater could be significantly greater than the measured historical cliff behaviour. The cliff behaviour response to future climate change and sea level rise should be taken into account in recession projections to reliably define the hazards and risk, which in turn inform coastal strategy and management plans and intervention measures to mitigate the cliff instability and erosion risks.

5. Key issues: what can we learn from this site to inform coastal risk management and adaptive planning?

A holistic long-term and proactive approach underpinned by reliable scientific assessment, prediction and monitoring provides the best means of mitigating the hazards and risk of cliff instability and erosion at Barton-on-Sea. Cliff recession projections from NCERM have been verified with good quality site-specific data and compared with the SMP. The erosion projections from these sources have sufficient range to account for the future impact of climate change and sea level rise.

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CASE STUDY H: STUDLAND

Location: Studland Spit is a 5 km long sand spit extending northwards into Poole Harbour, Dorset (Figure h.1).

Why was this study area chosen? Even though there are no properties directly at risk from erosion of Studland sandspit apart from the beach huts, visitor centre and car park at Knoll Beach (Figure h.2), it is a good example of a sand dune providing a natural defence to Poole Harbour.

1. Overview

Studland Spit is the only large dune heath site in the south and south-west of Britain, characterised by an extensive ridged dune system that has developed since 1700. The site is designated a National Nature Reserve and has been owned and managed by the National Trust since 1982. The coastal frontage is predominantly undeveloped although there are some defences protecting beach huts, beach cafes and water sports facilities.



Figure h.1:
Studland Spit,
Dorset

2. Geological and Geomorphological setting

The SCOPAC Sediment Transport Study (Carter *et al*, 2004) suggests that Poole Harbour was formed by submergence throughout the Holocene transgression (approximately 8500 years B.P). The origin of Studland spit is uncertain but it is supposed that the spit formed from consolidation of onshore migrating sand bars from Studland Bay.

3. The nature of historical evolution and coastal risks

The SCOPAC Sediment Transport Study (Carter *et al*, 2004) notes that Studland Sand spit has accreted in a seaward direction since 1785, through onshore migration and welding of sand bars. Between Redend Point and Knoll beach, periodic erosion has been recorded at a total of 80 m between 1890 and 1971, which is 0.7 m per annum (Figure h.2). Erosion increased to 7m at Knoll Beach car park and 10m at Studland Beach in 1990 and 1992. Consequently, a policy of managed re-alignment was adopted by the National Trust as it was concluded that the proposed soft engineering option of sediment recycling from the northern section might have moved the erosion problem northward.

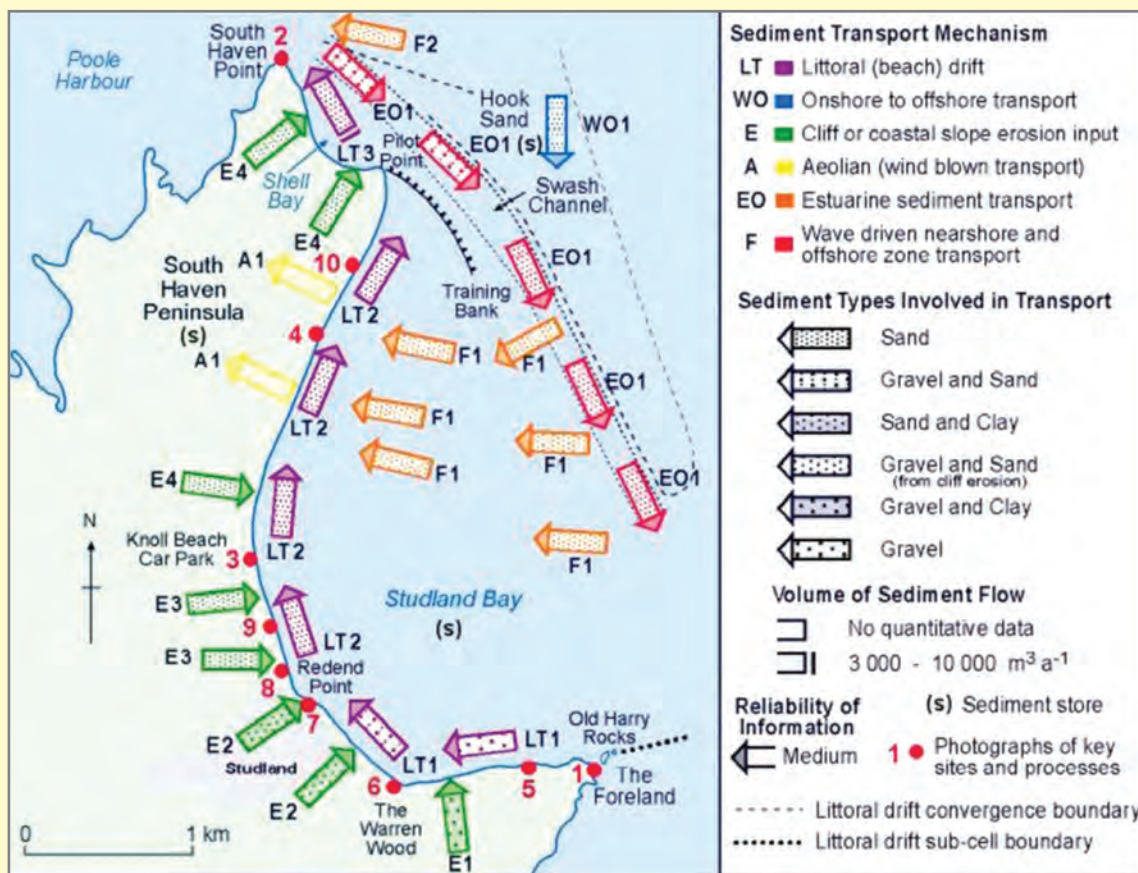


Figure h.2: Sediment transport in Studland Bay, Dorset © SCOPAC Sediment Transport Study (Carter et al, 2004)

4. Current Situation and Approach

- Investigation and monitoring

Since 2002, the South-east Strategic Regional Coastal Monitoring Programme (SSRCMP) has monitored beach profile changes on an annual basis using kinematic GPS. In addition, aerial photography and Lidar are flown for the frontage every year.

- Methods used to predict the Hazard and Risk Potential at Studland Spit

In terms of predicting erosion rates for the future, past erosion rates were extrapolated for the Poole and Christchurch Bays SMP (Royal Haskoning, 2010; Figure h.3). These were based on historical Mean High Water (MHW) records and refined using 2003 to 2008 Regional Monitoring data, such as the accretion and erosion mapping presented in Figure h.4. Analysis of MHW change between 2003 and 2008, using Channel Coastal Observatory Lidar data, indicates that the accretion and erosion rates vary considerably along the length of the spit but, on average, the MHW mark is retreating by 3m per year. By contrast, Shell Bay is accreting on average by 1 metre per year.

- Current status and actions: how are we adapting to coastal climate change in this location?

The Poole and Christchurch Bays SMP (Royal Haskoning, 2010) gave Studland village a policy of Managed Re-alignment in the 0-20 year epoch and No Active Intervention (NAI) in the 20-50 and 50-100 year epochs. Studland Spit itself and Shell Bay were given No Active Intervention Policies for all three epochs with a Hold The Line policy for the Training Bank. The SMP reports that the long term aim is to restore the natural functioning of the spit, although it is accepted that this function is modified by the control of the entrance channel, particularly in relation to the Training Bank. The intent of the plan is to allow existing defences to fail and actively remove or move the local fixed assets such as beach huts and car parks which will require co-operation between various interest groups and development of a shoreline use plan. The Training Bank will be maintained given that it is an important structure, providing a degree of control to the northern end of the spit and to prevent sediment migrating into the harbour entrance channel.

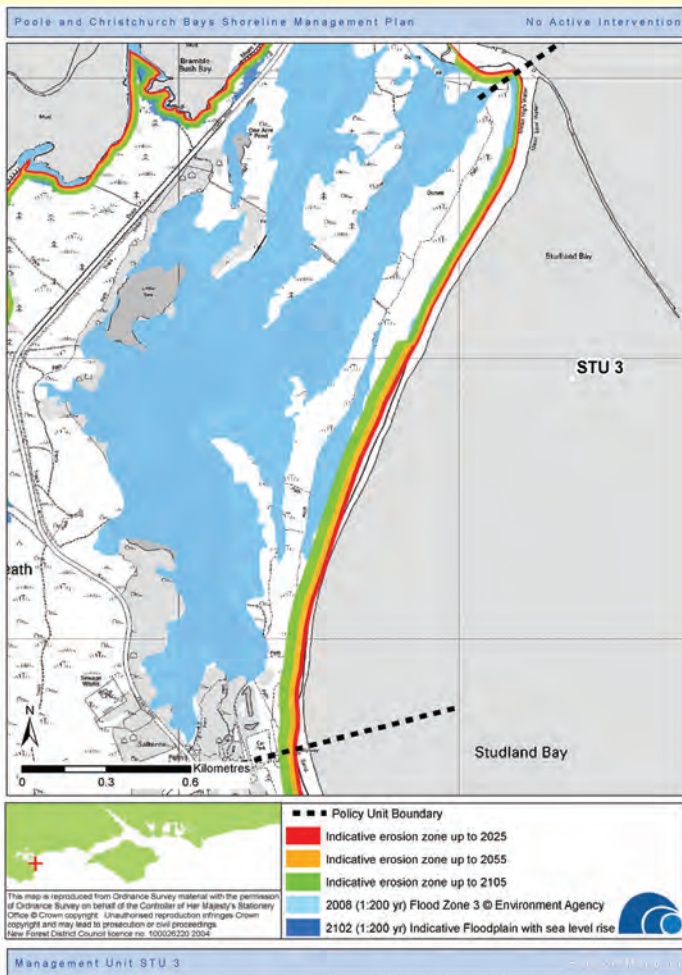


Figure h.3: Predicted indicative erosion rates under a No Active Intervention scenario © Poole and Christchurch Bays SMP (Royal Haskoning, 2010)



Figure h.4: Sediment accretion and erosion between 2003 and 2008 © Channel Coastal Observatory (2008)

5. Key issues: What can we learn from this site to inform coastal risk management and adaptive planning

The South-east Regional Coastal Monitoring data will be paramount as the data record builds in order to better understand the erosion and accretion behaviour of Studland Spit. Whilst northern parts of the bay accumulate large quantities of sandy sediment, continued erosion of the cliff and beach to the south of the bay present a threat to the bay's 'temporary' built environment (beach huts, visitor centre and car park) and to the amenity value of the beach. These features will have to be removed or moved further inland in the long term. Continued monitoring of this relict feature is essential to understanding the processes which might affect its integrity in the face of predicted increased sea level rise and storm surges.

Further Reading

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CASE STUDY I: LYTCHETT BAY, POOLE HARBOUR

Location: Lytchett Bay is located in the northern part of Poole Harbour, situated at the western end of Poole Bay, Dorset (Figure i.1).

Why was this study area chosen? Lytchett Bay is a good example of a site at risk of very low rates of erosion, where approximately 20 properties are at risk of flooding now and over 400 properties in 100 years time.

1. Overview

Poole Harbour is a large, natural harbour, characterised by internationally designated habitats. Lytchett Bay located in the north of the harbour is sheltered from wave attack and is characterised by inter-tidal habitats and reedbeds (Figure i.1). The west side of the bay is relatively undeveloped and under the policy of No Active Intervention and Managed Re-alignment set by the Poole and Christchurch Bays Shoreline Management Plan (SMP) (2010) the inter-tidal habitats and reedbeds will migrate inland. Conversely, the east side of the bay is highly developed and at risk of erosion and flooding in 100 years time, hence the policy of Managed Re-alignment and Hold The Line in the SMP which will set the defence line back.

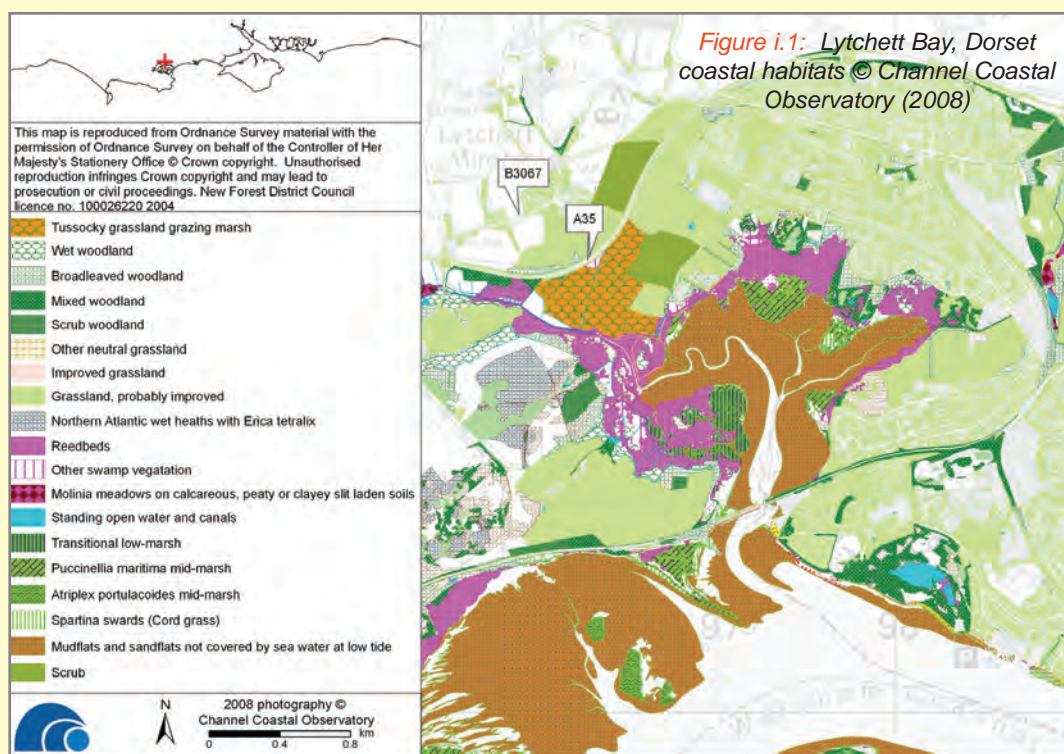


Figure i.1: Lytchett Bay, Dorset coastal habitats © Channel Coastal Observatory (2008)

2. Geological and Geomorphological setting

The SCOPAC Sediment Transport Study (Carter *et al*, 2004) notes that Poole Harbour was formed during the Holocene sea level rise from the remnants of a drowned palaeo-river that once flowed into the Solent River. Since its formation, the harbour, which is carved out of the Bracklesham Group (May, 2005), has become progressively enclosed at the mouth. The small tidal range (1.8m at springs, 0.6m at neaps) and double high water are the two main tidal features within the harbour. The double high water results in an ebb dominant tidal basin, although tidal asymmetry is complex.

The harbour is characterised by habitats such as, mudflat, saltmarsh, reedbed, grazing marsh, heathland and sand dune which are designated under European and national law for wintering and migrating birds in addition to many rare plants and invertebrates. The *Spartina* saltmarsh reduced by 46% between 1924 and 1980 (Gray, 1985). Between 1947 and 2005 the *Spartina* reduced in extent by 36%, whilst the reedbed habitat increased in area by 138% (Born, 2005). Still, the rate of saltmarsh loss is not as great as some sites in the north Solent which are suffering up to 83 % *Spartina* dieback (see Case Study C: Langstone Harbour).

3. The nature of historical evolution and coastal risks

According to Born's (2005) digitizing of historical aerial photography, Lytchett Bay has been relatively stable in terms of saltmarsh and reedbed colonisation since the 1940's, providing a natural buffer against wave attack. There appears to be some encroachment of saltmarsh onto reedbed (Figures i.2 and i.3) and general expansion of the two habitats although this may be attributed to interpretation error when using historical datasets. The 2008 dataset (Figure i.3) provides an accurate map of the saltmarsh and reedbed habitats having been interpreted from colour digital aerial photography.

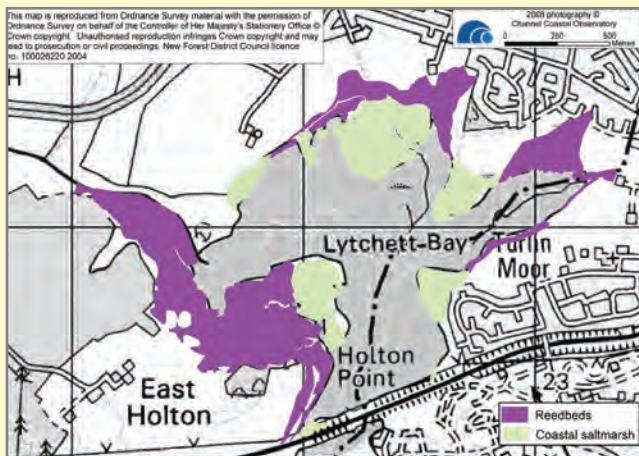


Figure i.2: 1972 saltmarsh and reedbed (Born, 2005)

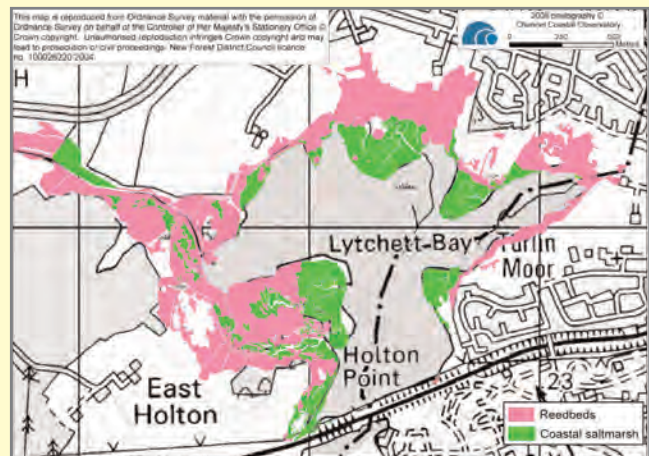


Figure i.3: 2008 saltmarsh and reedbed (CCO data)

The Rockley Viaduct at the mouth of Lytchett Bay is sufficiently narrow to prevent any significant wave activity entering from Poole Harbour. Still, the surrounding area of Lytchett Bay is at risk of flooding now and in 100 years time, with the area to the north-west most at risk (Figures i.4, i.5 and i.6). The Environment Agency's Flood Reconnaissance System recorded surface water flooding in this area in 1990, with flooding of the A35 and a local pub recorded in 1994 and 2007 and flooding of the B3067 recorded in 2009 (Figure i.1).

4. Current Situation and Approach

- Investigation and monitoring

In 2008, the South-east Strategic Regional Coastal Monitoring Programme (SSRCMP) undertook coastal Biodiversity Action Plan extent mapping (i.e. mudflat, saltmarsh, coastal grazing marsh, saline lagoons, vegetated shingle, reedbeds, sand dunes and maritime cliffs and slopes) using digital aerial photography and Light Detection and Ranging (Lidar) data (Figure i.1).

- Methods used to predict the Hazard and Risk Potential at Lytchett Bay

Lidar data, derived from the SSRCMP, was used as the basis for developing flood risk assessments in Poole Harbour, under a "No defences" scenario (Figures i.4 and i.5) for the Poole and Christchurch Bays SMP (2010). Flood zone areas were produced in a Geographical Information System, which were compared with co-ordinate defined address point data to identify those properties at risk of flooding for each ward. The approach adopted provides an overview of those areas that are clearly at flood risk under extreme conditions now and in 100 years time, taking into consideration sea level rise; these formed the basis for preliminary risk considerations when setting policy within the SMP.

More localized, detailed analysis was also undertaken in the Poole and Christchurch Bays SMP (Royal Haskoning, 2010) which considered what would happen to the shoreline if all coastal management ceased, otherwise known as a "No Active Intervention" scenario (Figure i.6). Predicting erosion of the shoreline for Lytchett Bay was complex because of the differing saltmarsh extents, and corresponding life expectancy.

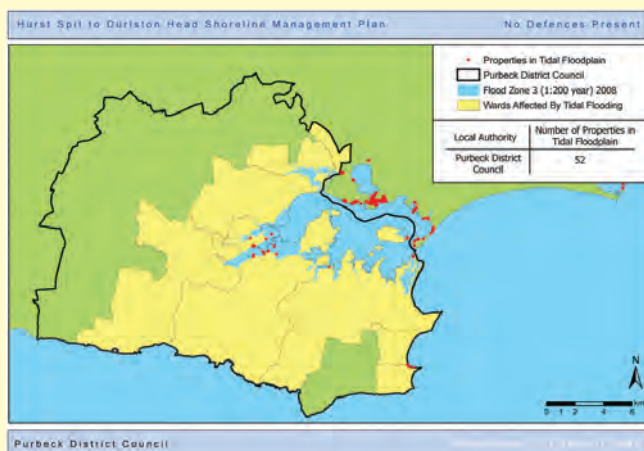


Figure i.4: 2008 floodzone

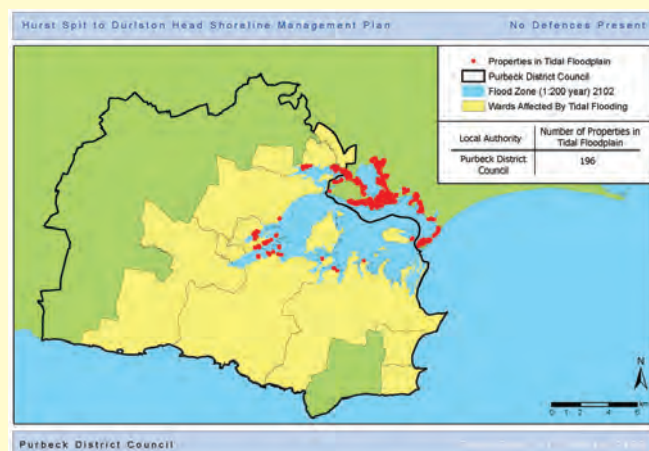


Figure i.5: 2102 floodplain

The saltmarshes behave as a natural barrier against erosion to the shoreline so as they die back, the risk of erosion and flooding increases. The life expectancy of the marshes was estimated based on historical records (Born, 2005) so that the onset of erosion to the land behind the saltmarshes could be calculated in the correct epoch; as an example, where the saltmarshes had a life expectancy of 50 years, erosion to the land would begin in epoch 50-100 years. The saltmarshes in Lytchett Bay are relatively stable, so erosion was predicted to commence in the 50-100 year epoch. Erosion of the land itself was not based on a long historical record as data was not available. Therefore, given the extremely sheltered nature of Lytchett Bay an erosion rate of 0.3m per annum was derived from estimates elsewhere in the harbour and Channel Coastal Observatory data. Refinement of this erosion rate will improve with data collected as part of the South-east Strategic Regional Coastal Monitoring Programme.

- **Current status and actions: how are we adapting to coastal climate change in this location?**

Lytchett Bay can be divided in two based on the built up nature of the east side of the bay and the more rural landscape on the west side of the bay. In the recent Poole and Christchurch Bays SMP (Royal Haskoning, 2010), east Lytchett Bay was given a Managed Re-alignment policy in the short term (0-20 years) to ensure the defences are set back to a more sustainable position and a Hold The Line policy for the medium and long term (20-100 years) to protect the assets from erosion and flooding. The west side of Lytchett Bay was given a No Active Intervention policy for the short to medium term (0-50 years) allowing natural development of the shoreline, followed by Managed Re-alignment in the long term (50-100 years) providing local defence to property, subject to sea level rise.

5. Key issues: What can we learn from this site to inform coastal risk management and adaptive planning?

The west side of Lytchett Bay is an unusual example of an area where roll back of the shoreline, to combat potential sea level rise and increased risk of erosion and flooding, is possible and will potentially result in the formation of new inter-tidal habitats (Cope et al, 2010). These new inter-tidal habitats will provide a natural form of protection to the shoreline and create valuable habitats for wildfowl and waders. This case study demonstrates the need for longer datasets to refine current erosion assessments and the requirement for adaptation to climate change, in the form of setting back defences, to protect people and property potentially at risk in the long term.

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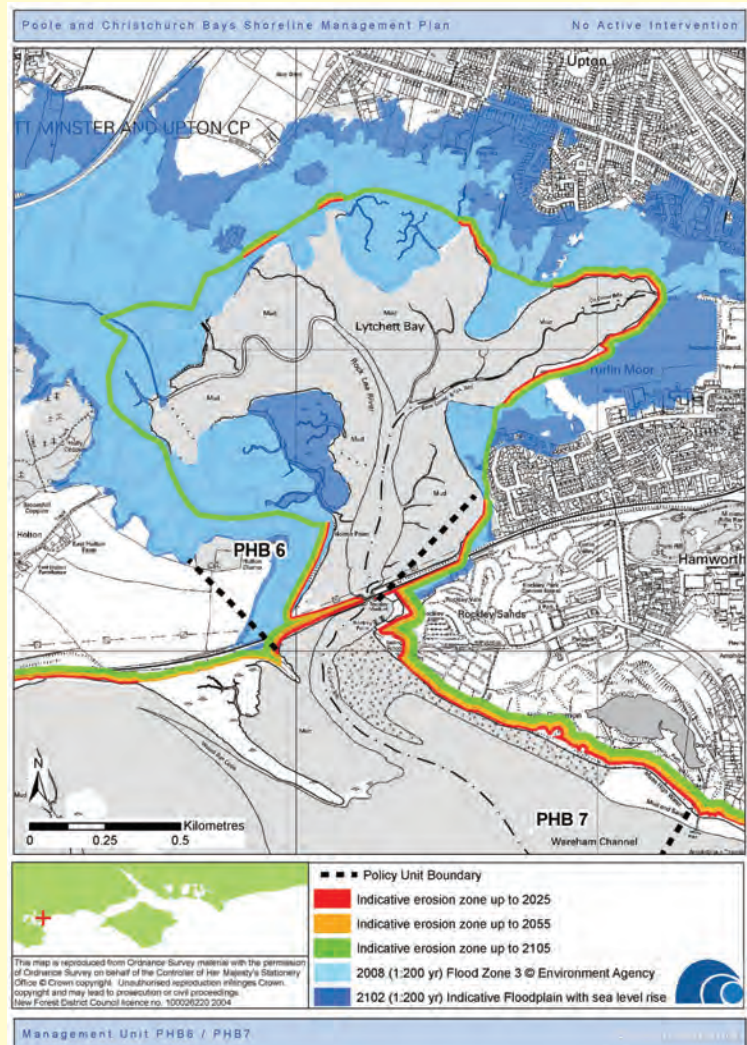


Figure i.6: Erosion under a No Active Intervention scenario
© Poole and Christchurch Bays SMP (Royal Haskoning, 2010)

CASE STUDY J: CHESIL BEACH

Location:

Chesil Beach, is a linear swash-aligned barrier beach located in Lyme Bay, Dorset, backed by the Fleet Lagoon (Figure j.1).

Why was this study area chosen?

Chesil Beach is a rare international example of a natural tombola form, being attached to the coastline at the proximal end (West Bay) and terminating at Portland Bill 28km eastwards. It is a critical control feature, protecting Weymouth Bay from incoming south-westerly swell waves.

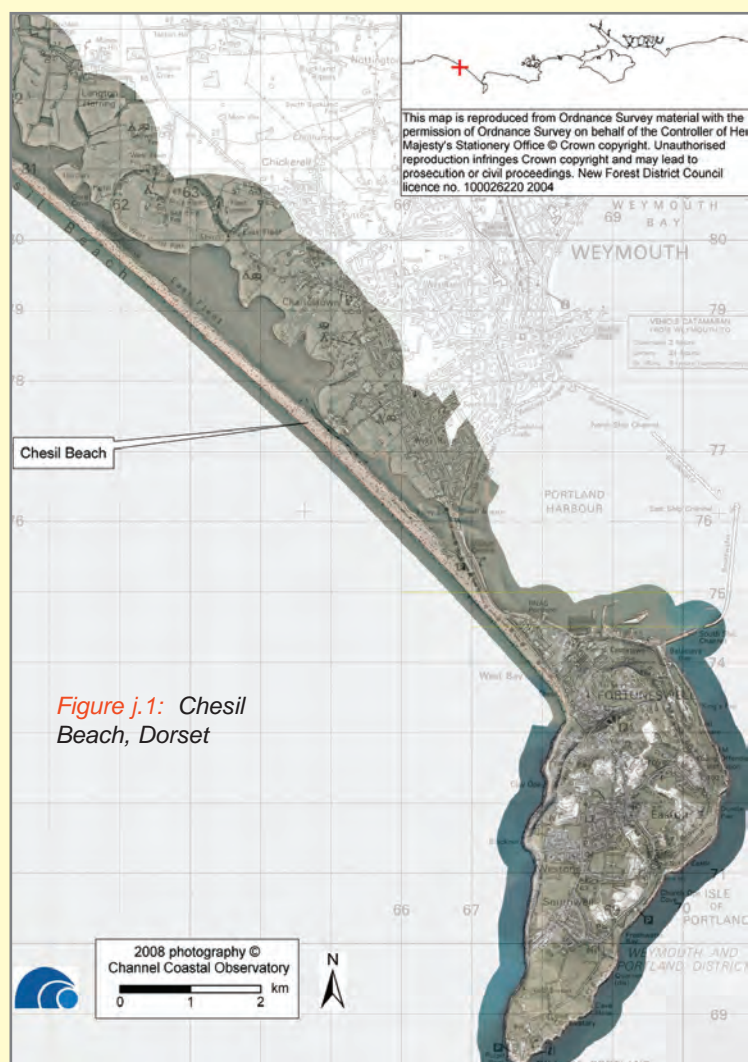


Figure j.1: Chesil Beach, Dorset

1. Overview

Chesil Beach is prone to south-westerly storm and swell wave attack given the extensive south-westerly fetch. The beach has prograded a natural, dissipative large cross-sectional area through time, characterised by seepage cans which allow water to efficiently percolate through the barrier whilst keeping it intact. Despite construction of sea defences in the 1980's and 1990's, the settlement at Chiswell is still vulnerable to flooding.

2. Geological and Geomorphological setting

The SCOPAC Sediment Transport Study (Carter et al, 2004) notes that there are various theories on the origin of Chesil beach due to the geology of the beach material, which indicates sediment input as far west as Lands End, Start Bay, Budleigh Salterton and Lyme Bay. The consensus is that the Chesil barrier migrated onshore throughout the rapid Holocene transgression, thereby incorporating gravel deposits into the system from Lyme Bay sea floor (Carr, 1978; Nicholls, 1985; Bennett *et al*, 2009). Cliff erosion from sites to the west, would have provided a longshore sediment source from which the beach prograded and became a sediment sink (Bray, 1996) (see Figure j.2). As sea level rise continued to slow in the late-Holocene, offshore deposits were no longer prominent as a sediment source and the beach became more dependent on the longshore sediment supply.

3. The nature of historical evolution and coastal risks

Chesil Beach, which is composed primarily of chert and flint, was in dynamic equilibrium with sediment supply from the west until the two piers at West Bay were built in 1825. By 1866, the eastward drift had declined (Posford Duvivier, 1998). This, along with over 1.1 million m³ of shingle extraction from Chesil beach since 1900 (from the 13 - 57 million m³ beach volume - Carr, 1978), promoted a closed unstable system more vulnerable to wave attack (Bray, 1996). Crest lowering and landward migration are dominant processes operating on the tombola, with numerous flooding events, particularly along the eastern end. Most breaches have sealed naturally in the past, although on some occasions human intervention has been necessary (Posford Duvivier, 1998). Conversely, Doe (2006) postulates that no clear breaches can be determined from historical evidence, besides the 1824 storm, although there were potentially 26 overwashing events between 1824 and 2006.



Figure j.2: West Bay to Portland Bill sediment transport
© SCOPAC Sediment Transport Study

multibeam data was collected for the area between Chesil Beach and Swanage, mapping the bathymetry to approximately 10 km offshore (Figure j.3).

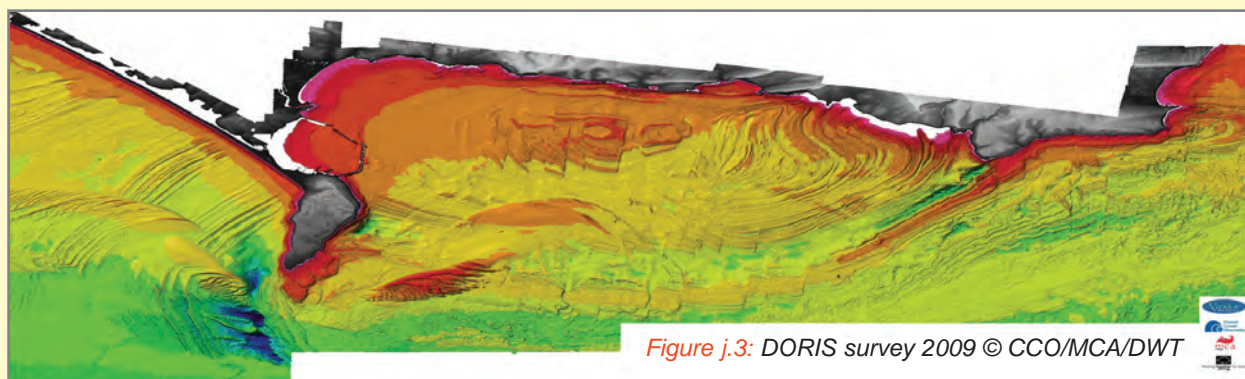


Figure j.3: DORIS survey 2009 © CCO/MCA/DWT

• Methods used to predict the Hazard and Risk Potential at Chesil

The Environment Agency used Lidar data to replicate the 1824 flood for which 22ft of water was recorded at Abbotsbury. In addition, using a coarse method of analysis, the number of properties at risk of flooding under the Environment Agency's 1:200 yr floodzone 3, for the area between West Bay and Portland Bill (MU2 and MU3) has been calculated as approximately 134 properties for the SCOPAC ACCESS project. The assets at risk will be much higher following more detailed methods of assessment and property values applied at Strategy level. In addition, the number of properties at risk will increase with sea level rise.

As part of the Chesil Sea Defence Scheme, completed in 1988, the sea wall at Chiswell was raised by 1.5 m and gabion cages implemented between Cove House Inn and the north-west to successfully raise the level of the beach in order to reduce the number of overtopping and overwashing events. In addition to this, a drainage channel was constructed to carry away flood water as Mere Lagoon, which once collected flood-water, was reclaimed and developed into a helicopter station (West, 2001). The sea defences mentioned above only provided protection against a 1:5 year flooding event, therefore, the gabion cages were extended further in 1996 to increase the standard of protection to approximately a 1:10 to 1:15 year storm event.

4. Current Situation and Approach

• Investigation and monitoring

Since 2006, the South-west Strategic Regional Coastal Monitoring Programme (SWRCMP) has monitored beach profile changes on an annual basis using 0.5m resolution Lidar data flown for the frontage every year. In addition, ortho-rectified aerial photography is captured by the programme every three years and a nearshore wave buoy was deployed in January 2007, collecting realtime wave data (see www.channelcoast.org). In 2009,

Predicting the future evolution of shingle barrier beaches and spits is notoriously difficult given their sensitivity to sea level rise and sediment input. In terms of predicting overwashing (Figure j.4) and breaching events for Chesil Beach, Bradbury's (1998) overwashing model provides the best available tool (see Case Study F: Hurst Spit). Still, the model was developed for predicting shingle barrier beach response to storm wave conditions, rather than accounting for a dominant swell wave component. The model therefore requires validation for bi-modal conditions at Chesil Beach.

- **Current status and actions: how are we adapting to coastal climate change in this location?**

The recommended long term policy from the Durlston Head to Rame Head Shoreline Management Plan (Halcrow, 2010) is for No Active Intervention along the natural section of Chesil Beach with localized maintenance of structures along the eastern shore of The Fleet under an emergency (subject to the availability of alternative funding) and for a Hold the Line policy for the eastern end of the beach at Chiswell. The Beach Management Plan (Halcrow, 2010) notes, however, that despite construction of the flood defence scheme in the 1980's, the area still remains at risk from a large storm or swell wave event, resulting in catastrophic flooding and rapid inundation. There is an emphasis on flood forecasting to minimize potential damages. The Shoreline Management Plan (Halcrow, 2010) notes that in the long term the beach will migrate inland, with an increasing risk of a storm or swell wave event that could cause significant damage in the form of a breach.



Figure j.4: Overwashing at Chesil Beach in 1979
(<http://www.chiswellcommunity.org/page.aspx?p=chbeach>)

5. Key issues: What can we learn from this site to inform coastal risk management and adaptive planning?

Chesil Beach is one of few remaining shingle barrier features in southern England that is un-managed for the majority of its length, thereby allowing the beach to form the best natural protection against storm and swell waves in the form of a well graded, naturally sorted, dissipative profile, characterised by seepage cans which allow water to efficiently percolate through the barrier whilst keeping it intact. Still, there is a need to better understand and predict the risk of breaching during extreme storm and swell wave events through development of existing tools and new models. The South-west Regional Coastal Monitoring data will be paramount in supplying long term data in order to better understand the behaviour of shingle barrier beaches such as Chesil Beach, and to refine flood forecasting and trigger levels.

Further Reading

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CASE STUDY K: LYME REGIS AND CHARMOUTH

Location: Lyme Regis to Charmouth, West Dorset, UK.

Why was this study area chosen? The Spittles and Black Ven form one of the most spectacular coastal landslide complexes in Europe and form part of a World Heritage site celebrated for its unique Jurassic geology and natural environment, yet they are subject to large-scale potentially catastrophic landslides which pose a significant risk to cliff top assets and public access.

1. Overview

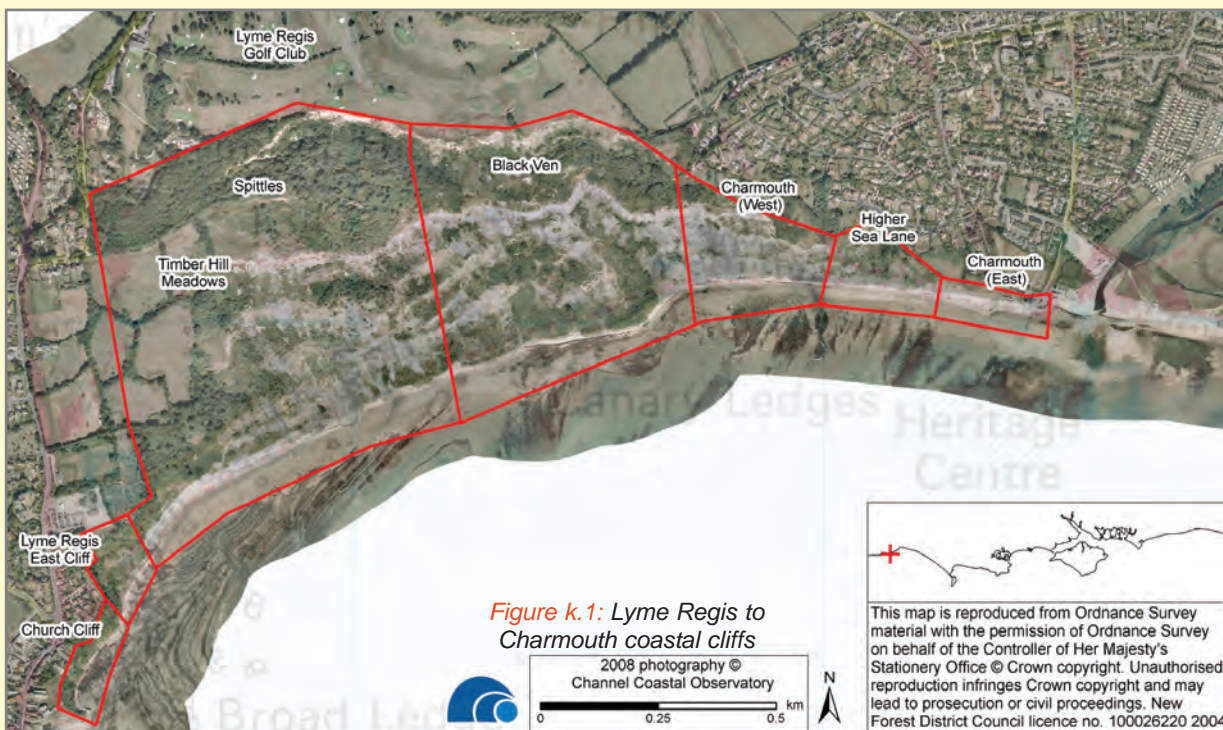


Figure k.1: Lyme Regis to Charmouth coastal cliffs

The Lyme Regis to Charmouth coastal cliffs provide an excellent case study of the issues concerning coastal erosion and landslides, protection of built assets, safe public access, natural environment and World Heritage status. Church Cliff and East Cliff are located at the western end of the study area adjacent to the urban area of Lyme Regis. They are characterised by steep terraced sea cliffs formed by coastal erosion over many decades; the cliffs are unstable which has an adverse impact on cliff-top property, mainly at East Cliff. The cliffs are protected by a concrete sea wall and groynes, constructed at different times during the 1950/60s, and more recent stabilisation measures above the sea cliffs comprising slope drainage and piling. These engineering measures have been effective at reducing the rate of sea cliff erosion and recession, but notably the works have not prevented land instability above the sea wall which takes the form of progressive ground movement and occasional large-scale and potentially catastrophic landslide reactivation.

For much of the historical period, the Timber Hill Meadows and the Spittles ancient landslide complexes have remained relatively stable; the coastal slopes here were formed by landslide processes that were last active in pre- and post-glacial times, more than 10,000 years ago. Historical rates of cliff retreat of the unprotected sea cliffs along this section range between 0.2m to 0.7m per year; erosion rates were exacerbated in the past by the removal of limestone ledges from the foreshore for local cement production. During the mid 1980s, major reactivation of the Spittles landslide complex commenced and has continued to the present day, most recently resulting in the reactivation of the ancient headscarp at Timber Hill, and exposure of a 20th century landfill as a result of major failure of the sea cliffs in May 2008. Historically, the most active area has been Black Ven, to the east, which was affected by major landslide events in 1958, 1968 and 1994, resulting in headscarp recession of about 50m every 25-30 years. The cliff section fronting Charmouth is notably different and is characterised by a steep stepped cliff section compared to the broad multi-tiered landslide systems at the Spittles and Black Ven.

The failure mechanisms and historical behaviour of the Charmouth cliffs is consequently different and active toe erosion and cliff-top recession poses a significant risk to property developed on the cliff top in the 1970s. The historical rate of cliff recession along this section is approximately 0.3m per year.

2. Geological and geomorphological setting



Figure k.2: Black Ven and Charmouth Cliffs

The Lyme Regis and Charmouth coastal cliffs are celebrated for their Jurassic fossil assemblages, geological exposures, coastal geomorphology, and vegetated sea cliff habitats, and form part of the World Heritage Jurassic Coast. The geology at Black Ven comprises the Shales with Beef, Black Ven Marls and Belemnite Marls of the Lower Lias (Jurassic), which dips at 2 to 3 towards the SE to ESE promoting past and contemporary large-scale landslides. The Jurassic sequence is overlain by the Gault Clay and the Upper Greensand (Cretaceous). The cliff profile shows well-developed terraces on resistant rocks, which correspond to the base of the Upper Greensand, the base of the Belemnite Marls and the base of the Black Ven Marls. The cliffs provide examples of simple cliffs (Church Cliff), complex cliffs (East Cliff and Black Ven) and composite cliffs (Higher Sea Lane). They have been subject to a relative increase in sea-level and winter rainfall over the historical period.

3. Impact of historical cliff instability and erosion

The natural processes of cliff instability and erosion maintain a unique, distinctive and diverse landscape and habitat, whilst active erosion and removal of debris from the sea cliffs continues to reveal fossils for which Lyme Regis is famous. However, these processes also give rise to adverse impacts; during historical times the impacts on land use and development across the frontage have been considerable and include:

- Loss of farmland and at least three coastal roads since the 18th century.
- Loss of several properties, a gas works and part of the churchyard at Church Cliff and East Cliff
- Over 117m recession of the cliff top at the Lyme Regis Golf Club since 1940 at an average loss of 1.8m per year

4. Current situation and management approach

• Study site hazard and risk potential

The cliffs between Church Cliff and Charmouth are sensitive to toe erosion and large-scale, potentially catastrophic, landslides due to the unique geology and soft rocks which offer little resistance to weathering, surface erosion, excess groundwater and toe erosion. Potential future cliff recession rates and landslide event frequency under a scenario of rising sea-level and increased winter rainfall could be significantly greater than experienced in the past. Hence the active landslide systems at the Spittles and Black Ven will continue to develop and enlarge, and the urban areas of Lyme Regis and Charmouth will be under increasing threat from high rates of coastal erosion and more frequent large-scale landslides. The SMP projection of average rates of erosion over the next 20 years are not expected to result in any loss of property; however, 15 properties (worth £4.1m) are at risk between 20-50yrs, and 65 properties (worth £17.7m) are at risk between 50-100yrs. The main Charmouth Road, buried services and car park are major assets at risk in the latter period. The coastal defence failure and cliff recession scenarios developed for the East Cliff Phase IV scheme reveal that 144 properties could be lost over the period 0-28 years; these estimates are corroborated by NCERM projections. The variance with the SMP appears to be due to the inclusion of episodic potentially catastrophic landslide events in the NCERM and Phase IV recession scenarios which the SMP does not consider.

• Investigation and monitoring

West Dorset District Council has taken a pro-active approach over many years to the challenges of coastal change and land instability which has involved significant investment in the systematic and phased

investigation and monitoring of coastal erosion and landsliding at Lyme Regis and East Cliff. As a result, the mechanisms, frequency and magnitude of coastal change processes are well understood and underpin shoreline and coastal strategy plans and scheme appraisal.

- **Current status and actions: how are we adapting to coastal change in this location?**

The management strategy for Church Cliff and East Cliff is to hold the line, and major coast protection and cliff stabilisation works (Phase IV) are proposed to protect the east flank of Lyme Regis including the main road into the town from the east. In the meantime, landslide warning systems have been used to alert the public of any impending threats. Minor coast protection works have been implemented in the past at Charmouth, however, continuing recession of the cliffs poses a significant risk to cliff-top properties in the long term. Planning restrictions are in place to prevent inappropriate development on potentially unstable land and planning guidance maps have been produced to inform planning officers, developers and members of the public. No attempts have been made to intervene in the ongoing large-scale geomorphological processes at the Spittles and Black Ven - this area is celebrated for its geology, landslides and natural history and is considered to be a major asset as an educational resource and attraction for local interest groups and tourists. The Golf Club have operated a policy of managed retreat where golf facilities lost to cliff top erosion have been replaced by others further inland. The local community has been instrumental in influencing coastal management policy and has been kept informed and engaged through the issue of information leaflets, exhibitions and regular public meetings.



Figure k.3: East Cliff, Lyme Regis

5. Key issues: what can we learn from this site to inform coastal risk management and adaptive planning?

Whilst there will undoubtedly be serious challenges ahead, this case history illustrates how an area affected by large-scale episodic coastal change can be successfully managed by striking a balance between the protection of people and the built environment through sympathetic engineering schemes, whilst embracing and celebrating the natural landforms, geology and processes that attract World Heritage status. Key to the success of the shoreline and coastal strategy has been the significant effort and investment by engineers to understand the geology, geomorphology, cliff behaviour, coastal processes and environment, whilst fully engaging the local community in determining acceptable and sustainable policy and scheme concepts. Complex ground conditions require complex solutions combining both slope stabilisation and coast protection measures which has not been the norm in UK coastal defence practice.

Further reading

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Chapter Three

Evaluation of case study sites

The ACCESS study has examined 11 sites where the potential hazards and risks from coastal erosion, breaching, flooding and cliff instability have been investigated in detail. This research provides a focus for improved understanding of the risks to coastal communities and assets and the identification of adaptation measures to mitigate the impacts of climate change over the next 100 years. Adaptation can take various forms from strengthening coastal defences to avoiding areas of increasing potential hazard and risk together with the provision of improved education and awareness-raising for coastal communities. However, it is first necessary for those involved in coastal risk management to agree on how the frequency and rates of coastal change and the evaluation of assets at risk are calculated. The research has highlighted a number of current inconsistencies that need to be addressed and agreed in order that coastal erosion, flooding and cliff instability risks are not under-estimated and to ensure that an equitable system of funding for coastal erosion risk management can be implemented. The following assessments focus on cliff instability and erosion.

Cliff instability and erosion assessments

The National Coastal Erosion Risk Mapping (NCERM) project (Halcrow, 2010) was conducted as part of the Government's Making Space for Water programme (Defra, 2005) on behalf of the Environment Agency. The final output of NCERM aims to provide information on coastal erosion and cliff instability and for professionals and the general public; original outputs were based on generic erosion predictions from FutureCoast (Halcrow, 2002), which were then reviewed and amended, as appropriate, by local authorities throughout England and Wales.

Following the first tranche of local authority validation, the Environment Agency commissioned further research to highlight where the NCERM erosion predictions should be modified to account for UKCP09 climate change scenarios, ensuring NCERM makes best use of the most up to date climate change projections (Moore *et al*, 2010). This additional research is referred to as, "validated NCERM09 predictions". The results of the validated NCERM09 research for 22 priority sites for which quantitative datasets are available, has revealed a close correlation with NCERM for cliff recession projections for high sensitivity non-complex cliffs but not for high-sensitivity complex cliffs (see glossary of terms). The differences are randomly distributed and highlight issues regarding mapping of complex cliff extents, and validation of appropriate landslide magnitude and frequency values. The majority of NCERM projections show a significant under-prediction of potential cliff recession for complex cliffs and generally do not have sufficient range to account for UKCP09 scenario impacts over the next 100 years (Moore *et al*, 2010). This is because NCERM was originally based on the FutureCoast (Halcrow, 2002) study which produced generic, indicative values of cliff recession and instability, rather than locally validated rates of cliff recession.

Part of the ACCESS study research involved a comparison between UKCP09 validated NCERM predictions and Shoreline Management Plan round 2 (SMP2) erosion mapping outputs for simple and complex cliffs. The UKCP09 scenarios point to significant increases in winter rainfall frequency, intensity and magnitude, drier summers and rising sea levels, which is likely to result in increased cliff recession and coastal landslide frequency (Moore *et al*, 2010). The majority of the second round of Shoreline Management Plans could not account for future climate change, especially related to rainfall, when undertaking erosion predictions.

The key differences between the NCERM09 and SMP2 erosion predictions for six sites across the SCOPAC region, at risk of cliff instability and erosion have been examined (see Figures 3.1

to 3.4). The implications of applying varying erosion assessment methods at national, regional and local levels are outlined in terms of the number of properties predicted to be at risk and the values assigned to them.

The baseline from which erosion is projected is similar in both validated NCERM09 and the SMP2 predictions for the majority of sites, however, two sites show some differences. At Charmouth and Lyme Regis (Case Study Site K) the NCERM09 baseline is further seaward than that of the SMP (Figure 3.3) whilst at Ventnor (Case Study Site D) the NCERM09 baseline follows the backscar of the Undercliff compared to the SMP2 which follows the shoreline (although, the difference in area and the properties at risk are covered by the SMP2 in the possible landslide reactivation zone shown in Figure 3.4). These examples serve to demonstrate that in the case of complex coastal landslide systems the baseline should follow the landward limit or backscar as the coastal slopes seaward of this line will be subject to ongoing or episodic land instability with associated hazards and risk.

The erosion rates applied at each site vary considerably between the NCERM09 and SMP2 scenarios with neither consistently over or under-predicting each other (see Table 3.1). The test sites show that the NCERM09 and SMP predictions can be very different. In some cases NCERM09 predicts higher erosion rates than the SMP, which would be expected given inclusion of UKCP09 climate change scenarios, but in other cases the predictions are lower (for example, Case Study Site G - Barton, Naish and Case Study Site H - Swanage). These differences arise as a result of applying different historical rates of erosion, prediction methods and whether or not coastal landslides and the effects of climate change are included. The 22 validated NCERM09 sites used existing quantitative datasets measured from map-accurate historical aerial photography, site surveys, ground investigation and coastal processes data, where available; they provide a small number of sites where empirical relationships exist to quantify cliff responses to sea level rise and climate which are used to underpin future projections of change within known confidence bands. The SMP2s used similar data, where available, as well as Regional Coastal Monitoring information, although continuous, geo-rectified, historical aerial photography was not always available for the whole SCOPAC coastline.

Determining future erosion rates varies between SMPs and the 22 validated NCERM09 sites depending upon what data was available at the time, methods employed, access to information and whether any climate change data was included. Data availability and access to information is extremely varied throughout the SCOPAC region although the South-east Regional Monitoring Programme provides consistent data from 2002. Prior to 2002, historical aerial photography is the main source of quantitative data for determining large scale coastal evolution at a decadal scale but only where the photography has been scanned and geo-rectified to make it map accurate. When identifying potential historical datasets, it is important to note that the data is generally of a lower resolution and accuracy than more recent imagery and may not have been flown at low tide. Obtaining a consistent coverage of map accurate historical aerial photography across the SCOPAC region is essential for future prediction of coastal change.

Another difference between the validated NCERM09 and SMP2 datasets is the defence data used to determine the onset of erosion, following predicted defence failure. The erosion distances calculated by NCERM09 consider the defence deterioration of the sites, derived from various parameters depending upon the type of structure, whereas the SMP2 erosion distances include locally derived defence residual life information. The difference in the defence information used results in the onset of erosion being predicted at different timescales, impacting on the number of properties at risk (see Table 3.2), which in turn affects the benefit-cost analysis used to determine the policy and funding for the frontages in SMP2s. The residual life, essentially, provides an offset to the time that erosion might be expected to commence. Although a standard approach is followed, the difficulty is that residual life assessments are generally subjective. It is

suggested that the variability of predicted and actual residual life may be as much as 20-30 years different, thereby placing the failure in a different SMP epoch; this has serious implications when assessing coastal defence policy options.

Another factor to consider when predicting erosion rates is the initial cut-back rate as the coastline adjusts to a new equilibrium shoreline position. Rates of erosion are often a lot higher following initial breaching or removal of defences and can be difficult to estimate where the surrounding shoreline is defended, offering no indication of where the shoreline would be under a no defences scenario. In such circumstances, use of analogue sites, where accelerated erosion and outflanking effects have been experienced, can be used to inform assessments.

To summarise, the key factors affecting erosion projections are as follows:

- Defining the baseline location
- Historical erosion rates and landslide frequency (quantitative datasets)
- Prediction method (including landslides and climate change)
- Defence residual life
- Initial cut-back erosion rate

Data and Methods used for determining properties at risk

The data and methods used for determining the number of properties at risk from instability, erosion or flooding will very much influence the outcome and in turn the benefit-cost analysis and the likelihood of scheme funding. Ordnance Survey Address-point data was used to represent individual residential properties, multiple occupancy holdings and commercial buildings for both the SMP2s and for the ACCESS project. Co-ordinates are provided for every address to enable the file to be added into a GIS system for quick spatial identification.

At the level of detail required for SMP2, only those property points that fell within the SMP2 erosion or flood risk zones were included in the total number of properties at risk. If a property point fell landward of the 50-100yr erosion zone, for example, this was not included in the totals (see Figure 3.5). This method is reliant on the property point representing the whole property area when in fact the point is not always positioned in the centre of the property and does not cover the whole property area. Indeed the edge of a property could be affected by erosion but this coarse method of analysis would not always identify this property as being at risk (see Figure 3.5).

Location	Map location (Figures 3.1-3.4)	NCERM predictions for low emissions scenario			NCERM predictions for high emissions scenario			SMP2 predictions			SMP2 predictions for high erosion scenario	
		Anticipated recession distance over 100yrs (m)	Estimated average erosion rate (m/yr)	Anticipated recession distance over 100yrs (m)	Anticipated recession distance over 100yrs (m)	Estimated average erosion rate (m/yr)	Anticipated recession distance over 100yrs (m)	Anticipated recession distance over 100yrs (m)	Estimated average erosion rate (m/yr)	Anticipated recession distance over 100yrs (m)	Estimated average erosion rate (m/yr)	Estimated average erosion rate (m/yr)
Barton-CBY4	a	60	0.60	78	78	0.70	175	175	1.75	290	2.90	2.90
Barton-CBY4	b	60	0.60	78	78	0.70	130	130	1.30	230	2.30	2.30
Barton-CBY4	c	40	0.40	52	52	0.50	130	130	1.30	230	2.30	2.30
Barton-CBY4	d	88	0.80	152	152	1.10	190	190	1.90	280	2.80	2.80
Barton-CBY4	e	129	1.20	155	155	1.30	290	290	2.90	230	2.30	2.30
Naish-CBY3	f	129	1.20	155	155	1.30	275	275	2.70	430	4.30	4.30
Swanage-SWA4	a	38	0.37	46	46	0.45	60	60	0.60	N/A	N/A	N/A
Swanage-SWA3	b	12	0.11	14	14	0.12	42	42	0.60			
Lyme Regis-MU 6	a	300	3.00	500	500	5.00	50	50	0.50			
Lyme Regis-MU 5-5	b	250	2.50	450	450	4.50	40-50	40-50	0.40-0.50			
Lyme Regis-MU 5-5	c	180	1.80	300	300	3.00	45-50	45-50	0.45-0.50			
Lyme Regis-MU 5-5	d	188	1.87	226	226	3.00	40-45	40-45	0.40-0.45			
Charmouth-MU 5-3	e	150	1.50	270	270	2.70	40-45	40-45	0.40-0.45			
Ventnor-VEN1	n/a	140	1.40	230	230	2.30	60-70	60-70	0.60-0.70			

Table 3.1: Comparison of NCERM09 and SMP2 erosion rates per year at selected sites across the SCOPAC coastline

Location	Management Unit	Properties at risk over 100 years						NCERM low
		NCERM low	NCERM high	NCERM landslip	SMP2	SMP2 higher rates	NCERM low	
Barton	CBY4	7	37		324	573		
Naish	CBY4	38	38		262	378		
Swanage	SWA3	0	0		102			
	SWA4	0	0	N/A	0		N/A	
Lyme Regis and Charmouth	MU5-3	1	3		0			
	MU5-5	65	156		5			
	MU6	15	20		75	N/A		
Ventnor	VEN1	39	63	3	1		3	
	VEN2	0	0	2508	116		2482	
	VEN3	0	0	343	6			

Table 3.2: Comparison of properties at risk as a result of NCERM09 and SMP2 erosion predictions at various sites across the SCOPAC region

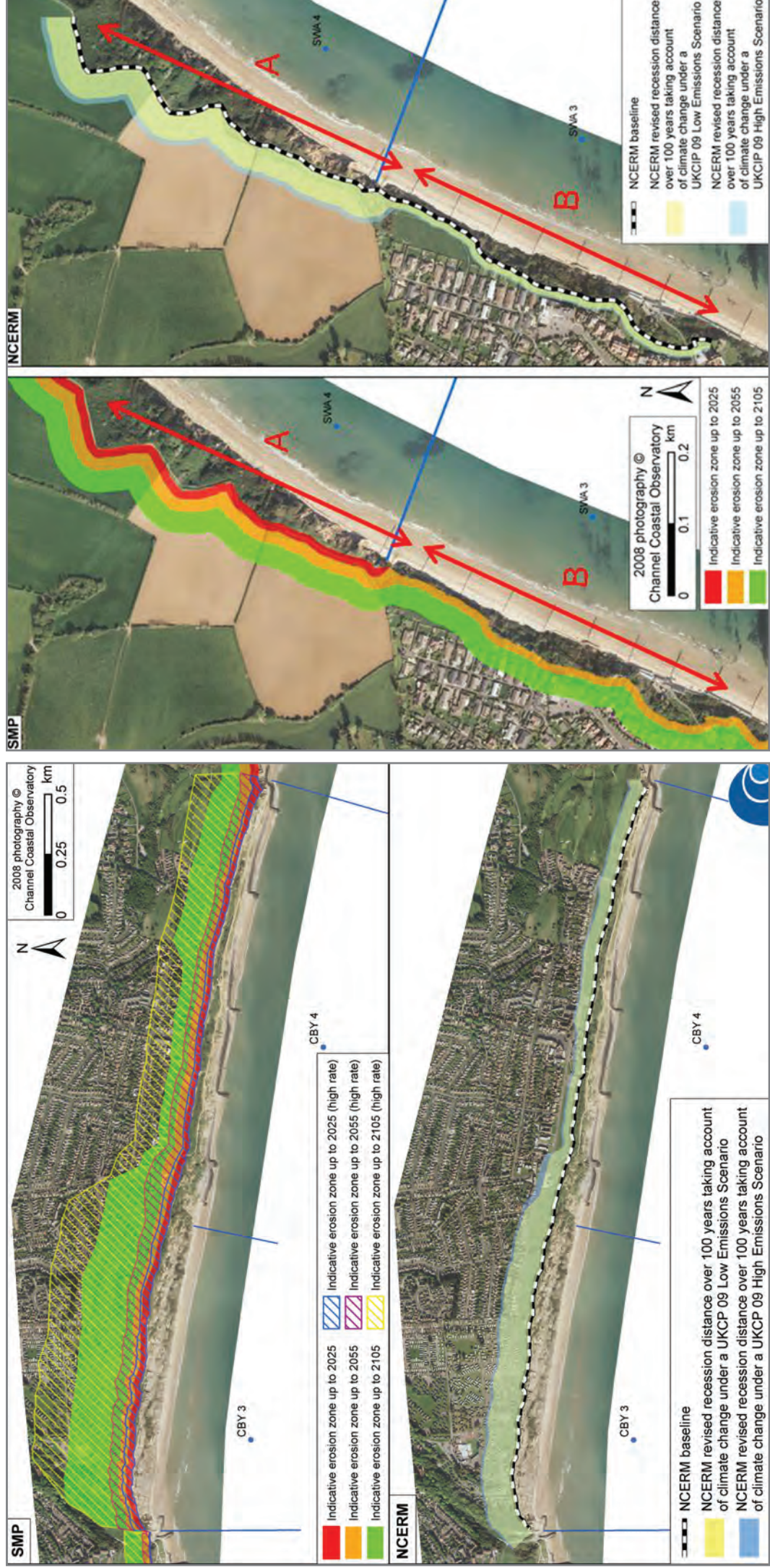


Figure 3.1: Barton-on-Sea and Naish, Hampshire - Comparison of predicted erosion rates between the Poole and Christchurch Bays SMP2 (top) and validated NCERM09 (bottom)

Figure 3.2: Swanage, Dorset - Comparison of predicted erosion rates between the Poole and Christchurch Bays (left) SMP2 and validated NCERM09 (right)

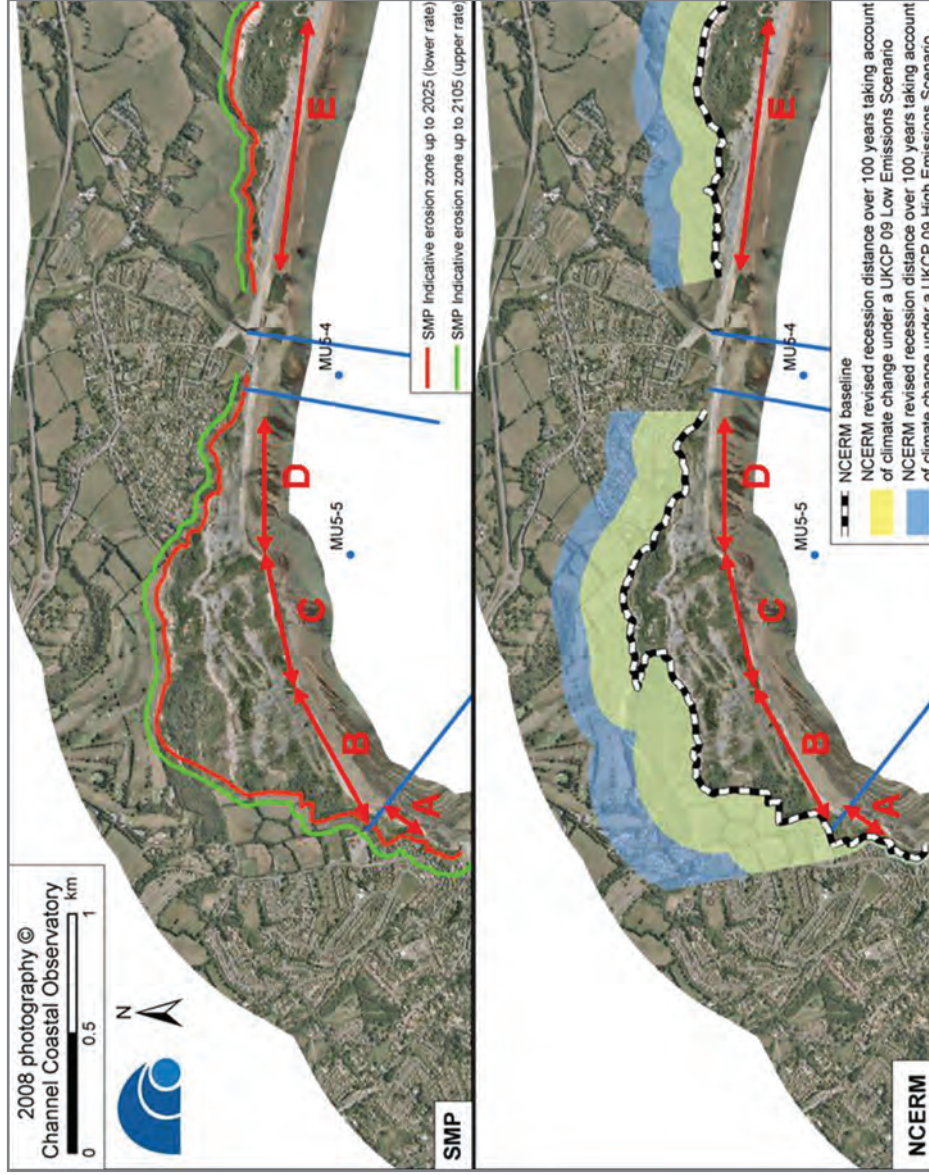


Figure 3.3: Lyme Regis and Charmouth, Dorset - Comparison of predicted erosion rates between the Durlston Head to Rame Head SMP2 (top) and validated NCERM09 (bottom)

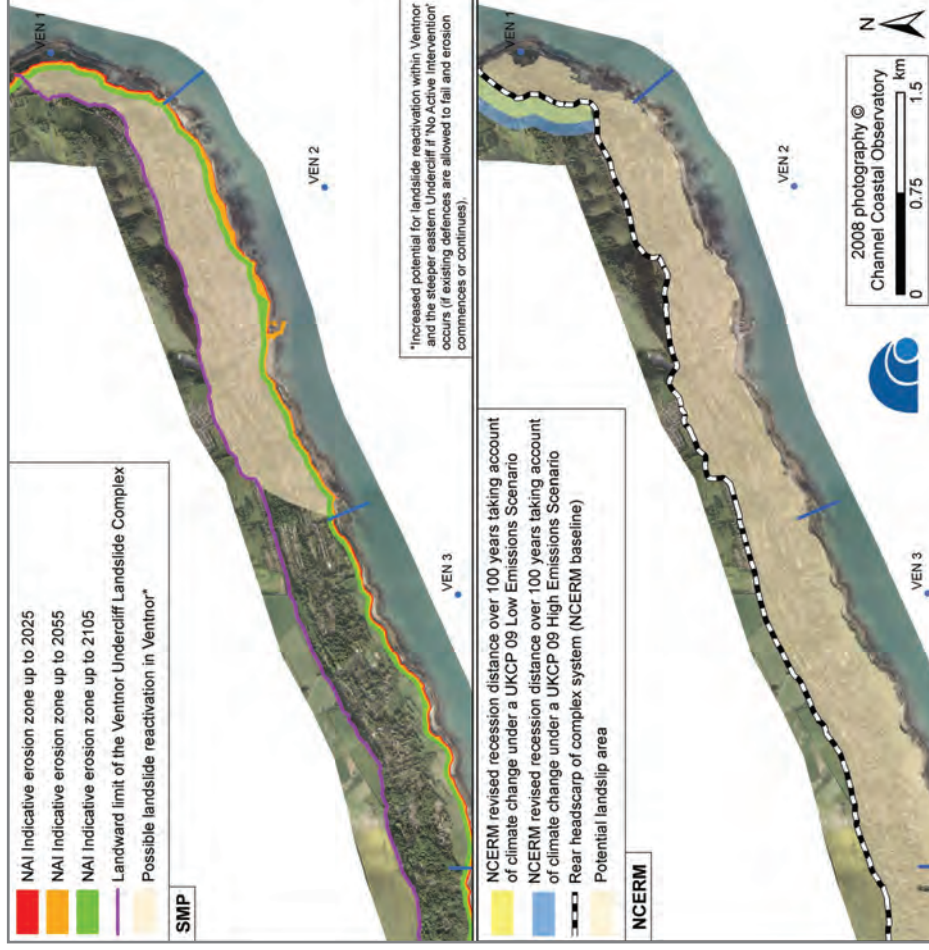


Figure 3.4: Ventnor, Isle of Wight - Comparison of predicted erosion rates between the Isle of Wight SMP2 (top) and validated NCERM09 (bottom)

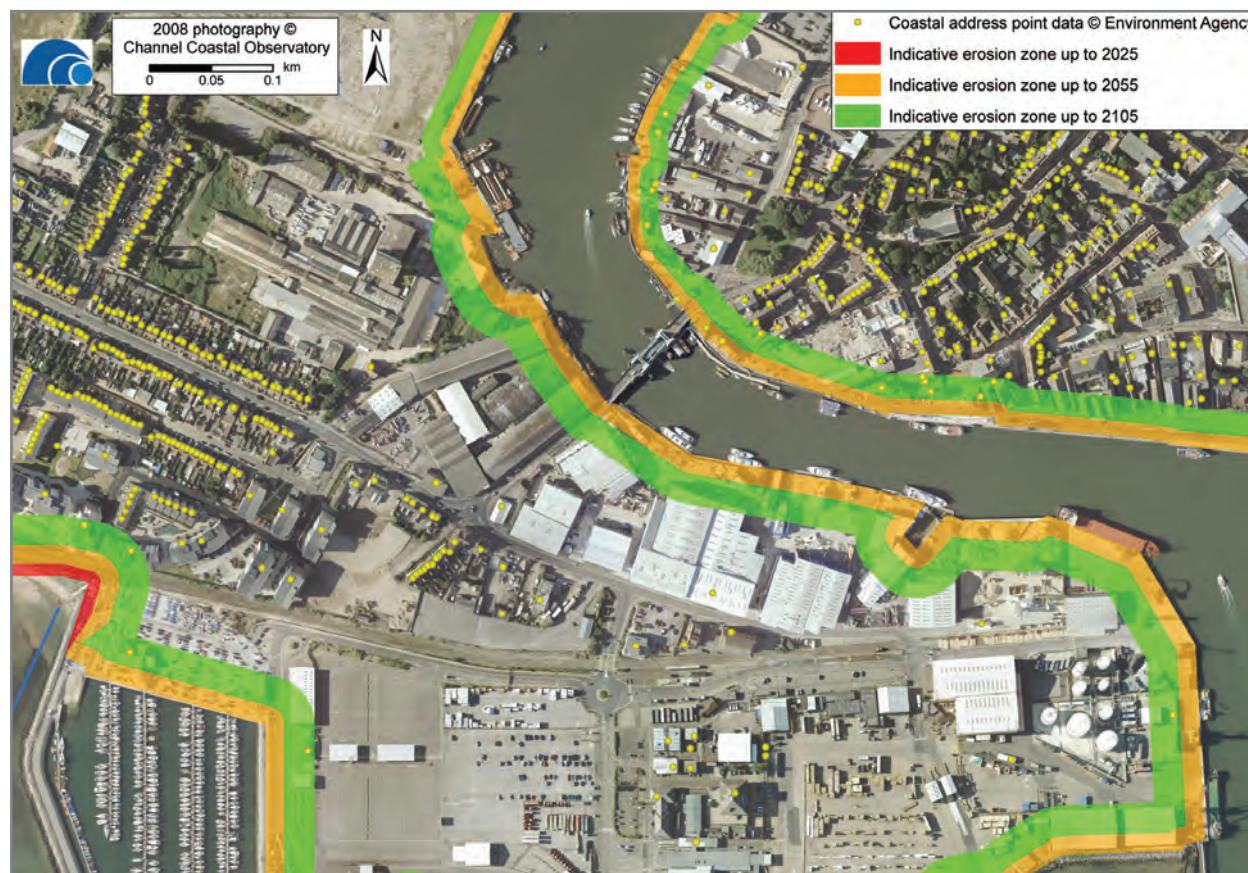


Figure 3.5: Method for identifying properties at risk at Poole Harbour, Dorset

Aerial photography was not used to identify the number of properties at risk in the SMP2s due to the requirement for a high level assessment, therefore, the total number of properties potentially at risk from erosion and flooding is typically underestimated compared to those identified in more detailed Coastal Defence Strategy Studies; Lee-on-the-Solent in Hampshire provides a good example of this. The number of properties at risk from erosion in 100 years time was zero using the address-point data approach in the SMP2, however the number of properties identified by using aerial photography was 136. This has significant implications when undertaking benefit-cost analysis, as does the fact that the Address-point data does not necessarily cover all buildings or identify industrial areas (see Figure 3.5 where not all industrial areas have an address point); this results in further under-estimation of assets at risk.

The National Receptor Dataset (NRD) is an updated version of the Address-point data and includes missing buildings and industrial areas. It is imperative that this national dataset, commissioned by the Environment Agency, is made freely available to coastal studies to ensure consistency between projects on a local and national basis.

Valuation of properties at risk

As recommended in the Defra 'SMP2 guidance' (Defra, 2006), the second generation SMPs and the ACCESS project have used broad scale local estate agent property values, such as those identified by the British Broadcasting Corporation (BBC) to determine the property benefits associated with erosion, instability and flooding (BBC, 2011). In contrast, Strategy Studies generally apply more detailed, local valuation to the loss of assets. Barton-on-Sea (Case Study Site G) is a good example, whereby the number of properties at risk identified in the SMP2 compared to the draft Coastal Defence Strategy Study and the property values applied are very different, even though both studies used the same predicted erosion zones (see Table 3.3).

BARTON-ON-SEA	
SMP number of properties	SMP property value
324	£84 million (average New Forest local authority property value £260,165)
Strategy number of properties	Strategy property value
520	£185 million (average property value for Barton-on-Sea £685,000)

Table: 3.3. Comparison of properties at risk and values applied in the SMP2 and Strategy Study at Barton-on-sea (values are 2010 estimates).

The differences in identifying the assets at risk and assigning property values are attributed to the different methods and the values applied. As would be expected, Coastal Defence Strategy Studies generally go into much more detail than SMP2s given that an SMP2 is a high level, broad scale, policy setting document, setting a vision for the coastline, whilst a Strategy Study provides the detail on how to implement the policies. Using a single uniform national GIS base layer (i.e. NRD) for both SMP2s and Strategy Studies and a locally derived property value that accounts for inflation of property values on the coast, would help in closing the gap. It is suggested that the value of the assets at risk from erosion is likely to be significantly higher than is shown in the SMP2s. More examples are required to provide further validation of this, although the example presented indicates that the required high level approach in the SMP2 accounts for only 45% of the value determined by more detailed assessment methods.

Predicting the evolution of barrier beaches, sand dunes and saltmarshes

The focus of the NCERM project was on predicting erosion of simple and complex cliffs, whilst the SMP2s covered all geomorphological systems when undertaking the 100 year Baseline Scenario Assessments. Given the lack of methods available for predicting the evolution of barrier beaches, sand dunes and saltmarshes, the majority of SMP2s in the SCOPAC region did not provide robust evolutionary predictions for these systems. This means at national and regional level there is a lack of evolutionary modelling for these dissipative systems, which act as a first line of defence against storm surges. Case study C and E provide suggestions for methods available for predicting the erosion of saltmarshes.

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Chapter Four

Conclusions and recommendations

There is no doubt that central southern England faces increasing risks from coastal erosion, coastal land instability, breaching and flooding over the next 100 years; these risks are quantified in the round two SMPs.

The ACCESS project research work has taken advantage of the Environment Agency's validated 'National Coastal Erosion Risk Mapping '09 research and the second round of Shoreline Management Plans as well as other sources. The ACCESS study team recognises the challenges of implementing coastal risk management particularly when financial resources are limited. It is important, therefore, to ensure that a sound, standardised basis for assessment of rates of coastal change, as well as for evaluating current and potential assets at risk can be put in place. The need to remove any inconsistencies of approach in terms of these assessments is deemed to be particularly important.

Conclusions

1. The case studies illustrate that in the context of climate change the SCOPAC region faces a significant increase in levels of risk from erosion, coastal land instability and flooding, which will impact upon people, property and important infrastructure.
2. The challenges of coastal climate change can be addressed most effectively through the continuance of the commissioning of monitoring, research and the sharing of findings by SCOPAC, the Coastal Groups, the Environment Agency and Defra.
3. The South-East Strategic Coastal Monitoring Programme is forming an historical database that is invaluable for understanding long-term coastal change.
4. The eleven case studies show that significant property and assets will become at greater risk from coastal natural hazards than that which is currently predicted. The ACCESS report, through the case studies, has highlighted these locations for action by the Coast Protection Authorities.
5. Various approaches used to assess rates of coastal erosion for NCERM and the SMP2s have resulted in widely differing estimates of retreat for the next 100 years; a standardised approach is required which also allows advantage to be taken of locally held datasets.
6. The evolution of fringing barriers, barrier beaches and spits, sand dunes and saltmarshes was not within NCERM's remit and has not been covered sufficiently well in SMP2s. This has resulted in a gap in modelling risk for these systems, for which SCOPAC has a high proportion.
7. The case studies clearly demonstrate the need for a standard approach to be adopted towards the economic valuation of assets at risk (including commercial assets and infrastructure) as the current system undervalues the economic benefits and hence the benefit-cost analysis of potential coast protection schemes.
8. Coastal instability hazard, comprising first time failures, re-activation of dormant landslides and ongoing instability sites, will pose increasing risks for parts of the SCOPAC coastline (e.g. Dorset and the Isle of Wight). Research commissioned by the Environment Agency into the case for funding coastal landslide remediation under the Coast Protection Act is welcomed as a way forward in addressing these problems.

General recommendations

1. The ACCESS case studies have highlighted inconsistencies between both rates of coastal erosion data and benefit-cost data in support of applications for coast protection funding. A working group led by the Coastal Groups in partnership with the Environment Agency and Defra should be established to develop national standards for calculation of coastal erosion and instability rates together with improved approaches to identifying the economics of assets at risk.
2. The South-east and South-west Strategic Monitoring Programmes have made an important contribution by providing historical datasets to support the research into coastal change. These will become increasingly valuable over time as a definitive record of change on the coast. Ongoing funding for the Programme should form an essential part of coastal risk management for the long-term.
3. The results of the ACCESS study should be disseminated through a sub-regional conference as well as nationally through the Coastal Groups and the Environment Agency National Coastal Forum.
4. SCOPAC continues to play a key role in terms of research that can be applied in the region as well as more widely. Membership of SCOPAC should be maintained and, if possible, expanded to increase the research potential to the benefit of constituent members.

Specific recommendations

In order to avoid future inconsistencies between various projects it is recommended that the following issues be given consideration at a national level:

1. A freely available, centralised database of erosion and accretion rates and a national baseline should be held by the National Network of Coastal Monitoring Programmes at the Channel Coastal Observatory (www.channelcoast.org), comprising historical photography interpretation and output erosion rates that can be updated as more recent Coastal Monitoring data becomes available. This should cover not only simple and complex cliffs but fringing barriers, barrier beaches and spits, sand dunes and saltmarshes.
2. Clarification is required on the methods to be applied for predicting evolution of fringing barriers, barrier beaches and spits, sand dunes and saltmarshes. It is recommended these systems be incorporated into NCERM in the future. Suggested saltmarsh evolutionary models are presented in Case Study C and E.
3. A centralised database is required for flood and coastal defence information, that can be updated and accessed by all agencies and local authorities to ensure all projects are using the same defence type, residual life, condition and standard of protection data.
4. Clarification is required of assets and valuation procedures that can be included in the current national economic criteria as part of Defra's Shoreline Management Plan guidance. Further robust methods should be prescribed for future Shoreline Management Plans to ensure that all assets at risk of erosion are counted and are assigned an appropriate value.
5. A regularly updated uniform, national GIS base layer is necessary, akin to the National Receptor Dataset (NRD), where the residential and commercial property footprint is digitized and the outputs are available to all parties and projects.
6. There is a need for wide dissemination of the ACCESS study report at both the regional and national levels in order to promote debate and share lessons learnt.

GLOSSARY OF TERMS

Adaptation Actions or research undertaken to prevent and reduce the risk and impact of future weather events on the natural or built environment.

Avoidance A planning policy which ensures that any new development is diverted from areas of high risk.

Benefit-Cost Analysis The comparison of present-value scheme benefits and costs as part of an economic appraisal. The benefit-cost ratio is the total present value of benefits divided by the total present value costs.

Breaching An exposed coastal breach can be defined as an entrance through a barrier or spit protecting low lying land, bay, lagoon or estuary which is characterised by tidal flow.

Coastal defence A term used to encompass both coastal protection against erosion and sea defence against flooding.

Coastal squeeze The process by which the coastal habitats and natural features are progressively lost or drowned, caught between coastal defences and rising sea levels.

Complex Cliffs Large-scale coastal landslide complexes characterised by strongly coupled sequences of scarp and bench sub-systems and complex feedback mechanisms; these include relict complex landslides formed many thousands of years old. The long-term effects of toe erosion act to remove toe support and reduce the stability of the cliffs. In the short-term groundwater effects can trigger ground movement and landslide events that transform the behaviour of the whole system. Episodic frequency and magnitude of complex coastal landslides is a key consideration in the assessment of future behaviour, hazard and risk.

'Do-nothing' scenario An option used in benefit-cost analysis to act as a baseline against which all other options are tested. This scenario assumes that no action is taken to protect and manage the coastline. In the case of existing works it assumes walk-away: cease all maintenance, repairs and other activities immediately. In the case of new works it assumes there is no intervention in the natural processes. Politically this is often seen as a non-viable option but it is an important comparison tool in the benefit-cost analysis.

Epoch This refers to a period of time. In the SMPs three epochs are defined - 0 to 20, 20 to 50 and 50 to 100 years from present.

Erosion The loss of land due to the effects of waves and, in the case of coastal cliffs, slope processes (such as high groundwater levels). This may include cliff instability, where coastal processes result in

Hazard A situation with the potential to result in harm. A hazard does not necessarily lead to harm.

Hold The Line To maintain or improve coastal defences on their existing alignment

Landslide The movement of a mass of rock, debris or earth down a slope

Managed realignment The management of a process of establishing a new defence line often set back from the existing position, with the aim of improving the long-term sustainability of the defences, or contributing to other aims such as habitat creation.

NCERM Commissioned by the Environment Agency, NCERM is a highly ambitious, national-scale undertaking to map lengths of coastline susceptible to erosion and instability from natural processes, whilst taking account of UKCP09 projections of climate change over the next 100 years, and current coastal defences and management. The co-operation of Local Authorities along the coastline of England and Wales has been vital to its success. The outputs of NCERM will be published using a sophisticated online portal and GIS tool.

Non-complex Cliffs Comprising relatively simple cliff systems and coastal landslides where future cliff recession will be driven by toe erosion. The frequency of erosion and landslide events is sufficiently high (i.e. <1:100 years) to be accounted for by assessments of long term historical erosion dating back to the 19th Century.

Operating Authority A body with statutory powers to undertake flood defence or coast protection activities, usually a maritime District Council or Unitary Authority or the Environment Agency.

Planning Policy Guidance/Statement A series of notes issued by the government setting out national policy guidance on planning issues, such as the countryside, nature conservation, coastal planning, unstable ground etc. These are gradually being replaced by Planning Policy Statements (PPS).

Quantitative Risk Assessment Use of measurable, objective data to determine asset value, probability of loss and associated risks.

Residual Life The amount of time until a defence may no longer be able to achieve its minimum 'acceptable performance'.

Residual Risk The risk which remains after the implementation of coastal management. It may include risk due to very severe storms or from unexpected hazards.

Return period The return period of an extreme event is usually expressed in years. For example, an event with a return period of 50 years has a probability of 1 in 50 of occurring in any given year. There can be no guarantee that such an event will not occur more than once in 50 years.

Risk Where a hazard has the potential to cause damage or disruption to the natural or built environment and communities.

Risk Assessment Consideration of the risks inherent in a project, leading to the development of action to control them (see FDCPAG4). **Or** Consideration of risks to people and the developed historic and natural environment.

Sea Level Rise Phenomenon occurring as a result of isostatic movement (north-west Britain is rising following glacial withdrawal at the end of the last ice age, causing the south-east to sink), eustatic changes (input of glacial meltwater into the oceans) and thermal expansion of the water under warmer temperatures, combined with subsidence of the coast associated with a tectonic fault between the Solent and north-east France. The combined effect of these changes is thought to result in an annual SLR of about 6mm per year by increasing over time.

Sediment Cell A length of coastline and its associated near shore area within which the movement of coarse sediment (sand and gravel) is largely self contained. Interruptions to the movement of sand and shingle within one cell should not affect beaches in an adjacent sediment cell.

Shoreline Management Plans Refer to plans developed by members of coastal defence groups, covering a stretch of coastline, which address factors such as the geological structure of the coast, the natural processes which influence it, the land use in the area, development plans and the flood and erosion risks along the coast, and propose a strategy for the future approach to the defence of the coast where that is appropriate.

Strategic Coastal Defence Option Generic term for any coastal management strategy, e.g. advance, retreat or hold the existing coastal defence line or no active intervention.

Sustainable policies The degree to which flood and coastal defence solutions avoid tying future generations into inflexible and/or expensive options for defence. This will usually include consideration of inter-relationship with other defences and likely developments and processes within a coastal cell or sub-cell. It will also take account of long-term demands for non-renewable material.