Quantifying coastal heritage change: an Isle of Wight case study

Submitted by Rebecca Dawn Loader to the University of Exeter
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I certify that all material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

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Abstract

The archaeology of the coast is rich but is vulnerable to a variety of natural and anthropogenic threats which are likely to be exacerbated by the predicted effects of climate change. It is only relatively recently that the value of the coastal heritage resource has been recognised and consequently there have been few attempts to produce a quantitative assessment of this resource and to evaluate the threats with which it is faced. This thesis examines the background to coastal management and the development of coastal archaeological research in the United Kingdom. It assesses the range of perceived threats to the coastal heritage and the means of ranking or prioritising sites in terms of their significance and vulnerability.

Six coastal areas of the Isle of Wight are selected as case studies representing geomorphological diversity and rich and varied archaeology. Using data from the county Historic Environment Record together with a range of datasets including historic mapping, aerial photographs and LiDAR surveys within ArcView GIS, the techniques used to calculate past coastal recession and heritage loss are assessed. The results are then used to predict future losses, applying formulae which are regularly used in shoreline management planning and using Defra (2006e) projections of sea-level rise.

The results indicate that it is relatively easy to produce a quantification of past coastal recession and heritage loss, and to use this data to predict future losses, but it is suggested that the results should be used with caution because of the errors inherent to the datasets and the unpredictable nature of coastal erosion. The current means of managing the heritage of the coast are discussed and recommendations are made for future work.

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Abbreviations

ALGAO	Association of Local Government Archaeological Officers
AONB	Area of Outstanding Natural Beauty
ASCII	American Standard Code for Information Interchange
BMAPA	British Marine Aggregate Producers Association
BRANCH	Biodiversity Requires Adaptation in Northwest Europe under a Changing Climate
CBA	Council for British Archaeology
CCMS	Centre for Coastal Marine Science
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
CFMP	Catchment Flood Management Plan
CHaMP	Coastal Habitat Management Plan
CIRIA	Construction Industry Research and Information Association
CUCAP	Cambridge University Collection of Aerial Photography
DEFRA	Department for Environment, Food and Rural Affairs
DEM	Digital Elevation Model
DfT	Department for Transport
DGPS	Differential Global Positioning System
DOE	Department of the Environment
DSAS	Digital Shoreline Analysis System
DSMS	Digital Shoreline Mapping System
DTM	Digital Terrain Model
EA	Environment Agency
EH	English Heritage
EIA	Environmental Impact Assessment
EN	English Nature
EU	European Union
FEPA	Food and Environmental Protection Act
FOE	Friends of the Earth
FROG	Foreshore Recording and Observation Group
GIS	Geographic Information System
GPS	Global Positioning System
HBSMR	Historic Buildings Sites and Monuments Record
HEAP	Historic Environment Action Plan

HER	Historic Environment Record
HLC	Historic Landscape Characterisation
HSC	Historic Seascape Characterisation
HWM	High Water Mark
HWTMA	Hampshire and Wight Trust for Maritime Archaeology
ICZM	Integrated Coastal Zone Management
IFCA	Inshore Fisheries and Conservation Authority
IWC	Isle of Wight Council
IWCAHES	Isle of Wight County Archaeology and Historic Environment Service
IWHER	Isle of Wight Historic Environment Record
JNAPC	Joint Nautical Archaeology Policy Committee
JNCC	Joint Nature Conservation Committee
JPEG	Joint Photographic Experts Group
LiDAR	Light Detection and Ranging
LIFE	L'Instrument Financier pour L'Environnement
LWM	Low Water Mark
MAFF	Ministry of Agriculture, Fisheries and Food
MARS	Monuments at Risk Survey
MCEU	Marine Consents and Environment Unit
MHW	Mean High Water
MLW	Mean Low Water
MMG	Marine Minerals Guidance
MMO	Marine Management Organisation
MPP	Monuments Protection Programme
MPS	Minerals Policy Statement
MSC	Manpower Services Commission
NFCDD	National Flood and Coastal Defence Database
NMP	National Mapping Programme
NMR	National Monuments Record
NRA	National Rivers Authority
ODPM	Office of the Deputy Prime Minister
OED	Oxford English Dictionary
OPSI	Office of Public Sector Information
OS	Ordnance Survey

OSL	Optically Stimulated Luminescence
PDZ	Policy Development Zone
PLUTO	PipeLine Under The Ocean
PPG	Planning Policy Guidance
PPS	Planning Policy Statement
RAF	Royal Air Force
RCHME	Royal Commission on the Historical Monuments of England
RCZAS	Rapid Coastal Zone Assessment Survey
PU	Process Unit
RIG	Regionally Important Geological/Geomorphological Site
RSL	Relative Sea-level Rise
SAC	Special Area for Conservation
SCAPE	Scottish Coastal Archaeology and the Problem of Erosion
SCOPAC	Standing Conference on Problems Associated with the Coastline
SELRC	Severn Estuary Levels Research Committee
SINC	Site of Importance for Nature Conservation
SMP	Shoreline Management Plan
SMR	Sites and Monuments Record
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
TIN	Triangular Irregular Network
TLS	Terrestrial Laser Scanning
UKCP09	United Kingdom Climate Predictions 2009
UNESCO	United Nations Educational, Scientific and Cultural Organisation

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For my father, John Charles Loader: 1932 - 2007

1 Introduction

1.1 General introduction

The wealth and importance of coastal archaeology has only been widely recognised in the last twenty years or so. The archaeology of the coast is wide ranging, both in date and variety of site, ranging from Lower Palaeolithic occupation sites to modern military installations. It embraces both the terrestrial and maritime zones, and includes terrestrial sites which are located on the coast for functional or strategic reasons; sites which were once terrestrial but which are now partially submerged due to sea-level rise; and sites such as fish traps which were positioned to exploit the intertidal and marine resource. Importantly, the silts and muds of the intertidal and subtidal zone, if undisturbed, can create anaerobic conditions which enable the survival of organic material, both archaeological and palaeoenvironmental, which does not normally survive in dry land situations. Because of their location coastal sites are often representative of times of climatic change and of human adaptation.

1.2 Reasons for research

With a few notable exceptions, which will be discussed below (see Chapter 3), the archaeology of the coastal zone has received little rigorous attention in the past. This has meant that recent surveys have concentrated primarily on making a rapid record of features and developing techniques for intertidal fieldwork. It was recognised that the coastal element of national and local authority Historic Environment Records (HERs) was often inadequate, and funding has been directed towards the rapid survey of coasts in order to gather data to inform the Shoreline Management Plan (SMP) process (English Heritage 2007a). Although it has been acknowledged that archaeology in the coastal zone is ‘finite, irreplaceable, and in many cases, highly fragile’ (Fulford *et al* 1997, 18), there has been little emphasis placed on quantifying the nature of the resource and the threats to it. Most surveys have concluded that they can only serve to produce a ‘snapshot’ of the archaeological resource and that further, more detailed work and regular future monitoring should follow the preliminary assessment to complete the record, but resources have rarely been forthcoming.

As a consequence of this approach, the results of these surveys can only permit a very basic and superficial quantification of coastal heritage assets and their management needs. They may have concentrated on one part of the coastal heritage resource, for example just the terrestrial coast edge, the intertidal zone, or palaeoenvironmental evidence. There are generally not enough data available, firstly to classify the sites by their function and date, and secondly to provide the time depth to their vulnerability.

A quantification of the coastal archaeological resource and the threats to it is becoming increasingly relevant as concern grows about the effects of climate change on the historic environment. Sites on the coast are particularly vulnerable to the predicted consequences of global warming, including sea-level rise, increased rainfall and the likelihood of more frequent extreme events such as storms and droughts. The UK Climate Projections 2009, published by the UK Climate Impacts Programme, suggest that by 2080 the mean winter temperature in the south east of England will have increased by between 1.4°C to 5.7°C and the mean summer temperature by between 1.4°C to 8.1°C (UK Climate Projections 2009a), and the predicted relative sea-level rise for London by the same date is between 30.5 and 43.3 cm (UK Climate Predictions 2009b). Other studies have suggested that that sea-level rise on the south coast of England could increase the rates of cliff recession by 22 to 133% by the year 2050 (Dickson *et al* 2007). Research undertaken by the National Trust indicates that 608 kilometres, or 60% of its coastal landholdings are threatened by coastal erosion, with over 500 monuments at risk from erosion or flooding (National Trust 2005a). The consequences of such changes would lead to the loss of a significant part of our coastal heritage.

The archaeology of the coast is also threatened by new coastal defences which may need to be constructed as a result of the effects of climate change. This not only includes the construction of hard defences such as sea walls and groynes, but also ‘soft’ options such as beach replenishment and managed realignment schemes which are becoming favoured options, as they are regarded as a more sustainable option and their effects on the natural environment can be beneficial. However, unlike the natural environment where habitats which are likely to be lost can be compensated for by the creation of similar conditions elsewhere through mitigation schemes such as managed realignment, the historic environment is irreplaceable. An additional likely impact of climate change is that of green energy schemes such as offshore wind farms, tidal and hydroelectric plant, and their associated infrastructure, the construction of which has the potential to cause damage to the coastal heritage.

1.3 Aims and objectives of research

The archaeology of the coastal zone is rich but poorly understood, and is very vulnerable to natural and anthropogenic pressures such as coastal erosion, development, coastal protection works, mineral extraction, and recreational activities. I am aiming to develop a methodology to quantify the archaeology of a representative range of coastal environments on the Isle of Wight, to assess the means of measuring the threats to it and to use the results to suggest options for the best management of the coastal archaeological resource.

The primary aim of my research is to produce for the first time a quantitative assessment of the effects of coastal processes and other natural and anthropogenic threats on the coastal heritage resource, using the Isle of Wight as a case study. The Isle of Wight has a long history of coastal archaeological research and has been relatively well studied in relation to shoreline change and morphodynamics, thus is ideally suited for a quantification of the resource and the threats which it faces. This will be the first time that a quantification of these issues has been undertaken.

The objectives are:

To devise a methodology for quantifying coastal heritage loss. This will include an evaluation of the techniques used more generally in both cultural resource management and in coastal management.

To test the methodology in a defined study area using readily available data.

To make recommendations about the management of the coastal heritage resource.

1.4 Outline of methodology

1.4.1 Choice of study area

The area chosen as the focus for this study is the Isle of Wight (Fig. 1.1). The Isle of Wight is a small island of approximately 38,000 hectares situated some 4 to 6km off the southern coast of England, and it is a location in which I have worked for more than 20 years. For much of this time I was specifically engaged in coastal archaeological projects, including both rapid extensive surveys and a detailed study of a shorter stretch of the coast and its related terrestrial hinterland. I have also been responsible for the management of the Isle of Wight HER for over ten years, which has given me a broad understanding of the curatorial and management requirements of the coastal historic environment.

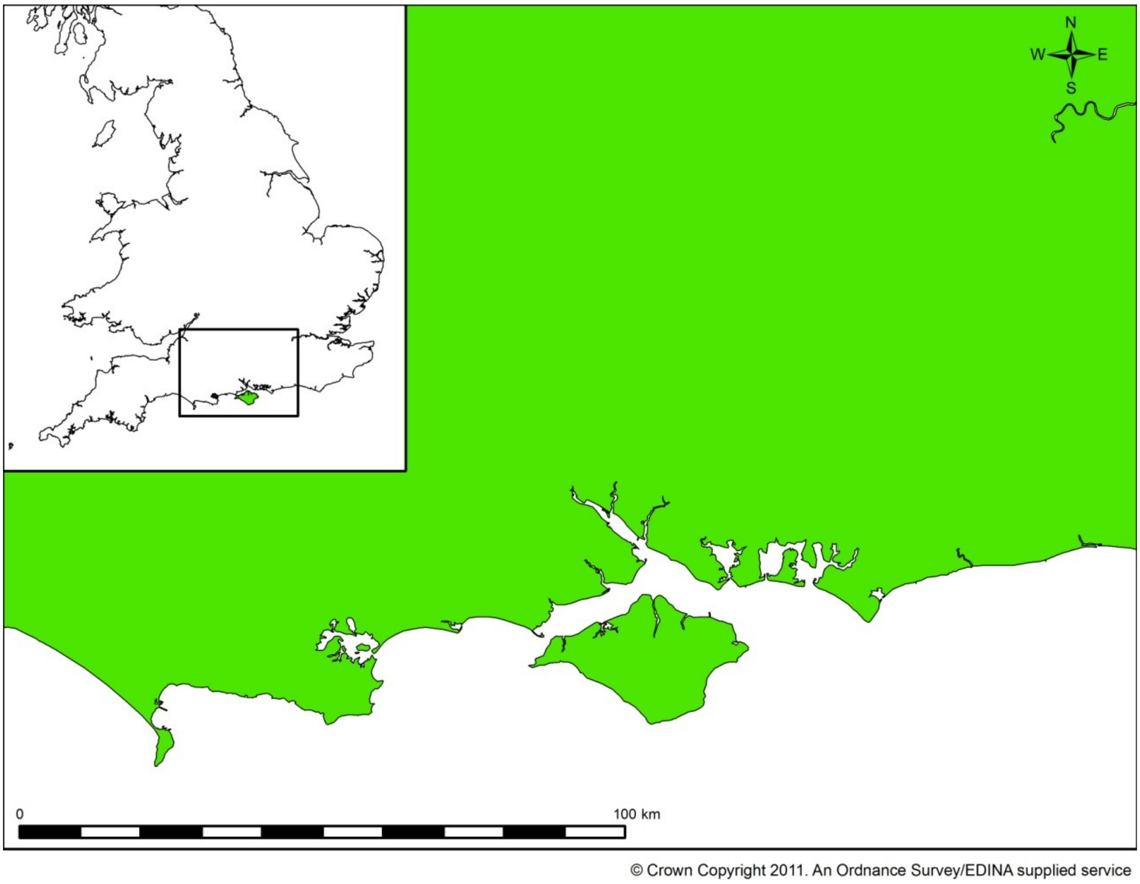

Figure 1.1 The location of the Isle of Wight

The Isle of Wight is an ideal study area, having both easily defined boundaries and a rich and varied coastal archaeology, for which there are good base line data available through the county HER. Sites are relatively well recorded and unquestionably under threat. The island is geomorphologically and geologically diverse in a small area, and is representative at the very least of the mainland of Southern England; it has been said that 'landscape elements and features of all lowland England can be found in one small geographical area on the Isle of Wight' (Isle of Wight AONB Partnership 2009, 17). The island's coastline is equally varied, ranging from high cliffs of chalk and soft muds and sandstones which are exposed to the full extent of the Atlantic storms, to wide expanses of sand and mudflats on the more sheltered northern coast and its estuaries.

There has been much debate about the archaeology of islands (see for example Fitzpatrick 2004; Rainbird 2007), and in relation to this study the terms 'microcosm' and 'islands as laboratories' have become rather a cliché. It could be argued that an island community develops in relative isolation and its archaeology is atypical and possibly impoverished, although more recently it has been recognised that islanders may be more outward-looking and the surrounding sea should be regarded more as an aid to communication and interaction rather than an impediment. The close proximity of the Isle of Wight to the mainland and the fact that for much of prehistory the two were connected may dispel the theory of isolation and introversion in relation to this particular island, although it cannot be denied that the Isle of Wight lacks the larger monumental sites found on the neighbouring mainland. However, the island's material culture is certainly not impoverished and displays wide-ranging connections dating back at least as far as the Neolithic.

Although it could be said that the whole of a small island is influenced by the coast it is not practical to consider the archaeology of the island in its entirety for this study. I have chosen to focus on archaeological sites which are likely to be directly impacted by coastal processes in the near future. I have used a dataset of sites within 500m landward of the coast edge, and have considered these in relation to the effects of coastal change predicted by local shoreline management planning.

The seaward extent of my study area is the limit of extreme low water. This cut-off point has been chosen because I believe that the archaeology of the coast and in particular the intertidal zone is still neglected in terms of management and research compared with its fully terrestrial or marine counterparts. Although it is unhelpful to categorise in terms of 'maritime', 'coastal', or 'terrestrial', and indeed it is generally advocated that 'marine and terrestrial archaeological remains provide a seamless physical and intellectual continuum' (Roberts and Trow 2002, 4), the archaeology of the intertidal zone in particular often gets subsumed into that of the terrestrial or marine zone. The above quotation itself goes on to describe sites in the intertidal zone as 'enjoying marine and dry land environments sequentially', not acknowledging the zone as having its own distinct identity with equally distinct management issues.

1.4.2 Methodology

The primary source of archaeological data to be used is information from the county HER. This will be combined with a range of resources including cartographic material, aerial photographs and LiDAR (Light Detection and Ranging) within a Geographic Information System (GIS).

Digitised maps and aerial photographs will be used within a GIS to calculate past rates of coastal erosion. The data obtained will be used to predict future recession rates, and different formulae used for such predictions will be examined and compared.

A sample of coastal HER data will be examined and the range of archaeological and palaeoenvironmental sites and landscapes found in the coastal zone or affected by coastal processes will be identified. The sites will be assessed against predicted rates of erosion and coastal management options. The value of sources such as aerial photographs and LiDAR both as a means of identifying coastal archaeological sites and assessing the threats to them will be considered.

1.5 Organisation of the thesis

Chapter 2 will include a summary of coastal zone management, outlining the development of coastal protection and initiatives such as SMPs and their impact on the historic environment in the United Kingdom. The concept of Integrated Coastal Zone Management (ICZM) will be introduced, looking at international, European and UK legislation. I will consider the legislation protecting the natural environment of the coast and how it impacts on the historic environment. Finally I shall discuss the potential effects of climate change on the archaeology of the coast.

In Chapter 3 I will discuss what is meant by the coast and review the development of coastal archaeological and palaeoenvironmental study in the United Kingdom. In Chapter 4 I shall consider the quantification of heritage loss, particularly in relation to the coast, and examine the range of threats to the resource. This will include a discussion of how previous surveys have sought to prioritise coastal sites with regard to further research and coastal defence.

In Chapter 5 I shall introduce my study area, the Isle of Wight, looking at its geology, coastal geomorphology and the coastal processes affecting it. This will be followed by a review of the local archaeological and palaeoenvironmental background, in particular looking at the separation of the Isle of Wight from the mainland and reviewing the development of coastal archaeological study on the island.

In Chapter 6 I shall focus in on the six particular areas which have been selected as case studies. I will then consider the main means of measuring coastal change, including cartographic sources, aerial photographs, remotely sensed data and ground survey, and look in detail at the datasets that I shall use for my research.

The results of my research will be presented in Chapters 7 and 8, and in Chapter 9 I shall discuss these results, assessing the choice of study areas and the wider application of the results and methodology generally. Finally, Chapter 10 will conclude with an overview of coastal heritage management and its possible future direction.

2 The Legislative Framework of Coastal Zone Management

2.1 Coastal protection in the United Kingdom

Prior to 1949, there were no statutory powers to protect the coast in the United Kingdom, although some local authorities constructed coastal defences under general local authority powers or local Acts. However, following the Second World War it was evident that those sea defences that did exist were in a poor state of repair. Thus the Coast Protection Act of 1949 was passed in order to give coast protection authorities powers to carry out works to prevent erosion or encroachment by the sea and also the duty to regulate protection works by landowners and other bodies with their own statutory powers.

The coast protection authority's powers are permissive rather than mandatory and they are not obliged to carry out works. Grant aid is available from Defra for schemes that are 'technically sound, environmentally acceptable, economically justifiable and cost-effective' (McInnes 2003, 50).

Coast protection works require planning permission from the local planning authority for works above low water mark; a licence from Defra to deposit any material in the sea (Food and Environment Protection Act 1985 Part II); a lease from the Crown Estate Commissioners for the use of the seabed; and permission from the Secretary of State for Transport to ensure that works in tidal areas do not affect navigation.

Defra has published 'Outcome Measures' (2008a) to measure how successfully Operating Authorities are fulfilling their flood and coastal defence objectives. These replaced 'High Level Targets' (MAFF 1999, revised Defra 2005), which assessed six objectives; policy delivery statements, the recording of information on the National Flood and Coastal Defence Database (NFCDD), the production of second generation SMPs, biodiversity, development control, and Internal Draining Boards organisation and administration. The nine Outcome Measures which replaced them apply to overall benefits (including where possible natural and historic environment benefits), households at risk, deprived households at risk, nationally important wildlife sites, UK Biodiversity Action Plan habitats, flood warning, contingency planning, inappropriate development, and long term policies and action plans.

Coastal defence policies are implemented by the government with the assistance of Operating Authorities, which are generally the District Council, Unitary Authority or the Environment Agency. In a hierarchical process the SMP is followed by strategic coastal defence studies which identify the most appropriate policy option for each coastal frontage and then more specific local studies relating to the construction of a particular coastal defence scheme. In tandem with SMPs, the Environment Agency is responsible for producing Catchment Flood Management Plans (CFMPs). These are high level strategic documents which seek to manage risk of flooding within the catchment of a river basin in a similar way to which SMPs act for the coast (Environment Agency 2004).

2.1.1 Shoreline Management Plans

The SMP is defined as ‘a large-scale assessment of the risks associated with coastal processes [which] helps to reduce these risks to people and the developed, historic and natural environment’. It aims to ‘manage risks by using a range of methods which reflect both national and local priorities to:

- Reduce the threat of flooding and erosion to people and their property; and

- Benefit the environment, society and the economy as far as possible, in line with the Government’s sustainable development principles’ (Defra 2006a, 4).

The production of SMPs was first mooted in MAFF’s *Strategy for flood and coastal defence in England and Wales* published in 1993, which recommended the setting up of stakeholder groups to address the issues of flooding and coastal defence ‘which reflect common interests within identified coastal cells comprising local authorities, NRA and other bodies with coastal responsibilities’ (MAFF/Welsh Office 1993, 4). Amongst other things, the strategy sought to encourage and provide guidance for the development of River Catchment Plans and SMPs. The first guidance on the preparation of SMPs was published in 1995 with the aim ‘to encourage the production of such plans around the coastline of England and Wales’ (MAFF 1995, 4).

The objectives of developing an SMP included: improving understanding of coastal processes; predicting likely future coastal evolution; identifying assets likely to be affected by coastal change; identifying the need for regional or site specific research and investigation; and facilitating consultation between those with an interest in the shoreline. It was stated that the completed plan should assess a range of and agree a preferred coastal defence option. It should outline future monitoring, research and data management; inform coastal zone planning; identify opportunities to maintain and enhance the natural coastal environment; and establish continued consultation.

The four key issues to be considered by a plan were listed as: coastal processes (including historical evolution), existing coastal data and future evolution; coastal defences; land use and the human and built environment (including historic and archaeological features); and the natural environment.

The original SMP guidance identified four generic coastal defence options. These were: do nothing; hold the existing defence line; advance the existing defence line; and retreat the existing defence line. It stated that the preferred option should be ‘sustainable, and compatible with the preferred options identified for adjacent management units and the processes at work within the sediment cell’ (ibid, 12), and should be adopted only after consultation. The guidance emphasised that SMPs should be working documents, subject to monitoring and review.

Further guidance was published in 2001 following a review of the strengths and weaknesses of the first generation SMPs (MAFF 2000). This guidance listed issues that should direct the revision of SMPs, including a focus on the assessment and management of flooding and coastal erosion over a consistent time scale, and the recognition that the SMP policy may become infeasible or unacceptable at some time during the plan’s lifetime. It stressed the need for an awareness of the implications of coastal evolution, climate change and sea-level rise over a longer time scale and also awareness of the uncertainties associated with predicting shoreline management requirements in the future. The need for more efficient and focussed consultation was recognised, as was the importance of informing and supporting the planning system. The guidance also recommended the inclusion of estuaries within the SMP process; identification of the consequences of adopting particular policies, including their effects on European sites; identification of anticipated funding sources; the value of a standard SMP format and the value of dissemination on CD-rom or via the internet (Defra 2001, 4-5).

The 2001 guidance included five generic management policies; namely, hold the existing defence line, advance the existing defence line, managed realignment, limited intervention, and no active intervention. The guidance again stressed that technical, environmental and economic factors should be considered (Defra 2001, 11) and emphasised that SMPs were working documents which should be reviewed and revised at appropriate intervals.

The guidance was further updated in 2006 to take into account recent initiatives such as Futurecoast (see section 2.1.2; Defra 2006a). The first round SMPs were based on sediment cell boundaries, defined as lengths of coastline within which the movement of coarse sediment is largely self-contained. The approach recommended for the SMP reviews was the ‘Behavioural Systems’ approach, which ‘involves the identification of the different elements that make up the coastal structure and developing an understanding of how these elements interact on a range of both temporal and spatial scales’ (Defra 2006b, Appendix D, 10). The new guidance returned to four shoreline management policy options, namely, hold the existing defence line, advance the existing defence line, managed realignment, and no active intervention (Defra 2006a, 13-14).

The 2006 guidance recommended that a consideration of the historic environment should be fully integrated into the SMP. Five main issues which should be taken into account when assessing shoreline management policies were listed. Together with coastal defences, land use, landscape and the natural environment the guidance included ‘Historic and archaeological features recorded in historic environment records, and areas of high archaeological potential, including maritime archaeological features, scheduled monuments, listed buildings and registered battlefields' (Defra 2006b, 23). It recommended the systematic collection of readily available information from local authority HERs, the National Monuments Record and English Heritage's regional teams. Beyond simply collating the data, the guidance proposed 'a wide-ranging assessment of the archaeological potential of the area based on its landforms and any recorded archaeological remains' and stressed that 'experienced HER staff, or a suitably qualified consultant who can relate local information to national priorities, need to assess how important this information is' (ibid, 28-29).

English Heritage has produced more specific guidance on how the historic environment should be integrated into the second round of SMPs (English Heritage 2006a). This guidance defines what is meant by the 'coastal historic environment' and sets out best practice during each step of the process, including who should be consulted during the plan's scoping stage, the collection and appraisal of historic environment data to inform choice of policy, and the implications of policy choice on heritage assets. It states that these implications should be considered as part of an Action Plan which 'should include provision for additional studies to quantify the rate of resource loss, and to identify appropriate mitigation strategies to be defined specifically as part of strategy development' (ibid, 4), with resources identified for conservation, publication and archive deposition.

Environment Agency 'Catchment Flood Management Plans' are similar, high-level strategic documents that aim to manage flood risk at a river catchment scale, considering fluvial and tidal flood risk rather than coastal flood risk (Environment Agency 2004).

2.1.2 Futurecoast

The Futurecoast study was commissioned by Defra and carried out by the Halcrow Group. It came about due to an awareness that the first round of SMPs were lacking because of the paucity of data available relating to long term coastal evolution. This made it difficult for long term management decisions to be made. The aim of Futurecoast was thus to provide enough information about past, present, and future coastal evolution to enable sound coastal management decisions to be made on a wider scale and covering a longer time frame. It sought to move away from the sediment cell approach taken by the first round SMPs, and to view the coast using the 'behavioural systems' approach (see above).

The outputs of the Futurecoast study were presented in a set of interactive CDs comprising data, reports, maps and oblique aerial photographs of the entire English and Welsh coastline. The thematic studies were presented as a series of reports and datasets which could be developed for further use (Table 2.1).

The key findings were presented as Shoreline Behaviour Statements, comprising three sections:

Coastal Behaviour System, a description of the large-scale and long-term influences acting on the coast.

Assessment of Shoreline Behaviour, including a summary of past shoreline evolution, identification of the key factors influencing shoreline evolution over the next century; prediction of future evolutionary trends based on no defences (unconstrained shoreline evolution); and an indication of the main uncertainties associated with understanding of coastal behaviour.

Local Scale Shoreline Response Statements, including an assessment of geomorphological elements, present management, historic trends; and prediction of the future evolution of the shoreline over the next century, firstly assuming all defence structures were removed and secondly with present defence practices continuing.

Table 2.1 The Futurecoast toolbox of supporting information (from Barter et al *2003)*

Theme	**Description of analysis**
Macro-review of coastal processes	Integrated understanding of the modern large-scale hydrodynamic regime.
Macro-review of Holocene coastal change	Assessment of the long-term, large-scale evolution of the coastline around England and Wales and identification of the impact of sea level rise over the Holocene on the inherited morphology.
Shore geology and morphological elements	Review of the shoreline geology and classification of morphological elements of both the foreshore and backshore.
Cliff behaviour assessment	Assessment of cliff erosion, potential failure mechanisms and contribution to local sediment budgets.
Past shoreline evolution	Review of change in shoreline position and characteristics, both over the Holocene and recent history. Analysis of historical OS maps to provide a consistent assessment of shoreline positions since the First County Series (published 1846-1901).
Offshore morphology and evolution	Review of existing literature and data on historical development, bathymetry and physical regime, sea bed sediments and offshore sediment transport trends.
Estuary influences	Definition of appropriate boundaries for predictions. Classification of estuary type and assessment of estuarine influences and their role as a source or sink of sediment.
Coastal processes	Analysis of the forces exerting influences on water movement in the coastal zone e.g. waves, tides and currents, including a review of shoreline characteristics and internal constraints, external forcing, and nearshore sediment transport.
Nearshore wave analysis (including climate change impacts)	Analysis of transformed nearshore wave data for 68 representative locations. Assessment of the possible impacts of 10 climate change scenarios on shoreline energy conditions, and thus sediment transport potential.
Climate change and sensitivity	Review of key climate change research applicable to the coastline of England and Wales and development of regional coastal climate change scenarios, considering natural variability, sea level rise, storm surges, wave climate and precipitation. Generic assessment of the sensitivity of different landforms to climate change and its impact upon future behaviour.
Uncertainty assessment	Assessment of the uncertainty of predictions, based upon the quantity and quality of existing information and the degree of understanding.

Predictions were made of future shoreline change, including shoreline movement trends (landward/seaward/stationary); foreshore change (intertidal narrowing/widening); extent of change relative to current/recent magnitude; coastal geomorphological response and wider interactions; and the level of uncertainty based on the present level of knowledge and understanding of coastal evolutionary processes.

When the Futurecoast data was first released, the level and type of information present did seem quite ground-breaking. However, the wealth of data that has since been made available with accompanying advances in technology makes the approach now seem quite broad-brushed.

2.2 Integrated Coastal Zone Management (ICZM)

ICZM has been defined as: 'a dynamic, multi-disciplinary and iterative process to promote sustainable management of coastal zones. It covers the full cycle of information collection, planning (in its broadest sense), decision making, management and monitoring of implementation. ICZM uses the informed participation and co-operation of all stakeholders to assess the societal goals in a given coastal area, and to take actions towards meeting these objectives. ICZM seeks, over the long-term, to balance environmental, economic, social, cultural and recreational objectives, all within the limits set by natural dynamics' (Commission of the European Communities 2000, 25). More simply, it aims to 'establish sustainable levels of economic and social activity in coastal areas while protecting the environment (English Nature 2005, 7).

2.2.1 International ICZM

The concept of ICZM grew out of a small number of initiatives starting with the 1972 United States' Coastal Zone Management Act. These initiatives are listed below:

The United States' Coastal Zone Management Act (United States Congress 1972)

This act recognised that 'important ecological, cultural, historic and esthetic [sic] values in the coastal zone which are essential to the well-being of all citizens are being irretrievably damaged or lost' (16 U.S.C. § 1451. Congressional findings (Section 302), e). One of the national policies was 'to encourage and assist the states to exercise effectively their responsibilities in the coastal zone through the development and implementation of management programs to achieve wide use of the land and resources of the coastal zone, giving full consideration to ecological, historic and esthetic [sic] values as well as the needs for compatible economic development' (16 U.S.C. § 1452. Congressional declaration of policy (Section 303), 2).

Agenda 21

Agenda 21 is the United Nations' commitment to sustainable development which was ratified at the United Nations Conference on Environment and Development at Rio in 1992. In Chapter 17 the document calls for the protection of the oceans, all kinds of seas, including enclosed and semi-enclosed seas and coastal areas, and the protection, rational use and development of their living resources (United Nations 1992), although it is not specific about protection of the historic environment.

The UNESCO Convention on the Protection of the Underwater Cultural Heritage (2001)

The UNESCO Convention on the Protection of the Underwater Cultural Heritage was adopted with the aim 'to ensure and strengthen the protection of underwater cultural heritage', which is defined as 'all traces of human existence having a cultural, historical or archaeological character which have been partially or totally under water, periodically or continuously, for at least 100 years such as:

i. Sites, structures, buildings, artefacts and human remains, together with their archaeological and natural context;
ii. Vessels, aircraft, other vehicles or any part thereof, their cargo or other contents, together with their archaeological and natural context; and
iii. Objects of prehistoric character' (UNESCO 2001).

Although this definition implies the protection of the intertidal as well as the marine resource, this is not made explicit in the text.

2.2.2 ICZM in Europe

In 1996 the European Commission Demonstration Programme on Integrated Coastal Zone Management provided funding for 35 projects which considered the operation of integrated management and cooperation procedures, and their efficiency. The resulting proposals recognised the coastal zone's significance as ‘repositories of cultural heritage – both in living communities and at archaeological sites’ (European Commission 1999, 7).

The demonstration programme listed eight principles for successful ICZM:

- A broad, holistic perspective
- A long term perspective
- Adaptive management during a gradual process
- Reflect local specificity
- Work with natural processes
- Participatory planning
- Support and involvement of all relevant administrative bodies
- Use of a combination of instruments.

Two documents were adopted as a result of the Demonstration Programme. These were the *Communication from the Commission to the Council of the European Parliament on Integrated Coastal Zone Management: a strategy for Europe* (Commission of the European Communities 2000), and the *Recommendation of the European Parliament and of the Council concerning the implementation of Integrated Coastal Zone Management in Europe* (European Parliament and Council 2002).

The strategy aimed ‘to promote a collaborative approach to planning and management of the coastal zone, within a philosophy of governance by partnership with civil society’ (ibid 2). It intended to improve the management of the coastal zone using existing legislation and by developing best practice and better communication.

The recommendation identified the need to ‘implement an environmentally sustainable, economically equitable, socially responsible, and culturally sensitive management of coastal zones, which maintains the integrity of this important resource while considering local traditional activities and customs that do not present a threat to sensitive natural areas and to the maintenance status of the wild species of the coastal fauna and flora’. Specifically, it listed ‘natural resources’ and ‘protection of coastal settlements and their cultural heritage’. It proposed that national strategies should be developed following the principles of ICZM, and after carrying out a national stocktaking on all administrative levels which should consider amongst other topics the cultural heritage. In the United Kingdom this stocktake was carried out by Atkins (2004; see below).

The *Council of Europe Model Law on Sustainable Management of Coastal Zones* was adopted in 1999 with the purpose of providing a standard text that could be used as a basis for national legislation. Emphasis was placed on the natural coastal environment (Council of Europe 1999a).

The *European Code of Conduct for Coastal Zones* (Council of Europe 1999b) identified the ‘delicate mix of natural, cultural and historical elements in the coastal environment’ (ibid 5) and the need to preserve cultural heritage, monuments, features, etc, but was not explicit about what is encompassed by these terms. Understandably, such high level documents have to present a broad overview and cannot be too specific about individual definitions, but there is a danger that to the unenlightened they are likely to suggest the more tangible aspects of the historic environment, such as buildings and standing monuments.

The *Europa Nostra 2005 Declaration on Coastal Culture* highlighted the importance of the coastal cultural heritage and stressed the vulnerability and risks faced by the resource, including those of development, of natural processes and of climate change. It emphasized the need for an understanding of the values put upon the coastal cultural heritage by local communities and others when considering sustainable management of the coast. The need for adequate resources for the understanding, conservation and sustainable management of the coast was stressed, as well as the importance of taking a long term perspective in coastal management, working with natural processes. This concept of working with natural processes was adopted from the National Trust’s coastal policy (2005b).

Most of these international or European high level strategic documents do pay regard to the historic environment, using terms such as ‘heritage’, ‘cultural heritage’ etc. However they do not define what is encompassed by these terms, which does leave them open to interpretation in their very narrowest sense.

2.2.3 ICZM in the United Kingdom

ICZM initiatives in the United Kingdom have in the past been largely voluntary and outside of any statutory framework, generally being funded 'as short term "projects" rather than being seen as part of the effective functioning of the day-to-day activities of government and coastal users at national, regional and local levels' (Gubbay 2002, 4). ICZM has generally been advanced by the setting up of local and sub-regional/county fora and partnerships, including representatives from local authorities, statutory agencies, and conservation groups (Halcrow Group 2005).

Following the European Parliament's recommendation a 'stocktake' of ICZM in the United Kingdom was carried out by Atkins consultants (2004). The stocktake report concluded that the current coastal management framework in the United Kingdom was spread across many organizations, providing clarity to specific groups but not meeting the holistic vision which lies at the heart of ICZM principles. Local initiatives had developed, but in an uncoordinated way and they were limited by the lack of long term resources (ibid 96). The report concluded that there was a need for more secure funding and for more coastal stakeholders to engage at all levels.

With respect to the historic environment, this report summarized the range of cultural and heritage values of the coast, from prehistoric submerged land surfaces to the inspiration it has given musicians, writers and artists (p.20-21). It outlined the heritage legislation protecting coastal archaeological sites (p.58), and identified relevant stakeholders.

The stocktake was followed by consultation (Defra 2006c) and a resulting strategy document was produced (Defra 2008b). This set out the government's 'vision for coastal management', which included 'Sustainably managed coastal areas, where competing demands and pressures have been taken into account and the social and economic needs of society have been reconciled with the need for conservation of the natural and historic environment', (ibid, 7).

2.3 Natural environment

The natural environment on the coast is protected by a raft of legislation, and coastal or flood defence works will only proceed if they meet the objectives of European and international designations.

The European Union Habitats Directive (Council Directive 92/43/EEC) aims to promote the maintenance of biodiversity and sets out measures to maintain or restore natural habitats or species of EU interest. Similarly, the EU Birds Directive (Council Directive 79/409/EEC) provides a framework for the protection of all wild birds and their habitats with special measures for migratory birds and those considered rare or vulnerable. Both directives have requirements for the designation of conservation areas; Special Areas for Conservation (SACs) for habitats and Special Protection Areas (SPAs) for birds. These form a network of protected sites known as 'Natura 2000'.

CHaMPs (Coastal Habitat Management Plans) are now being produced to fulfil the government's obligations under the European Union Habitats Directive, the Birds Directive and the Ramsar International Convention on Wetlands (1971) to avoid damaging Natura 2000 and Ramsar sites during coastal protection and flood defence works. It is intended that they should be used to inform SMPs and Flood and Coastal Defence Strategies (EN/EA/CCMS 2000; Bray and Cottle 2003).

2.3.1 Heritage Coast

Almost a third of England's coastline is defined as 'Heritage Coast'. Drawn up by local authorities in consultation with the Countryside Commission, this is not a statutory designation, although a large proportion of Heritage Coasts are also in Areas of Outstanding Natural Beauty (AONB) or in National Parks.

The objectives of Heritage Coasts include 'to conserve, protect and enhance the natural beauty of the coasts including… their heritage features of architectural, historical and archaeological interest', whilst also promoting the enjoyment and the sustainable development of the coast (DOE/Welsh Office 1992, 7).

2.4 Planning policy relating to the historic environment on the coast

2.4.1 Planning Policy Statement 1 (PPS1)

PPS1: Delivering Sustainable Development sets out the government's overarching policies relating to planning. With regard to the historic environment, the statement encourages the 'protecting and enhancing the natural and historic environment', and on the coast, suggests that development should take account of the impact of flooding and sea level rise, particularly in relation to climate change (ODPM 2005, 2 and 9).

2.4.2 Planning Policy Statement 5 (PPS5)

In 2010, *Planning Policy Guidance 15: Planning and the Historic Environment* (DOE/Welsh Office 1994), which dealt with the built historic environment, and *Planning Policy Guidance 16: Archaeology and Planning* (DOE/Welsh Office 1990), were replaced by a single Planning Policy Statement, applicable to the historic environment in its entirety.

PPS5 introduces the concept of 'heritage assets' which it defines as 'A building, monument, site, place, area or landscape positively identified as having a degree of significance meriting consideration in planning decisions' and 'the valued components of the historic environment' (Department for Communities and Local Government 2010a, 13).

The PPS is accompanied by a practice guide setting out how the policies of PPS5 should be used and interpreted (Department for Communities and Local Government *et al* 2010b). It specifically highlights 'buried remains and marine sites, including evidence of past environmental change, landscapes now submerged in rivers, estuaries and coastal areas to the low-water mark' (ibid, 42). It also states that proposals affecting the marine environment (i.e. up to the mean high water spring tide mark) should take into account the Marine Policy Statement and marine plans developed under the Marine and Coastal Access Act 2009 (see section 2.4.4 below). The practice guide also indicates that 'stabilisation and erosion protection strategies' with regard to wrecks might be included in marine plans (ibid, 47).

2.4.3 Planning Policy Statement 25 (PPS25)

PPS25: Development and Flood Risk, covers development at risk from flooding of all types. It advocates a risk-based approach, in that the planning process at all levels should be subject to flood risk assessment. This ranges from Regional Flood Risk Appraisals to inform Regional Spatial Strategies, through Strategic Flood Risk Appraisals at a local level to feed into Local Development Documents, to site-specific flood risk assessments at the planning application stage. The assessment of flood risk should consider the effects of flooding on the historic environment (Department for Communities and Local Government 2006a).

Previous guidance on coastal planning, PPG20, has been replaced with a supplement to PPS25 (Department of Communities and Local Government 2010c). This supplement states that decisions on planning on the coast should be based on an understanding of coastal change over time. Apart from those types of development that specifically require a coastal location, development should be directed away from vulnerable coastal areas, and development that would add to negative impacts on the coast should be avoided. Plans should be in place to ensure the long term sustainability of coastal areas and should be informed by an evidence base on an appropriate scale and level. Regional policies should take a strategic approach to long term coastal adaptation.

On a local scale, the PPS25 supplement recommends the establishment of Coastal Change Management Areas which it defines as areas particularly vulnerable to the effects of coastal change. Within these, the type of development permissible and circumstances in which it would be allowed should be set out. Provision should be made should it become necessary to relocate development and infrastructure outside of the vulnerable area. With regard to the historic environment, the only stipulation is that, where restrictions are placed on the life-time of developments within Coastal Change Management Areas, planning conditions should be applied where there is a need to minimise the impact of removal of the development on the community, the natural and the historic environment.

2.4.4 The Marine and Coastal Access Act 2009 (HM Government, 2009)

The Marine and Coastal Access Bill, which received Royal Assent in November 2009, was developed 'to provide enhanced protection of the marine environment and biodiversity, improved management of freshwater and migratory fisheries in England and Wales and improved access to the English coast' whilst integrating 'the socio-economic needs of all marine users with the need to protect the marine environment and preserve biodiversity' (Defra 2009, 1). Covering the area from high water to the limit of the UK Exclusive Economic Zone (i.e. out to 200 nautical miles) its aim is to streamline and simplify legislation relating to the marine zone. This is to be achieved by the establishment of a Marine Management Organisation (MMO), working closely with external bodies to deliver policy and regulate activities in the marine environment. The MMO's responsibilities include the production of a forward plan for marine planning, to be achieved by the preparation of a Marine Policy Statement and regional marine plans. The Marine Policy Statement was published in March 2011 (HM Government 2011; see below).

Marine licensing is also within the organisation's remit and it will regulate activities in the marine zone with the exception of oil and gas installations, renewable energy and major ports classified as 'nationally significant infrastructure', shipping, and land based or associated activities. It will assist with the selection of sites for designation as Marine Conservation Zones, will manage inshore fisheries, migratory and freshwater fisheries, and shellfishery, will coordinate the response to marine emergencies, and will provide advice to Government and other bodies. Finally, it will enforce marine legislation.

The Marine and Coastal Access Act also proposes improved public access to the coast by making a strip of land available around the entire English coast for access on foot. Despite several references to archaeology and the historic environment having been made during consultation on improved coastal access (Defra 2007), there is little mention of the historic environment in Part 9 of the Act, which relates to coastal access.

The Marine Policy Statement published in 2011 includes numerous references to the protection and management of the marine cultural environment, including a section dedicated to the historic environment. Here ‘heritage assets’ are defined as ‘those elements of the historic environment – buildings, monuments, sites or landscapes – that have been positively identified as holding a degree of significance meriting consideration’ (HM Government 2011, 21), and it is stated that, whilst some heritage assets are afforded statutory protection, there are many others potentially of equal significance which are undesignated but should be ‘subject to the same policy principles as designated heritage assets (including those outlined) based on information and advice from the relevant regulator and advisors’ (ibid, 22). However, somewhat contradictorily, paragraph 2.6.6.8 of the Statement only considers the desirability to avoid substantial damage to or loss of designated heritage assets.

It seems likely that most benefits to the historic environment brought about by the Marine and Coastal Access Act will come about as either a result of the more focussed approach to marine planning or indirectly through interests shared with nature conservation issues. For example, although they are being set up primarily for the protection of marine habitats and species, and features of geological or geomorphological interest, Marine Conservation Zones can include heritage sites (Natural England and JNCC 2010). Similarly, the establishment of Inshore Fishery Conservation Authorities (IFCAs) to replace Sea Fisheries Committees may be of benefit to the maritime historic environment because they have a responsibility towards the sustainable management and conservation of the marine environment as a whole.

3 The archaeological and palaeoenvironmental background

3.1 Defining the coast

The Oxford English Dictionary defines the coast as *the edge or margin of the land next the sea, the sea-shore. From Latin costa 'rib, flank, side'* (OED 2006).

The terms 'coast', 'coastline', 'coastal zone', 'shoreline', are words that are used daily and their meanings are taken for granted. However, the actual definition of these terms is less clear. The coast has to be defined for many different purposes, including geomorphological, environmental, planning, economic, coastal management, and archaeological purposes. Each of these places a different emphasis on what is perceived to be significant about the zone and may define the coast differently.

3.1.1 The Coastline

Most sources are consistent in their definition of the coastline as a very narrow band, generally described as the interface between the land and sea. The European Code of Conduct for Coastal Zones (Council of Europe 1999b) defines it as 'the boundary between land and sea'; whilst in the Ramsar Convention Resolution on Integrated Coastal Zone Management it is described as 'the contact line dividing the land from the coastal water bodies' (Ramsar Convention on Wetlands, 2002).

English Coastal Planning Policy (PPG20) describes the coast thus: 'The coastline is dynamic and shaped by powerful natural processes. It is varied in its topography, including cliffs, estuarine marshes and mudflats, coastal lowlands and sand dune systems. Each is subject to its individual set of natural processes and has its own special qualities as an environmental economic and recreational resource'. It goes on to define the coastal zone as extending seaward and landward of the coastline, with its limits being 'determined by the geographical extent of coastal natural processes and human activities related to the coast' (DOE/Welsh Office 1992, 4). The Planning Policy Statement PPS25 which replaced PPG20 has a different emphasis, being concerned with flood risk of all kinds, and thus has no specific definition of the coast, although the PPS25 Supplement defines coastal change, which it describes as 'physical change to the shoreline, i.e. erosion, coastal landslip, permanent inundation and coastal accretion' (Department for Communities and Local Government 2010c, 4).

Sometimes the coastline is defined more specifically as the mean high water line (e.g. Firn and McGlashen 2001, 58). From a geomorphological perspective, Bird differentiates between the terms 'coastline' which 'indicates the land margin at normal high tide (behind the backshore zone) and may be a cliff or the seaward margin of dunes or dryland', and 'shoreline', which, he states, 'is strictly the water's edge, migrating to and fro as the tide rises and falls' (Bird 2000, 2).

In this thesis, I have interpreted the coastline as being the dividing line between that part of the coast that is terrestrial and that which is fully or partially submerged. This may be demarcated naturally, such as by cliffs, or may comprise man-made sea defences.

3.1.2 The Coastal Zone

The coastal zone is a wider area than the coastline, and for the purposes of ICZM it is generally agreed that it is so varied that it can have no one definition. However, as a rule it is recognized that the coastal zone will include an area of land, an area of water, and an intermediate area that is intermittently covered by water, the intertidal zone (King and Green 2001).

The European Code of Conduct for Coastal Zones defines the coastal zone as 'an area including both land and sea, of indeterminate width, sometimes including river catchment areas, depending upon a wide variety of definitions currently in use. An area of a few kilometres can be assumed for general purposes' (Council of Europe 1999b, 11). However, the EU has no common definition of the coastal zone.

In the United Kingdom it is accepted that, because the coast is so varied, the coastal zone should have no nationally agreed boundary. However, the fact that individual laws have their own definitions means that these can become sectorial and complex (Brown *et al* 2005). A Defra consultation document on

ICZM states ‘Creating an official “coastal zone” would suggest the need for a separate management approach to those generally in place on land and sea at present, whereas what is desired is in fact effective integration between the two. In any case it would be difficult to create a definition for an area so dynamic in nature’ (Defra 2006c, 9).

Local planning authorities are left to define the most appropriate coastal zone in their area (Atkins 2004), although the seaward boundary of their jurisdiction is the low water mark. Hence, for example, the first Isle of Wight SMP took as its landward boundary a line that ‘represents a modelled evolution prediction to the year 2070 based on historical trends in Low Water Mark movement, modified to reflect accelerated sea level rise through the application of Brunn’s [sic] rule’ (Halcrow 1997, vol. 2, 2.13). This line varies from between 15m to 225m inshore of the coast edge, and in low lying areas at risk from flooding it is substituted by the 5m contour line. The Isle of Wight SMP revision was less rigid in its coverage. Other SMPs consider a more extensive terrestrial zone, for example the Eastern Solent SMP covers an area to 1km inland of the coast edge or to the 5m contour, whichever is greatest (H R Wallingford 1997).

The definition of the coastal zone for geomorphological purposes is no less contradictory. According to Masselink and Hughes (2003) the boundaries of the coastal zone ‘correspond to the limits to which coastal processes have extended during the Quaternary geological period and include the coastal plain, the shoreface and the continental shelf’ (ibid, 1). Bird (2000, 2), conversely, describes the coast as ‘a zone of varying width, including the shore and extending to the landward limit of penetration of marine influence: the crest of a cliff, the head of a tidal estuary, or the solid ground that lies behind coastal dunes, lagoons and swamp’.

3.1.3 The coastal zone and archaeological survey

In *England’s Coastal Heritage*, English Heritage’s survey of coastal archaeology, Champion and O’Regan (1997, 22) describe the coastal zone as ‘a dynamic natural and human system which extends seawards and landwards of the coastline, the limits of which are determined by the geographical extent of the natural processes and human activities of the present, and the natural processes and human activities that have taken place in the past. Within this zone it is possible to define a narrower zone in which natural processes and human activities are playing an active role in the modification of the archaeological resource and where more positive management measures may therefore be required' They add, however, that 'this managerial definition is unlikely to coincide with the jurisdictional definitions relevant to the powers exercised by many of the local and national agencies which have a direct interest in the coastal zone'.

In his discussion of Historic Scotland's programme of archaeological surveys, Ashmore (2003, 4) states: 'A general-purpose definition of an archaeological coastal zone should be a melding of models of past topographies and likely natural resources with archaeological and ethnographic data or models'. Davidson (2002, 20), in his review of the Welsh coastal archaeological surveys advises a consideration of 'both past and future changes as well as current forces affecting the study area'. He believes that 'In order to achieve this it is more appropriate to consider the idea of a coastal zone (Gubbay 1991) which may be taken to incorporate a wider area than the present coast edge'. For the purpose of the Welsh surveys, the coastal zone was taken to include 'the intertidal zone (i.e. between low and high water at normal tides) and an area extending approximately 150m inland from the high water mark'.

The archaeological survey of Strangford Lough in Northern Ireland was described as a survey of the coastal zone, intertidal zone and subtidal zone (McErlean *et al* 2002). By implication, the coastal zone here is taken to be the terrestrial component. This survey also introduces the concept of the 'littoral zone', which it describes as the zone 'which by virtue of its proximity to the sea and coastline, exerts a strong influence on past settlement and economic strategies' (ibid, 8). However, in biological terms, the littoral zone has a more specific meaning, with its own subdivisions (Campbell 1989).

To conclude, the coast needs to be defined for a wide range of purposes, which have been said to fall into three main categories: academic, jurisdictional, or managerial (Champion and O'Regan 1997). There are two basic ways of defining the coastal zone; firstly in terms of area and secondly in terms of human activities and natural processes, and the influence that the sea has upon the land and vice versa. How one actually defines these areas is again open to debate, and in an island location such as the Isle of Wight it could be argued that coastal human activities and natural processes exert an influence upon the whole island. It would seem that any study must be explicit in its definition of the coast because probably no two will be the same.

Although the coastal zone can be characterised by a distinctive range of socio-economic factors it was felt that for the purposes of this research the most appropriate definition of the coastal zone is the area landward and seaward of the Mean High Water Mark which is currently or will be affected by coastal change in the next hundred years, in line with current shoreline management planning policy. Although coastal influences can extend some distance inland on the mainland coast, the socio-economic processes associated with the coast and 'islandness' have a bearing on the character of the whole of the Isle of Wight.

3.2 Post-glacial development of coasts

The coast as we know it today is largely the product of processes which have been taking place since the close of the last glacial period, when ameliorating temperatures caused the melting of the ice sheets that covered much of the United Kingdom. This released vast quantities of meltwater, causing a rapid eustatic rise in sea-level. However, the rate of sea-level rise varied throughout the country. At the same time as the melting ice caused water levels to rise, the release of the weight of ice led to glacio-isostatic adjustment of the earth's crust causing land which had been under the greatest weight of ice to rise and that which had been just beyond the limit of the ice sheets to subside. As a result of this, land in Scotland is continuing to rebound (Lambeck 1995; Firth and Stewart 2000); the north of England has experienced both crustal uplift and periods of relative stability, whereas subsidence is the trend in the south of England. Churchill (1965) has suggested that the south east had downwarped during the Holocene relative to the south west by 6.1m, a figure that was modified by Devoy to between 2 and 3m (1979). Waller and Long (2003) indicate that the altitudinal difference is more in the region of 1-2m and they suggest that the variation might be due to not only to differential crustal movement but also to sediment compaction and differences in tidal range.

For the southern English coast, it is thought that sea-level was around -130m OD at the Devensian glacial maximum (*c* 18,000BP) but by 10,000 BP a rapid rise had taken the sea-level to below *c* -30m OD, (Dix 2001; Lambeck 1995).

According to Long and Scaife (forthcoming), sea-level studies in the area of the the Solent have been unsystematic and progress has been slower than in other parts of the country; for the Isle of Wight coast, apart from investigations at Yarmouth (Devoy 1987) such data were virtually non-existent prior to analyses undertaken as part of the Wootton-Quarr project (see below section 5.3.2). Long and Scaife have produced a sea-level curve which indicates that by *c* 6000 cal BC (*c* 7200 BP) sea-level had risen to *c* 12m OD and the rapid rise continued to above -3m OD at *c* 3000 cal BC (*c* 4500 BP), after which the rate fell (Fig. 3.1).

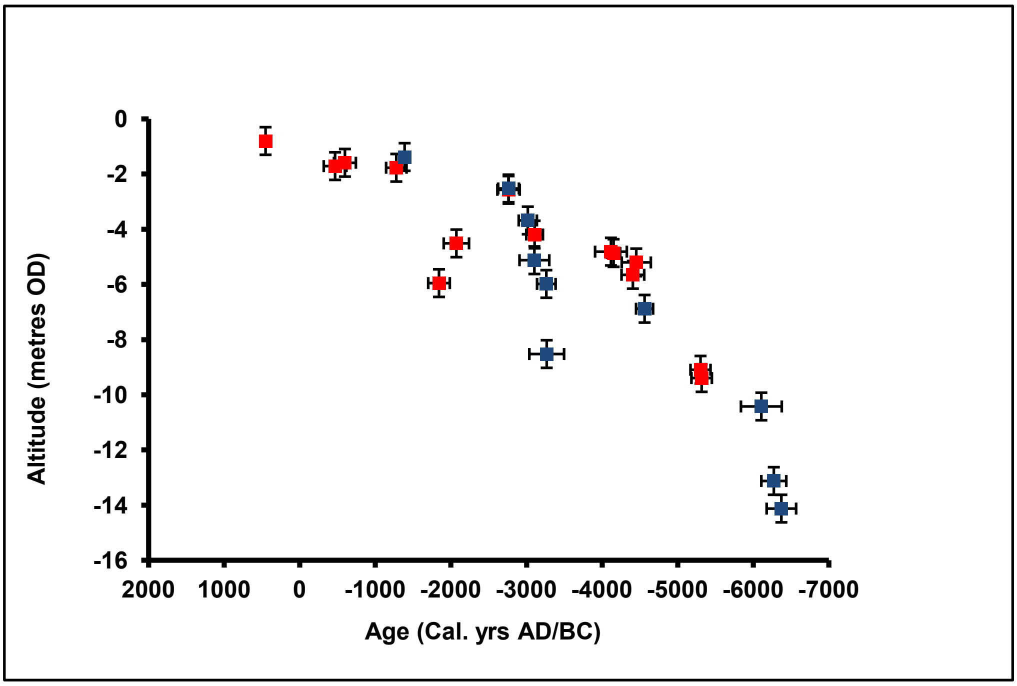

Figure 3.1 Solent sea-level curve (from Long and Scaife forthcoming. Red – mainland, Blue – Isle of Wight

The record for the Late Holocene is incomplete due to the paucity of coastal peats of this date. The reasons for this are uncertain but Long and Scaife suggest that it might be due to reduced sediment supply brought about by a decrease in the rate of Relative Sea Level Rise (RSL) accompanied by a decrease in coastal erosion, or alternatively the reduction in the rate of RSL led to tidal and wave energy being concentrated into a narrow range, making it more difficult for peat to develop.

3.3 The development of coastal archaeological survey in the United Kingdom

Some areas of the United Kingdom have a long history of antiquarian interest in the archaeology and palaeoenvironment of the coast. This section will examine the progression from the earliest antiquarian investigations to the surveys of today when, although the vulnerability of and threats to the resource are well recognised, the emphasis is placed on gaining a broad yet quite superficial record of the coastal archaeological resource for the purposes of coastal management and planning.

As early as the 1750s, William Borlase observed the remains of walls and fallen trees and tree boles well below the high water mark in the Scilly Isles and Cornwall and deduced that the sea-level must once have been much lower (Borlase 1753; 1757). His theories were later developed by O.G.S. Crawford who suggested that the submerged structures visible on Scilly were the result of the land having sunk following their construction (Crawford 1927).

In Essex in particular, it was recognised that there were many archaeological and palaeoenvironmental sites in the intertidal zone which could make it possible to closely integrate the two strands of evidence (Wilkinson and Murphy 1995, 1). Fieldworkers such as Spurrell, Reader and Hazzledine Warren identified and recorded both evidence of human occupation and its relationship with palaeoenvironmental features such as submerged forests and buried land surfaces (see for example Spurrell 1889, Reader 1911, Warren 1911, 1912 and 1919, Warren *et al* 1936), whilst on the south coast, the formation of the Solent River was the source of much antiquarian speculation throughout the nineteenth century (see section 4.3 below). The Solent coast was well served by antiquarians such as Hubert Poole on the Isle of Wight (Poole 1929; 1936, undated), and on the coast of Dorset and Hampshire intertidal peats and submerged forest deposits were noted by Clarke (1838), Evans (1872) and

Reid (1913); see also English Heritage (2008a) and Dorset Coast Forum (undated).

The north west coast also has been the subject of antiquarian interest since the early nineteenth century. At Meols this took the form both of collection of artefacts and recording the intertidal peats and submerged forest. Notable amongst researchers here was Ecroyd Smith who in 1866 published records of the position of finds relative to the stratigraphy of the intertidal sediments (Ecroyd Smith 1866, reproduced as fig.1.2.4 in Griffiths *et al* 2007). Similar antiquarian research was undertaken on the north east coast, in particular by researchers such as C.T. Trechmann (Waughman 2005; Tolan-Smith 2008).

In the nineteenth century the growth of merchant shipping resulted in the expansion of ports requiring the construction of docks which necessitated deep excavations. These revealed long palaeoenvironmental sequences, sometimes with associated archaeological material (see for example James 1847, Codrington 1870, Shore and Elwes 1889). However, the early recognition of the link between archaeological and palaeoenvironmental evidence was not really developed until the major surveys of the late twentieth century.

3.3.1 Twentieth century developments

The mid-twentieth century saw advances being made in palaeoecological studies with workers such as Godwin using pollen and plant macrofossil analysis of coastal sediments to produce a sequence of environmental change which could then be correlated with dateable archaeological material (Godwin and Godwin 1940, Godwin 1943, 1945). These same coastal sediments were sampled to provide index points for the construction of sea-level curves (see for example Heyworth and Kidson 1982, Devoy 1979, 1982 and 1987, and reviews by Shennan and Horton 2002, and Waller and Long 2003). However, according to Long and Roberts, it was not until the later part of the twentieth century that sea-level researchers began to use a standardised methodology which enabled the ‘compilation and correlation of spatially disparate data’ (1997, 34). At the same time, major coastal archaeological projects began amassing significant numbers of radiocarbon dates, but Long and Roberts suggest that many of these dates were of limited use to sea-level researchers who require dates from regressive or transgressive contacts, generally the boundaries between freshwater deposits and brackish or marine deposits. They highlight the importance of interdisciplinary projects such as the Fenland Project, the Wootton-Quarr survey and work in the Severn Estuary where archaeologists and sea-level researchers have worked closely together.

Despite the pioneering studies of the late nineteenth and early twentieth century antiquaries, the archaeology of the coastal zone received little attention, apart from some localised and largely amateur investigations (for example Draper 1951, de Brisay 1978), until the 1970s and early 1980s, when archaeologists started to become more aware of the potential of coastal archaeology and the threats posed to it. A number of small-scale surveys were carried out when it became evident that coastal sites were being destroyed by coastal erosion. These include surveys conducted in Langstone and Chichester Harbours and on the Sussex coast, (Bradley and Hooper 1973, Bedwin 1980, Cartwright 1982, Holgate 1986). Meanwhile in the area of the Thames Estuary, archaeological work between the 1960s and 1980s was described as 'rescue driven, with research, management, conservation, or SMR enhancement as secondary considerations' (Williams and Brown 1999, 3).

3.3.2 Large scale coastal surveys

It was not until the 1980s and 1990s that major coastal archaeological surveys were undertaken in the United Kingdom and Ireland. Tyson *et al* (1997, 74) cite the motivation for these surveys as being not only 'past research and casual discoveries' but also 'fresh discoveries and development-led threats' in areas which had no history of coastal archaeological research. Not surprisingly, in view of the great geomorphological variety of the coast and its diverse cultural heritage, the coastal zone was defined differently for each survey and each focussed on different aspects of its archaeological and historical resource. The Essex coastal survey was almost entirely confined to the intertidal zone (Wilkinson and Murphy 1995); in the Scilly Isles, the intertidal deposits and cliff faces were recorded and sampled to establish their palaeoenvironmental potential (Ratcliffe and Straker 1996); and in Wales, more emphasis was placed on the terrestrial coast edge (Davidson 2002). What all these surveys had in common, however, was the quantity and quality of the archaeological resource that they revealed, and the scale of threat to that resource from both natural and human factors. Noticeably, most did not place much emphasis on recommending options for the management of the coastal heritage.

In the mid-1990s, English Heritage commissioned a desk-based assessment of the country's coastal archaeology in response to the growing realisation of the wealth of the coastal archaeological resource. It was hoped that this would help improve the management of the resource and identify priorities for further study. The survey had seven aims (Fulford *et al* 1997, 17-18):

- to characterise the nature of the resource;
- to assess the nature and severity of threats;
- to synthesise evidence for sea-level change and the implications for future change;
- to examine management frameworks and initiatives established for the coast by other authorities and agencies;
- to recommend future priorities for survey based on an assessment of the importance and vulnerability of remains;
- to recommend ways to integrate heritage interests into coastal zone management plans;
- to review intertidal survey methodologies.

Of necessity, this assessment was published relatively early in the development of coastal archaeology in England with the drawback that, whilst pointing out the potential and priorities for recovering data from the coastal zone, it was destined to become quickly out of date as more work was completed and techniques developed.

Tyson *et al* state in their review of coastal archaeological survey in *England's Coastal Heritage* that, at the time of publication, a large proportion of archaeological research carried out in the intertidal zone was 'reactive to new discoveries or the accelerated erosion of known sites' (1997, 78), but, despite being reactive, projects often developed explicit research aims.

Around the same time as this assessment, a review undertaken by the Association of Local Government Archaeological Officers (ALGAO) stressed the importance of a local, experienced, knowledgeable team available at short notice to record the threatened coastal archaeology (ALGAO 1996).

Essex

The earliest systematic English coastal archaeological survey was carried out on the Essex Coast (Wilkinson and Murphy 1995). This began as a detailed study of a limited area around Hullbridge, and was subsequently extended to cover around 200km of the coast, concentrating on the intertidal zone. The objective was to cover as much of the foreshore as possible, and the methodology consisted of a general walkover survey to identify significant features, structures and artefact scatters, followed by a more detailed coverage of areas of high potential. This second stage included more detailed recording and surveying, and sampling for dating and environmental analysis, although recording of sites was generally completed during a single tidal window. Only one site, ‘The Stumble’, was systematically excavated, and publication is awaited (Wilkinson and Murphy forthcoming).

The Essex coastal survey recommended two priorities for further work. It was identified that sites were only visible because they were eroding, and thus continued monitoring of the coast was required in order to record both the known sites before they were destroyed and new sites which were being revealed. The implication was that the erosion and destruction of sites was inevitable. There was no suggestion of attempting to quantify the number of sites or rates of erosion. However, in 2001 English Heritage funded a further project, the *Greater Thames Estuary Essex Zone Monitoring Survey*, which aimed to record newly exposed sites in the intertidal zone of the Essex coast and to monitor sites which had previously been recorded. The purpose of this was to produce data on changes to archaeological sites and deposits in the intertidal zone which could be used to inform ‘decisions on heritage management with regard to natural erosion, development proposals and schemes of nature conservation/enhancement’ (English Heritage, undated a).

Over a three year period, sites which had been identified during the Hullbridge survey were monitored using two separate techniques (Heppell 2004). These were, firstly, the rapid assessment of a selection of sites and, secondly, repeated visits to an area on the shore of the River Blackwater where a variety of different sites were located. Here, changes through erosion were documented by regular re-recording. The survey demonstrated that there was some degree of threat to all sites, but causes of erosion were very localised and complex. The data gathered were considered to make a valuable contribution to the development of other research projects. It was also suggested that monitoring could be used as a mitigation method on sites where destruction was caused by erosion as it allowed ‘the creation of a composite picture, gradually adding to the overall understanding of a site, which may never be seen all at one time’ (Heppell and Brown 2008, 47). However, the practical problems and limitations of producing quantifiable data whilst working in such an inhospitable and unpredictable environment were also stressed (Heppell 2004, 32-33).

Langstone Harbour

The Langstone Harbour Survey, carried out between 1993 and 1998, aimed to employ ‘a seamless approach to devise, develop and test a series of methodological approaches for the recording [of] the archaeological and palaeoenvironmental evidence in the study area’ (Allen and Gardiner 2000, 3). This was born out of a need to understand the resource in order to ‘implement proper curation and management strategies for that resource’ (ibid p.4). The survey was one of the first to use GPS and to develop a project GIS which was used to integrate the archaeological and palaeoenvironmental resource more closely with current ecological and other environmental data.

The survey was implemented in four stages and comprised five elements: an archaeological and palaeoenvironmental desk top study; mapping and digitising existing maps and aerial photographs; auger survey; walkover and swimover survey; and detailed recording of selected areas.

The survey classified the most obvious potential threats to the archaeological resource under the three headings of natural environment, development and activities. Threats from the natural environment were perceived to be constant wave attrition, *Spartina* die back and changing current and tidal regimes. Development of the harbour edge, the coastal margins, and both within and across the harbour was recognised as a threat to the historic environment, as were activities such as dredging, buoying, fishing and recreation.

The conclusions of the survey stressed the need for an integrated approach to the management, protection and curation of areas such as Langstone Harbour which are not only important archaeologically but also for their nature conservation value.

Cornish estuaries

In Cornwall, archaeological surveys of the major estuaries, the Fal, the Fowey and the Helford Estuary, have been carried out. The first of these, an audit of the Fal Estuary, was undertaken by the Cornwall Archaeological Unit in 1995-1996 and was funded largely by English Heritage. The aim of the audit was 'to gain an overall impression of the historic environment [of the estuary], the historic components that comprise it and its management requirements', (Ratcliffe 1997, 2). This was largely to inform strategic guidance being developed by the Falmouth Bay and Estuaries Initiative and the survey was heralded as the first opportunity nationally to study the archaeology and history of an estuary in its entirety and to ensure that the historic environment was fully integrated into an estuary management strategy, as well as serving as a pilot for recording coastal archaeology in Cornwall.

The survey comprised desk top assessment of the Cornwall Sites and Monuments Record, Listed Buildings, cartographic sources, published histories and photographs, the RCHME inventory of marine sites and the results of the National Mapping Programme, followed by fieldwork to identify additional sites, establish the survival of sites identified during the desktop assessment and provide brief descriptions of the character of surviving remains. This was then used to assess the condition and threats to sites, to assess their future management requirements and their potential for public access and interpretation. Emphasis was placed on the rapid recording of sites which were estuary specific by virtue of their location and/or function.

The Fal Estuary Historic Audit was followed by similar surveys of the Fowey (Parkes 1999) and Helford Estuaries (Reynolds 2000).

Scilly Isles

Preliminary survey work and sampling was carried out in the Scilly Isles in the 1980s and early 1990s. An assessment and management plan was produced by the Cornwall Archaeological Unit following a programme of fieldwork (Ratcliffe 1989, cited in Johns *et al* 2004). Subsequently English Heritage funded a small-scale sampling programme which was carried out over a five-year period, with an emphasis on recovering palaeoenvironmental data to assess the potential of coastal sites and intertidal peat exposures both for reconstructing past vegetation and sea level rise and to provide evidence of past subsistence and diet (Ratcliffe and Straker 1996).

Severn Estuary

Archaeological survey in the Severn Estuary has been carried out over more than twenty years by a number of organisations under the aegis of the Severn Estuary Levels Research Committee (SELRC). The work undertaken to date has been primarily either research- or development control-led, with little emphasis on management, a point discussed by John Coles in his review of research in the Severn Estuary on the tenth anniversary of the formation of the SELRC (Coles 2000, 210).

The formation of the SELRC was triggered by the proposal to construct a Severn Tidal Barrage in 1987 (Turner *et al* 2000). This led in 1989 to a rapid, primarily desk-based survey of a large part of the English shore of the estuary. Two years later, a more localised and detailed survey was carried out in advance of the Second Severn Crossing (Tyson *et al* 1997, 81). This was followed by rescue excavation (Godbold and Turner 1993).

The Severn Estuary has also seen longer term field survey prompted by natural erosion rather than the threat of development. A programme of five years of fieldwork was carried out at Goldcliff, where a range of sites dating from the

Mesolithic to the post medieval period were recorded (Bell 1994). Here, excavation was accompanied by a full range of palaeoenvironmental analyses which allowed the archaeology to be placed in the context of a detailed picture of environmental change (Bell *et al* 2000). The repeated visits to the sites brought a familiarity which meant that observations about the relative stability of parts of the intertidal zone could be made. It was assumed that parts of the site were relatively unthreatened, but one year it was found that erosion had severely damaged Structure 8, a building radiocarbon dated to 50 cal BC-cal AD 220 (Car-1503, 1930±50BP), which had been believed to be in no danger. Bell consequently commented on the episodic nature of erosion at Goldcliff, and the fact that the cause of the erosion was unclear. He concluded that 'all the intertidal archaeology is vulnerable', and expressed the intention to monitor erosion of selected peat edges and wooden structures in order to increase the timescale against which the vulnerability of intertidal sites could be judged (Bell 1994, 115; 142). This method of survey was developed in the intertidal zone at Redwick, Gwent, by comparison of aerial photographs taken in 1993 with a theodolite survey carried out in 1999. Acknowledged problems of accuracy were caused by comparing data gathered using two different survey methods, and by the georectification of aerial photographs using few control points. It was concluded that the only accurate way to measure erosion rates was by repeated ground surveys of selected areas at regular intervals (Bell and Neumann 1999, 29-30).

The Welsh Coast

The Welsh response to the recognition of the threats to coastal archaeology was to commission field surveys. A series of archaeological surveys was carried out on the Welsh coast starting in 1993 and continuing throughout the 1990s. The surveys were funded by Cadw with support from the Royal Commission on the Ancient and Historic Monuments of Wales. They were designed to record the archaeology of the coast in order to 'allow proactive management of threats posed by rising sea levels, and by the recognition of a range of other threats posed by, for example, development, natural erosion and the maintenance and construction of sea defences' (Davidson, 2002, xii). The aims of the surveys were (ibid, 19): to assess the nature and extent of the archaeology situated along the coastal edge; to assess the nature of threats and rate of erosion of the coast and of archaeological sites; and to recommend appropriate management strategies.

The coast was split into thirteen survey areas, and each was subjected to a desk based assessment supported by a rapid field survey which took in the intertidal zone and a band approximately 150m inland of the high water mark (Cadw 1999). Sites were described and photographed, and allocated a category of importance ranging from National (A), through Regional (B), Local (C), Other (D) and Undetermined (D).

The nature of the foreshore, coastal edge and land edge were recorded according to predefined categories, and the extent of active erosion was noted, as were active or potential threats. Five categories of erosion were defined; Stable: no erosion, aggrading or man-made protection; Slight: some soil exposure but with good vegetation cover; Medium: widespread soil exposure, intermittent slumping; Major: general soil exposure, frequent slumping, little vegetation; and Severe: widespread slumping, no vegetation.

Approximately 1500km of coastline were surveyed and more than 3000 sites of archaeological or historic importance were examined, 2000 of which were previously unknown (ibid). Following the completion of the surveys, the main threats to the archaeological resource were identified as coastal erosion, sand dune movement, visitor pressure, changes in soil conditions, development, and coastal protection works. By looking at the relationship between the type of coast, the archaeological resource, and the nature of the threat, it was possible to identify areas of high risk and high importance, low risk and high importance, etc. This prioritisation of parts of the coastline was considered to be important as it meant that limited resources could be concentrated on monitoring and recording specific areas, but the number of unevaluated sites which were at risk was found to be a major problem.

Northumberland

Coastal archaeological survey in Northumberland was prompted by one of the aims of the Northumberland Coastal Management Plan, published in 1991, which recognised the need to conserve and manage coastal, intertidal and submerged archaeological sites. Preliminary fieldwork was carried out by the Glasgow University Archaeology Research Division and comprised a rapid survey of 70 miles of coastline, however without systematic survey of the intertidal zone (Tyson *et al* 1997). The survey assessed both the archaeological potential and the threat of erosion along individual stretches of coast. Sites were recorded by photography and a condition statement was prepared. The results were incorporated into a strategy document (Northumberland County Council 1994). The continued monitoring of sites was considered to be an important part of the project which could be taken forward by volunteers.

Other coastal investigations which were less extensive in their coverage have been undertaken around the English coast. For example, in Liverpool Bay, numerous human and animal footprint trails have been recorded in association with palaeoenvironmental material (Huddart *et al* 1999; Gonzalez and Cowell 2007). In Hartlepool Bay, antiquarian interest in the intertidal palaeoenvironmental deposits and artefact collection was followed by more focussed palaeoenvironmental analyses carried out during excavations in advance of the construction of new sea defences which sought to put the archaeological evidence in its environmental context (Waughman 2005). At Pakefield in Suffolk and at Happisburgh on the Norfolk coast, nationally important Palaeolithic sites are being revealed and threatened by coastal erosion (Parfitt *et al* 2005; British Museum undated).

Scotland

In 1994 Historic Scotland published a paper which identified the issues facing coastal archaeology and recommended ways forward (Ashmore 1994). Amongst the recommendations were collaboration with other groups concerned with coastal zone resource management to ensure that archaeology is taken into account in strategic planning, more and better targeted surveys, and a continuing evaluation of techniques and results. Acting on one of these recommendations, Historic Scotland then specified a brief for rapid coastal archaeological assessment surveys (Historic Scotland 1996). The brief set out to create a gazetteer of sites of archaeological and historic interest set against an objective record of perceived erosion at the time of survey, as it was acknowledged that specifying a recession rate for individual stretches of coast would be complex and prohibitively expensive (ibid, 14). Although they followed a specific brief, individual surveys placed particular emphasis on different aspects of the historic coast, dependent on the character of the coastline and no doubt to some extent, the perception of the individual fieldworkers.

The Scottish rapid coastal surveys and associated focal studies were discussed at a conference in 1998 (Dawson 2003). Most speakers (for example Wilson 2003, 44, Hale and Cressey 2003, 106, Moore 2003, 152) stressed the importance of the regular monitoring of stretches of coast, the need for repeated surveys, and the value of local knowledge. It was emphasised that a large number of the sites which had been identified were too poorly understood to develop research proposals or to assign values to them. This, too, made it difficult to prioritise sites and areas for further investigation (Ashmore 2003). Rapid assessment surveys have been completed for approximately a third of the Scottish coast, and the reports made available on the SCAPE Trust's website (SCAPE Trust, not dated a).

It was acknowledged that resources were not available to record adequately the large numbers of archaeological sites under threat around the Scottish coast, and as a consequence the Shorewatch project was set up with support from the Heritage Lottery Fund (SCAPE Trust, not dated b). The project encourages local community groups to record and monitor eroding archaeological sites (see below, section 3.3.5).

Ireland

The survey of the Shannon Estuary was the first systematic survey of the foreshore to be carried out in Ireland. It was the result of fortuitous timing; the recognition of the significance and vulnerability of coastal archaeological and palaeoenvironmental sites on the Severn Estuary coupled with the initiation of a major archaeological survey of the north Munster region by the Discovery Programme (O'Sullivan 2001). The survey's three main aims were 'to confirm the potential of the intertidal zone for archaeological research in Ireland; to investigate the character, date, contexts and condition of prehistoric and historic archaeological sites… and to integrate these intertidal sites with the archaeology of the surrounding drylands' (O'Sullivan 2001, 26).

The survey commenced with a review of available documentary and cartographic resources followed by two or three weeks of field work each year between 1992 and 1997. Sites were recorded by photography, plans and a written description, and sampling was carried out for radiocarbon dating, wood species identification or to assess the condition and likely date of timber structures. Only limited excavation was undertaken. Despite limited resources the survey significantly improved knowledge of the archaeological resource, identifying Neolithic and Bronze Age submerged forests, Neolithic and Middle Bronze Age occupation sites, a late Bronze Age trackway, early historic and medieval fishtraps, and a large number of post medieval fishtraps and other maritime structures, the significance of which had previously been unrecognised (idem 35). However, the lack of an integrated palaeoenvironmental assessment was acknowledged as a critical flaw which meant that the effects of sea-level rise and environmental change on the archaeological resource remained poorly understood.

Other intertidal survey projects have been carried out in the Republic of Ireland and are cited by O'Sullivan (2001), but the results are less easily accessible. These include (idem 25) a study of Baltimore Harbour, County Cork, reported in an unpublished MA thesis (Kelleher 1998), and surveys of Waterford Harbour, the Boyne Estuary, Lough Mahon in Cork Harbour, and Killala Bay in County Mayo. There have also been developer funded works in the coastal zone, including excavations at North Wall Quay, Dublin, which revealed at least five Mesolithic fish traps (McQuade and O'Donnell 2007; O'Sullivan and Breen 2007).

Northern Ireland

In Northern Ireland, the most significant coastal survey to be carried out to date was that of Strangford Lough. The survey was commissioned by the Environment and Heritage Service, Northern Ireland, which had previously initiated a project to record wrecks on the seabed of Northern Ireland (Breen and Forsythe 2001). The survey of the foreshore was a natural progression from this seabed survey, and Strangford Lough was chosen as a pilot. The reasons for this choice were firstly that approximately one third of its area is intertidal and it makes up approximately 38% of the coastline of Northern Ireland. Secondly, it was hoped that the rich archaeology of the hinterland would be reflected in the intertidal zone; and thirdly it is designated as a Marine Nature Reserve and Area of Outstanding Natural Beauty (AONB). The survey was carried out between 1995 and 2000.

The main aims were ‘to approach the study of the maritime cultural landscape of Strangford Lough through its three physical components, the coastal zone, the intertidal zone and the subtidal zone; to integrate archaeological and historical evidence as survey practice and as an interpretive tool; to attempt to inspect all the foreshore archaeology of the lough to achieve an overview of the cultural material present; and to identify and prioritise areas for future coastal research revealed through the findings of the survey’ (McErlean *et al* 2002, 2). Field survey was coupled with documentary research, looking at historic maps and charts, aerial photographs, estate papers, commentaries and tours, government reports, newspapers, and oral history accounts.

A pilot study in the first season focussed on the intertidal zone and aimed to assess the quantity and quality of surviving archaeological material. Results were encouraging and the survey was extended for a second season. The fieldwork confirmed the survival of important archaeological remains, but it was recognised that the intertidal archaeology could not be understood in isolation but should be viewed in the context of the entire coastal zone. It also stressed the value of historical sources in the interpretation of sites. Consequently, further seasons of survey, whilst concentrating largely on the intertidal strip, also examined the terrestrial and sub-tidal zones. Small scale excavation was also carried out in the final year of the project.

The survey of Strangford Lough identified ‘evidence of a remarkable range of human activity’ (ibid, 20), ranging from Mesolithic to Post Medieval in date, much of which it was felt warranted further study. It also showed that erosion and human activities were both revealing and destroying sites, and stressed the need for similar surveys to be carried out in other coastal regions. The survey concluded that little could be done to combat natural erosion, but detailed recording of those sites which were at greatest risk needed to be undertaken.

A review of the individual surveys

The coastal archaeological surveys described above are quite wide ranging in their focus and methodology. Some, such as those carried out in Scotland and Wales, were large scale, rapid surveys undertaken to provide an overview of the archaeology present and the scale of threats such as coastal erosion. Others focussed on one aspect of the coastal heritage; for example the work undertaken by the Cornwall Archaeological Unit in the Scilly Isles concentrated on sampling for palaeoenvironmental analyses, and the Hullbridge Survey on the Essex coast dealt with the archaeology of the intertidal zone, with a strong emphasis on palaeoenvironmental studies. The Langstone Harbour survey was one of the first to take a holistic approach to the archaeology of the terrestrial, intertidal and marine zones. Archaeological investigations in the Severn Estuary have been implemented for a variety of reasons, ranging from work carried out in advance of development, to intensive investigations of eroding sites.

The most successful coastal archaeological projects seem to me to be those such as the Hullbridge Survey on the Essex coast (Wilkinson and Murphy 1995) and at Goldcliff in the Severn Estuary (Bell *et al* 2000) which identify the wealth of data available in the coastal zone which is not generally encountered on terrestrial sites and which combine archaeological investigation with a broad suite of environmental analyses and a comprehensive programme of radiocarbon and dendrochronological dating.

3.3.3 Rapid Coastal Zone Assessment Surveys (RCZAS)

Following the example of Historic Scotland, English Heritage issued a brief for carrying out rapid archaeological surveys of the coast in 1999 (English Heritage 1999). Known as Rapid Coastal Zone Assessment Surveys (RCZAS), they were the response to an awareness that coastal sites were poorly represented in the HERs of coastal local authorities and so could not be adequately considered in the SMP process. The approach is still advocated (English Heritage 2005), despite the limitations of this type of survey having been highlighted in English Heritage’s own survey of the state of coastal archaeology as early as 1997 (Tyson *et al* 1997). The surveys are often carried out by contracting units, who may well employ competent coastal archaeologists but who will have little local knowledge. For contractual reasons, surveys may have to be completed over an uninterrupted block of time, often in mid-summer when maximum hours of light can be exploited, a time when much of the foreshore can be masked by weed, not at a time in the year during which the best equinoctial low tides occur, so it may not be possible to examine the lowest parts of the foreshore. A prime example of this is the fieldwork for Phase 2 of the North Kent RCZAS which was ‘carried out as close as possible to the summer solstice (21 June) to maximise the daylight available and provided longer opportunities to use suitable tidal windows’ (Wessex Archaeology 2006, 5).

Paradoxically the limitations of such survey were pointed out in the Langstone Harbour project report, written by members of staff of one of the major contracting units who now carry out RCZAS. This concluded: ‘General survey, in particular, is most appropriately conducted by small teams carrying out small scale searches over long periods of time… Thus, intertidal projects are not easily conducted within the time-scales, nor fieldwork frameworks, designed primarily for projects on dry land. Further, the constantly changing and eroding nature of these landscapes means that no survey can be definitive…As such it is necessary to repeat the exercise at suitable intervals to re-evaluate the evidence’ (Allen and Adam 2000, 222).

RCZAS are carried out in two phases; a desk based assessment followed by rapid walk-over survey (Murphy and Trow 2004), the two phases generally treated as discrete projects. The broad aims of RCZAS are:

- to enhance HER and National Monument Record (NMR) data to allow an improved response to strategic coastal planning and management initiatives or commercial developments and schemes in advance of more detailed evaluation;
- to provide data compatible with the needs of other coastal managers;
- to provide an overview of coastal change from the Late Upper Palaeolithic onwards;
- to assess the degree and nature of threat to the archaeological resource;
- to assess the archaeological potential and vulnerability of stretches of coast;

- to provide information to enable the development of management and research priorities, including the identification of sites or areas requiring further survey or positive management action, sites which may be worthy of listing or scheduling, areas of high risk, and the establishment of research priorities for the coast;
- to enhance public understanding and enjoyment of the resource (English Heritage 2007a).

RCZAS have been completed, are underway or are being commissioned along the entire length of the English coastline, and the reports of RCZAS and other coastal surveys are being made available for download from the English Heritage website.

The first Rapid Coastal Zone Assessment Surveys were completed in areas with known archaeology that was perceived to be the most at risk from coastal erosion, namely Norfolk (Robertson *et al*, 2005), Suffolk (Everett *et al*, 2003; Hegarty and Newsome 2005), Essex (Heppell and Brown 2001), and North Kent (Wessex Archaeology 2000; 2002; 2004a; 2005a; and 2006). These were followed by surveys on the Yorkshire/Lincolnshire coast, which were completed in 2008 (Buglass and Brigham 2007a and b; 2008a and b; Deegan 2007), the North East coast (Tolan-Smith 2008; Bacilieri *et al* 2008) and the North West coast (Bacilieri *et al* 2009; Johnson 2009). In areas which had not already been assessed for English Heritage's National Mapping Programme, the mapping of features shown on aerial photographs to NMP standards formed a significant part of the first phase of the project.

The RCZAS for the Scilly Isles took a slightly different format. Following the extension of its responsibilities to the marine zone, English Heritage funded a pilot project in Scilly to extend the concept of RCZAS to the 12 nautical mile limit (Murphy and Trow 2005; Johns *et al* 2004). Unlike most other RCZAS projects, that for the Scilly Isles also included historic landscape characterisation of the intertidal and marine zone.

In 2006 the first phase of a RCZAS was commissioned for the eastern bank of the Severn and that part of the western bank that lies within England (Mullin 2005; English Heritage 2006b). This survey included an assessment of aerial photographic sources to NMP standard, and also a limited trial examination of LiDAR data for two small areas (Crowther and Dickson 2008; Truscoe 2008). This was followed by a pilot fieldwork project prior to the main fieldwork phase because the practicalities of working in an estuary such as the Severn with deep muds and a wide tidal range were seen to be different than those experienced on the open coast (Catchpole and Chadwick 2010a).

Wessex Archaeology was commissioned to undertake the RCZAS for the south east coast, covering the coast from Hampshire to Kent, with an expected completion date for phase 1 of April 2012 (Wessex Archaeology 2011a). This leaves just the survey for the south west coast to be commissioned.

Other RCZAS have been commissioned for slightly different reasons. The purpose of the Dorset RCZAS was to feed into the Dorset Coast Strategy and to produce a research framework for the coastal and marine historic environment of that county (Wessex Archaeology 2004b and c). The RCZAS for the New Forest had a strong emphasis on outreach and public engagement (Maritime Archaeology Ltd 2008; Wessex Archaeology 2010 and 2011b).

Having worked for more than 20 years on an island where coastal and marine archaeological and palaeoenvironmental sites have, for as long as I can remember, been treated equally to their terrestrial counterparts, it is easy to be critical of the RCZAS approach. It has been recognised that both the desk based assessment and rapid fieldwork surveys are likely to locate only the most robust sites which are, by their nature, usually post medieval or modern in date (Tyson *et al* 1997). The identification of more ephemeral sites requires more detailed survey and a greater familiarity with an area's coastal zone, ideally with repeated visits at different times of year and on various states of the tide. It is also likely that many sites such as wooden structures, hearths, and palaeoenvironmental features cannot be dated without recourse to scientific dating. However, it is evident that many coastal counties are lacking even the most fundamental records of their maritime and coastal heritage, and in these cases, the RCZAS can serve as a useful starting point.

The nature of rapid survey means that although the existence of a site may be established, it is often undated and its function is unclear, making it very difficult both to prioritise and to justify which areas and sites need protection, and to assess a site's vulnerability. As Dyson *et al* point out (2006) the primary purpose of these surveys is to gather data which can inform coastal management or spatial plans, but the archaeological sites and features that are identified often remain poorly understood. The same authors recommend that provision is 'made for targeted dating of key features such as fishtraps and targeted boreholing or test pitting to assess the potential and depth below ground surface of buried archaeological landscapes' (ibid, 84). The need for resources to be allocated for scientific dating as a matter of course during coastal surveys generally has been highlighted by Erlandson and Moss who advocate the use of radiocarbon dating as a 'reconnaissance tool to place sites in space and time during the early stages of archaeological investigation' (1999, 432).

Whilst it is difficult to assess the relative qualities of individual surveys from the reports alone, the added dimension that local knowledge brings is evident and is explicitly stated in the Isles of Scilly RCZAS *Assessment of significance of wrecks*: 'professional judgement needs to be married with an in-depth local knowledge and experience if the appraisal of significance is not to be a superficial exercise', (Johns *et al* 2004, 192). English Heritage's own survey of coastal archaeology itself stressed the value of repeated visits and that 'local knowledge was essential in identifying sites and areas of potential' (Tyson *et al* 1997).

Rapid surveys can identify the most obvious archaeological features in the coastal zone and recommend further work or management provisions, but what is often less clear is what the next step should be and how it should be funded. Mitigation may be built into coastal management schemes where some action is involved, but it is unrealistic to rely on the shoreline management process to protect the majority of archaeological sites, a large proportion of which are on coasts with a preferred management option to 'do nothing' or 'retreat', and which are also important for their nature conservation value. Mitigation measures are likely to apply only to those sites which will be directly affected by a coastal management scheme, and the budget available for recording poorly understood archaeological features is often minimal. There are many sites, particularly those in the lower intertidal zone which are, arguably, likely to be those which are more coast specific and thus more informative about coastal change, and therefore unlikely to survive in other circumstances.

3.3.4 Historic Seascape Characterisation (HSC)

Historic Seascape Characterisation grew out of the technique of Historic Landscape Characterisation (HLC). HLC was developed during the 1990s as a tool for managing changes to the historic environment on a macro scale. Its purpose was to create an overview of the historic environment at a point in time rather than to focus on individual archaeological or historic sites, and to place conventional HER data within a landscape context. HLC is seen as an assessment of the landscape's sensitivity, vulnerability and capacity for change (Clark *et al* 2004) which can also to some extent give some time depth to the landscape. Characterisation is usually carried out by county, and the first projects, such as that undertaken for Cornwall (Herring 1998), were quite simple, using annotated paper maps. However, with the more widespread use of GIS they have gradually became more complex, and most HLC projects now use GIS with a linked database. The use of GIS enables HLC to be viewed as just one layer of a complex HER.

The National Heritage Act 2002 extended English Heritage's remit to the 12 mile territorial limit, and so it was regarded as a natural progression to extend the characterisation technique into the coastal and marine zone (Hooley 2003). This became more pertinent when the Marine and Coastal Access Act 2009 proposed the introduction a system of spatial planning including the preparation of area marine plans (HM Government 2009).

A pilot study to test the HSC methodology was carried out in Liverpool Bay (Wessex Archaeology 2005b and c). The study was then extended to four other pilot areas in order to trial the technique in a variety of settings. These comprised Scarborough to Hartlepool (Baker *et al* 2007), Withernsea to Skegness (Museum of London Archaeology Service 2009), Clacton to Southwold (Oxford Archaeology 2007), and Solent and Isle of Wight (Pee *et al*

2007). A third phase carried out by the Cornwall County Council Historic Environment Service reviewed the methodologies of the five pilot studies and produced a method statement for future HSC projects. This aimed ‘to consolidate the England-wide methodology in close liaison with English Heritage, ensuring that the selected elements from the pilot methodologies function together in a practicable manner to meet the needs of the method’s anticipated end-users both within and beyond English Heritage’ (Tapper 2008, 13). The methodology was then tested in a large area off the north east coast of England (SeaZone 2009) before four further studies covering approximately 60% of the England’s seas and adjoining UK Controlled Waters were commissioned (English Heritage, undated b).

3.3.5 Large-scale community projects

As a response to the numbers of archaeological sites at risk in the coastal zone, large scale community projects have been set up to record and monitor sites. These include the Shorewatch project in Scotland, and the Thames Discovery Programme in London. English Heritage has also started to encourage the participation of volunteers in Rapid Coastal Zone Assessment Surveys, who, it says, can continue to monitor sites after the main surveys have been completed (English Heritage, undated, c). The New Forest RCZAS is an example of this approach (see above, section 3.3.3).

Shorewatch

Shorewatch was set up in 1997 and is managed by the SCAPE Trust, a charitable organisation. The project sets out to assist local groups in recording eroding archaeology around the Scottish coast, both by monitoring sites and excavation. Funding has been supplied by the Heritage Lottery Fund and Historic Scotland, and individual projects have received additional funding and professional support.

The Thames Discovery Programme

The Thames Discovery Programme is a three year project running from October 2008 to September 2011 funded by the Heritage Lottery Fund, with support from English Heritage, the Museum of London, and the Institute of Archaeology, University College London.

The project has two strands: a detailed survey of twenty stretches of the river by the professional archaeological team, supported by monitoring by a team of trained volunteers known as the FROG (Foreshore Recording and Observation Group). This, according to the project website, will provide 'a long-term sustainable future for the monitoring and enjoyment of the river's historic maritime heritage' (Richardson, 2009).

Both Shorewatch and the Thames Discovery Programme are backed by considerable support, both financial and professional. In particular the Thames Discovery Programme can call on the expertise of one of the leading commercial archaeological organisations and the largest university archaeological department in the country. Without such support it is difficult to see how similar projects could even be initiated.

3.4 Summary of the archaeological and palaeoenvironmental background

The archaeology of the coast was well served by antiquarians but the coastal zone suffered a period of neglect during the mid-twentieth century. The reasons for this are somewhat unclear. Bell believes that this might reflect 'a move away from the polymathic scientific interest of the amateur to the more specialised and narrowly demarcated academic disciplines... to which these curious intertidal sites may not have appeared so directly relevant as they did in the last century' (1997, 56). Both Wilkinson and Murphy (1995) and Williams and Brown (1999) suggest that this neglect may be due to the fact that archaeologists believed that key sites had been published and little could be gained from further research, 'almost that the last word had been said on them' (Wilkinson and Murphy 1995, 223).

It is clear that the multidisciplinary projects of the late 1980s and 1990s have advanced knowledge considerably whilst placing the archaeological dimension of the coast within a wider context of changing environment and sea-level rise. They have also highlighted the enormous potential of the archaeology of the coastal zone and the wealth of material that survives, if somewhat precariously, particularly in the intertidal zone. They were, however, focussed on particular areas of the country where the value of the resource had already been identified, and a national overview was lacking.

In 1997, *England's Coastal Heritage* concluded that whole classes of medieval and post medieval coastal monuments were unrecorded, thus there was insufficient information to attempt to characterise the heritage of the coast (Fullford and Champion 1997). At the same time it was recognised that rapid surveys identify exactly this type of monument, 'the most obvious features, usually post-medieval or modern', (Tyson *et al* 1997, 102). Whilst the RCZAS programme has addressed this shortcoming, there are now not the resources available to study in depth the prehistoric and Roman sites which are particularly vulnerable in the intertidal zone.

Ever diminishing funding in the twenty-first century has seen a change of emphasis with more extensive survey being focussed on providing data for the purpose of the shoreline management process, whilst other sources of funding specify large scale community involvement. However, such projects require a considerable amount of organisation, and fieldwork in certain parts of the intertidal zone and on cliff tops can be extremely arduous, hazardous and unsuitable for community participation. This was also the conclusion arrived at by those planning the fieldwork component of the Severn Estuary RCZAS, stating that volunteers would not be used because 'there are too many health and safety and insurance and liability issues involved' (Catchpole and Chadwick 2010b, 18).

Further funding is given to projects which synthesise data, although more often than not they conclude that the coastal archaeological record is inadequate.

The archaeology of the coast features strongly in the forthcoming Maritime and Marine Research Assessment for England, although this document intentionally avoids discussion of the management of the resource unless it relates directly to specific research questions. It does, however, stress the importance of 'coherent and well planned management responses' to threats such as climate change, development and coastal erosion (Ransley *et al*, forthcoming).

Changes in the coastal zone can be highly episodic and unpredictable, which makes it extremely difficult to prioritise the response to such threats, and methods of calculating rates of change generally cannot show the episodic nature of coastal change. Coastal erosion is often the result of a combination of environmental factors which may only rarely coincide, such as storm events or strong winds from a particular direction coupled with exceptionally high tides, or prolonged rainfall following a period of freezing weather. The effects of such conditions can be very localised but the consequences for individual archaeological sites can be devastating.

It seems that more specialist survey with adequate provision for dating and analysis is needed if the vulnerable archaeology of the coast is to be properly understood and managed. The current relatively broad-brushed and superficial approach to coastal survey cannot produce the necessary levels of data to understand adequately the nature of the resource.

3.5 Why is the archaeology of the coast important?

The archaeology of the coastal zone is significant on many levels. As an island nation, the coast has always been the primary point of contact with the wider world. Consequently it is important in terms of communication, trade and defence. There are classes of sites which are associated with coastal and maritime activities for which a location at the coast is essential, thus their distribution will be limited. These include ports and harbours, coastal fish traps and fish processing sites, salt production sites, lighthouses, marine industrial sites, and seaside resorts. Those features which are found on the developed coast will be offered some protection against coastal erosion and rising sea-levels; they are arguably more threatened by inappropriate development and the erosion of the character of coastal settlements.

The archaeology of the coast includes that on the coast edge, in the cliff face, in the intertidal zone and in the marine zone. Not all sites which are on the coast now were originally coastal, for example those on eroding cliff lines might have been located some distance inland. Thus coastal sites are not all of equal significance. For this reason sites should be assessed on their rarity, survival, vulnerability and the contribution they can make to further knowledge. Often it is not possible to make this assessment without preliminary investigation and scientific dating.

Sites in the intertidal zone are particularly valuable because the waterlogged and anaerobic conditions found in many intertidal situations allow the survival of organic materials which would not survive on dryland sites. As well as archaeological materials, for example worked wood and leather, these include palaeoenvironmental deposits such as Holocene sediments, intertidal peats and submerged forests, representing a time of climatic change and human adaptation to sea-level rise.

However, not only do they represent times of climatic change in the past but they are among the most vulnerable to the predicted effects of future climate change, including sea-level rise and increased storminess. The fact that such sites have only relatively recently received serious multidisciplinary attention means that they are still under researched in many areas.

4 Quantification of heritage and heritage loss

4.1 Introduction

Quantification of the historic environment is difficult and not often attempted. This is probably due partly to the fact that our understanding of heritage sites is often incomplete, and there is not the depth of information available to assess a heritage asset's significance, survival, and vulnerability to the range of threats which it might face. National projects such as the Monuments Protection Programme and the Monuments at Risk Survey have attempted to quantify the condition and importance of archaeological sites but these projects have only touched on the heritage of the coastal zone.

4.2 The Monuments Protection Programme (MPP)

The Monuments Protection Programme was conducted by English Heritage between 1986 and 2004 and was developed to identify monuments worthy of statutory protection using criteria relating to their importance and management needs (Table 4.1). The survey applied a scoring system to data held in county HERs to produce a national overview (Darvill 1988).

Table 4.1 MPP scoring criteria (from Darvill 1988)

Characterisation criteria:	Period (currency)
	Rarity
	Diversity (form)
	Period (representativity)
	Discrimination criteria
Discrimination criteria:	Survival
	Group value (association)
	Potential
	Documentation (archaeological)
	Documentation (historical)
	Group value (clustering)
	Diversity (features)
	Amenity value
Management appraisal criteria:	Condition: Form
	State
	Stability
	Fragility
	Vulnerability
	Conservation value

4.3 The Monuments at Risk Survey (MARS)

The most comprehensive survey of the condition and survival of archaeological sites in this country to date is the Monuments at Risk Survey (MARS), carried out between 1994 and 1996 (Darvill and Fulton 1998). The survey had two aims: to 'provide a general picture of the survival and condition of England's archaeological monuments', and 'to set benchmarks against which future changes can be monitored' (ibid xix). Using data held by national and local records as a basis, MARS assessed the survival of a representative sample of archaeological sites. Quantification of sites was by both by number and by area.

The survey quantified risk, which it defined as 'the combination of the probability or frequency of the occurrence of a recognised hazard in relation to the magnitude of the consequences' (ibid 218), vulnerability, and condition/survival, defined as 'a point-in-time measure of the prevailing state of a monument relative to some former state, a reflection of the cumulative effects of all the natural and human processes that have come to bear on the monument' (ibid 107). However, MARS did not satisfactorily address the threats facing coastal archaeology. This was partly due to the sampling strategy; transects covering 5% of the country's land area were interrogated, of which 2.4% was defined as coastland. Also, it was noted that the results of recent coastal surveys had not yet been integrated into the record. However, with regard to the coast it was also concluded that 'the processes that represent key hazards tend to be long term, if progressive' (ibid 227) so the survey did not regard them as being high risk.

4.4 Coastal heritage loss

All surveys of coastal archaeology undertaken to date have concluded that there are a range of threats to the resource, both natural and anthropogenic, each of which may exacerbate the other (Table 4.2). Some surveys have identified a generic list of threats (for example Dawson 2003, Van de Noort and Ellis 2000, Davidson 2002), while others have been more specific (for example Tomalin 1997 and forthcoming).

Table 4.2 The range of threats to coastal heritage identified during archaeological survey

England's Coastal Heritage	**Scotland**	**Wales**
Erosion	Marine erosion	Coastal erosion
Accretion	Aeolian erosion	Sand dune movement
Biological processes	Coastal works (harbours, sea walls etc)	Visitor pressure
Chemical processes		Changes in soil conditions
Coastal defence		Development
Development:		Coastal protection works
Port and harbour		
Electricity, oil and gas		
Telecommunications		
Transport		
Minerals - dredging/quarrying/waste dumping		
Fishing/shellfish collection		
Rural development, agricultural and forestry activities		
Navigation		
Natural processes: waves, current, wind		
Reclamation		
Recreation		
Marine safety and emergencies		
Military activity		
Northumberland	**Hamble Estuary Management Plan**	**Strangford Lough**
Natural erosion/accretion: wind and sea. Gradual or dramatic	Dredging	Natural erosion
Human:	Construction	Shellfish collection/processing
Tourist activity (erosion, construction of visitor facilities)	Bait digging	Coastal protection
Re-sanding beaches may disrupt natural cycles	Boat wash	Deposition of sediments
Groyne construction	Direct visitor impact	Protected to some extent by natural environmental designation and National Trust leasehold
Seawalls, jetties and piers		
Inshore dredging		
Industry (mineral extraction, pipeline construction, colliery waste dumping)		
Essex	**Humber**	**Shannon**
Erosion	Erosion	Erosion:
Development	Sea defence upgrade	Gradual
		Catastrophic
Severn	**Langstone Harbour**	**Tomalin (LIFE 2000)**
Natural:	Natural environment:	Coastal processes
Erosion	Wave attrition	Mineral dredging
Deposition	Spartina die back	Navigational dredging
Development:	Changing current and tidal regimes	Bait digging
Industrial & commercial	Development:	Coastal engineering works
Sea defences	Harbour edge	Induced biological change
Indirect:	Coastal margins	Outfalls, effluent and pollution
Mineral extraction	Within the harbour	Trawling
Severn Barrage	Across the harbour	Activities with all terrain vehicles
	Activities:	
	Dredging and buoying	
	Fishing and recreation	

Norfolk RCZAS	**Dorset RCZAS**	**Gibraltar Point to Norfolk RCZAS**
Coastal erosion	Natural erosion	Managed realignment schemes
	Dredging	
	Development	
Severn RCZAS	**North Kent RCZAS**	**Bempton to Donna Nook RCZAS**
Natural threats:	Development	Erosion
Coastal change	Erosion	Flood defence e.g. construction of lagoons to hold flood water
Sea-level rise	Dredging	Marine aggregate extraction
Anthropogenic		Wind farms
Coastal defence schemes		Oil and gas - pipelines, facilities and onshore storage 'caverns'
Infrastructure works (tidal barrage, road schemes)		M anaged realignment including habitat recreation
Compensation for habitat loss		Maintenance of sea defences
Increased visitor pressure due to improved coastal access		Desiccation and rewetting
Marine aggregate extraction		Mineral extraction
Development		
Whitby to Reighton RCZAS	**New Forest RCZAS**	**Donna Nook to Gibraltar Point RCZAS**
Erosion	Erosion	Erosion
Agriculture	Flooding	Development
Access roads, steps and drainage (Undercliff area)	Development	Managed realignment programmes
Commercial, industrial and residential development	Marine engineering/dredging works	Coastal habitat creation
Relocation of current coastal facilities to areas not at immediate risk	Visitor pressure as result of Marine & Coastal Access Bill	
Scilly RCZAS	**North East RCZAS**	**North West RCZAS**
Transport related development	Sea-level rise	Erosion
Sea level rise/climate change/coastal erosion	Natural erosion	Inundation
Unsystematic sampling and collection of finds	SMP mitigation strategies	Unintended consequences of mitigation strategies
Sea action	Footpaths	
Dredging, sand and gravel extraction	Recreational activities and facilities	
Visitor pressure	Dumping of colliery waste	
Irresponsible diving	Construction:	
Marine wood borers, bacterial and fungal activity	Sea defences, jetties, piers	
Commercial fishing activity	Pipelines	
Submarine cable laying	Wind farms	
Fly tipping	Housing and caravan parks	
Minor threats: bait digging, metal detecting, anchors moorings and outhauls		

However, most surveys can only provide a snapshot of the range of archaeology present in the coastal zone and the threats which it faces. There are rarely enough data available to make quantitative statements about the rates and severity of those threats. An important next stage, therefore, must be to provide quantifiable data which can support these statements about the perceived threats to coastal archaeology.

4.4.1 Natural erosion

Natural erosion has been highlighted as a major threat by all surveys, but more than any other form of threat it is unpredictable in its nature and scale.
Most coastal archaeological surveys include erosion by waves, tidal currents and wind, which can be exacerbated by storm events, as a threat to the archaeology of the coast. However, extremes of weather such as drought and excessive rainfall, and freezing and thawing can also cause erosion and damage to the coastal archaeological resource. This is particularly evident on soft-cliff coasts such as the south coast of the Isle of Wight where cliff falls and major landslips can be triggered by intense or prolonged periods of rain (McInnes *et al* 2000), especially when followed by freezing temperatures. Drought conditions too can cause the cliff to dry out and crack causing both small trickles of sediment to cascade down the cliff or large areas to crumble (Fig. 4.1).

Figure 4.1 Erosion on the south coast of the Isle of Wight at Chilton and Compton

The effects of natural erosion on the coastal archaeological resource can be difficult to quantify. Lateral erosion can be calculated using maps and charts, aerial photos or satellite imagery but there are many limitations to the accuracy of the results (see Chapter 6) and they can only at best give a short to medium term indication of coastal change. The most reliable technique is ground survey using total station theodolite or survey grade GPS. Vertical erosion is more difficult to assess, the most obvious technique being ground survey. However, this has the disadvantage of being very time consuming and, particularly in the case of archaeological survey, can divert limited time/personnel resources.

4.4.2 Development

Development has been cited as a major threat to the archaeological resource by most coastal archaeological surveys. Some developments, such as port improvement and expansion, need to be located at the coast because of their function. Others may be located there because of the relative ease and sustainability of transport by sea, and many industries are for this reason located on the coast. Residential development may take place because the coast is an attractive place to live.

The effects of development can take the form of direct damage to historic buildings or harbour structures. Associated reclamation can bury intertidal structures, wrecks, or palaeoenvironmental deposits, which may help preserve them but may also lead to compaction and desiccation. Reclamation and dredging may both create changes to currents and tidal flow which may contribute to coastal erosion, either locally or remotely. Furthermore, the necessity for new or improved infrastructure such as road or rail links associated with the development can extend the scale of damage to the historical environment (English Heritage 2006c).

Development above mean low water is subject to the *Town and Country Planning (Environmental Impact Assessment) (England and Wales) Regulations* (1999) and should be guided by the policies set out in PPGs 15 and 16 (replaced by PPS5) with regard to the historic environment.

For works relating specifically to port or harbour installations, the *Harbour Works (Environmental Impact Assessment) Regulations* (1999) carry a requirement to undertake an Environmental Impact Assessment, which should include a 'description of the environment likely to be significantly affected by the proposed project… including the architectural and archaeological heritage'. This is reiterated in the Department for Transport's project appraisal framework for ports, which includes in its 'table of objectives, principal sub-objectives and further considerations', 'to protect the heritage of historic resources' (Department for Transport 2002).

Port and harbour authorities must consider the environment but also, under their own enabling legislation, must ensure safe navigation. Safety generally is given a higher priority than environmental considerations.

4.4.3 Dredging (aggregate and navigational)

In the United Kingdom mineral rights to the seabed are owned by the Crown Estate which issues dredging licences only if permission is granted by the Department of the Environment, Transport and the Regions, the National Assembly of Wales or the Scottish Parliament (BMAPA undated, a). The marine aggregates industry is represented by the British Marine Aggregates Producers Association (BMAPA), a constituent of the Mineral Products Association. BMAPA acknowledges that it operates in a sensitive environment with many issues relating to sustainability, damage to marine life, and archaeology, and attempts to limit its impacts, particularly by working in partnership with other interested bodies. With regard to archaeology, it has worked with English Heritage to produce a guidance note and protocol for reporting archaeological finds made during dredging operations (Wessex Archaeology 2003 and 2005d).

Aggregate extraction is regulated by *Minerals Policy Statement 1* (MPS1; Department for Communities and Local Government 2006b) which encourages the extraction of aggregates from ‘environmentally acceptable’ marine sources where it is consistent with sustainable development.

Marine Mineral Guidance Note 1 (MMG) sets out six guiding principles. These include minimizing and careful location of the licensed area; the requirement of a supporting Environmental Impact Assessment (EIA); the adoption of practices that minimize the impact of dredging; the requirement on operators to monitor environmental effects; and conditions attached to licences (Department for Communities and Local Government 2002). The required Environmental Impact Assessment should include a Coastal Impact Study which should assess the implications for coastal erosion, including the likelihood of beach drawdown, interruption of sediment supply to beaches and the possible effect on offshore bars and banks protecting the coast, and the impact on tidal patterns and currents. Production of Environmental Impact Assessments for marine aggregate extraction is regulated by *The Environmental Impact Assessment* *and Natural Habitats (Extraction of Minerals by Marine Dredging) (England and Northern Ireland) Regulations 2007* (Department for Communities and Local Government 2007). MMG adds that where there is any uncertainty about the effects of dredging on the coast, shoreline monitoring may be required, and cites guidance from CIRIA (Brampton and Evans 1998) and the Joint Nautical Archaeology Policy Committee code of practice (JNAPC 2006).

The Hampshire and Wight Trust for Maritime Archaeology has carried out a review of how archaeology is considered in Environmental Impact Assessments accompanying marine dredging license applications. This review found that coastal and intertidal sites are generally poorly represented in Environmental Statements 'largely due to there being no perceived threat to these site types', (Hampshire and Wight Trust for Maritime Archaeology 2007, iii).

Approximately 21% cent of the aggregates used in England and Wales are acquired from marine sources (BMAPA and English Heritage 2003). There are more than 70 licensed dredging areas (Fig. 4.2), mostly off the south and east coast of England (The Crown Estate, 2004a). Marine aggregates are used in the construction industry, where their use is said to reduce significantly the effects of pollution and congestion because they can be transported by sea rather than by road (The Crown Estate ibid). Increasingly, however, marine aggregates are being used in 'soft engineering' coastal protection schemes such as beach replenishment, where large quantities of material are often required (Gubbay 2005).

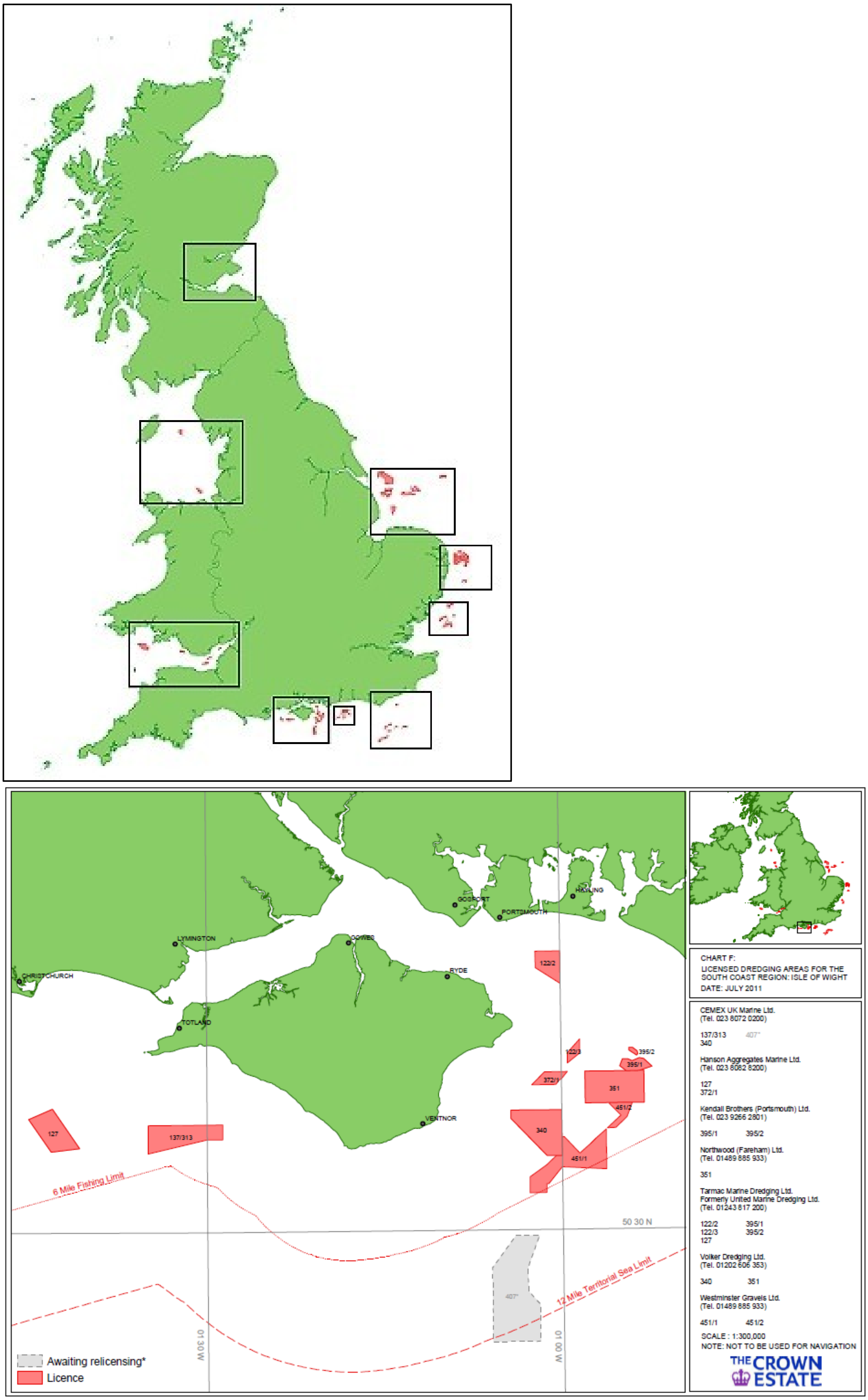

Figure 4.2 Licensed marine dredging areas in the UK and off the Isle of Wight (© The Crown Estate 2011)

The effects of marine aggregate extraction on the coast are controversial. BMAPA states that there is no evidence that aggregate dredging exacerbates coastal erosion, which, it says, is a natural phenomenon (BMAPA undated, b). Gubbay (2005) carried out a review of marine aggregate dredging on behalf of The Crown Estate, in which she highlights studies such as the Southern North Sea Sediment Transport Study (CEFAS 2008), the South Coast Seabed Mobility Study (Brampton 1993) and the Inshore Seabed Characterisation Project (Evans *et al* 1998), which conclude that marine aggregate extraction is currently not having an effect on the coast. However, she recommends that 'given concerns and the potential significance of any such effects, it is important that this type of investigation remains a key consideration in the consenting process' (ibid 25).

In response to public concerns BMAPA, in association with SCOPAC (Standing Conference on Problems Associated with the Coastline), initiated a study of the current procedures for assessing the impact of marine dredging on the coast (Simons and Hollingham 2001). The study aimed to review and compare current practice with equivalent international procedures; to identify the major areas of concern to stakeholders and the general public; to assess coastal process models; to discuss the currently acceptable level of impact and the cumulative effect of aggregate dredging on the coast; and to review standards for data collection and monitoring.

The main issues raised by this study were: poor communication between the dredging companies, scientists, and the public; the inadequacies of coastal process models and the lack of baseline survey data against which to assess their accuracy; poor understanding of the long term and cumulative effects of marine aggregate dredging; and the lack of research to establish the level of coastal change that can be regarded as acceptable and insignificant.

According to Bradbury *et al* (2003) monitoring is a requirement of all aggregate production licences; however, because most dredging areas are in relatively deep water, detailed monitoring of the coastal zone is not usually required. English Heritage and BMAPA guidance states that marine aggregate dredging is usually carried out 'at depths' and 'in areas where dredging is unlikely to affect adjacent coastlines' but adjacent coastal areas should be included in Environmental Impact Assessments to 'provide appropriate contextual information… where there is potential for formerly terrestrial archaeological and palaeoenvironmental material' within the application area (BMAPA and English Heritage 2003, 10, 16).

In contrast to the views held by the government and the aggregate industry, there are numerous groups who believe that marine aggregate dredging contributes to coastal erosion. The Friends of the Earth (FOE) has a network dedicated to marine issues, and the effects of marine aggregate dredging both generally and on the coast feature highly amongst its concerns (MARINET undated a). Other groups are motivated by changes to the coast in their immediate area, (although, conversely, some regard the exposure of archaeological features by coastal erosion as beneficial; MARINET undated b). As a consequence, their actions are often confrontational, and this stance is intensified by the fact that the reviews of the effects of marine dredging on the coast are funded on the whole by the government and the aggregate industry which has commercial interests in the activity. Although denying that marine aggregate extraction contributes to coastal erosion, the fact that these reviews make little attempt to establish what might be causing the problem adds to the frustration (May 2007).

There is a large body of anecdotal evidence which suggests that marine dredging may exacerbate coastal erosion processes but in reality issues such as the cumulative effects of aggregate extraction, the fact that there might be a considerable time lag before changes become evident, the lack of long term data and monitoring, and the likelihood that there may well be a range of contributory factors causing coastal erosion make this difficult to establish with any certainty.

Navigational dredging

Navigational dredging includes maintenance dredging to remove accumulated sediment from channels, and capital dredging to create new channels or during construction works within ports.

Many port and harbour authorities have statutory powers granted by local acts, or harbour revision or empowerment orders made under the Harbours Act 1964. These local acts allow the harbour authorities to undertake dredging works within the limits of their jurisdiction, although these generally require the approval of the Secretary of State for the Environment, Food and Rural Affairs (MCEU 2008). There are further requirements under the *Harbour Works (Assessment of Environmental Effects) Regulations* (1999), and, if the works are to be undertaken within or adjacent to a European conservation site, an 'Appropriate Assessment' will be necessary under the *Conservation (Natural Habitats etc) Regulations* 1994. In addition the *Food and Environmental Protection Act (FEPA)* 1985 usually requires a licence to deposit the resulting dredged material at sea or within tidal waters.

Outside of the harbour authorities' areas of jurisdiction, dredging normally requires consent under the *Coast Protection Act* 1949.

4.4.4 Coastal protection works

Coastal protection works may have a direct or indirect effect on the historic environment, but their impact can be considerable. At a recent conference addressing climate change and archaeology, it was said that 'the most immediate impacts (20 year time-scale) are not from climate change as such, but from the coastal management decisions now being taken in response to perceived future climate change' (Murphy 2007).

Mitigation may only be possible for sites which are most directly affected by works and it may be difficult to justify full recording of poorly understood sites. For example, in 2003 coastal protection works were carried out on the foreshore at Seaview Duver on the north east coast of the Isle of Wight (Wessex Archaeology 2004d). Archaeological survey was carried out during a time when the tides were not very low so a limited area was surveyed due to safety constraints and it was not possible to survey the entire area that would be affected by the operations. Although timbers structures and palaeoenvironmental deposits were recorded, no radiocarbon dating was undertaken. It is not immediately obvious what the reasons for these shortcomings were. Possibly if a more specific brief for the archaeological work had been produced or better monitoring had been carried out when the work was underway then more of a case could have been made for additional analysis. Although budgets for carrying out coastal protection works may seem generous compared with the funding available for land-locked archaeological projects, there is rarely any contingency for dealing with unexpected finds.

In some parts of the country which are seen to be particularly susceptible to the effects of climate change, the consequences of mitigation present more problems to the archaeology of the coast than the natural processes. For example, the Gibraltar Point to Norfolk RCZAS concluded that the principal risk to the archaeology of the coast was not from coastal erosion or development but from the need to carry out managed realignment schemes due to the risk of flooding (Buglass and Brigham 2007b) and habitat creation schemes to replace protected habitats that will be lost (Brigham *et al* 2008).

4.4.5 Bait digging

Bait digging has been identified as a high risk activity within SPAs and SACs because of the damage caused by digging and associated trampling (Defra 2006d). The main techniques used are digging, boulder turning and bait dragging. The effects of the activity may be ‘local but intense’. Studies have examined the impact of bait digging on the natural environment, in particular in relation to protected species and designated areas (cited in Defra 2006d; e.g. Fowler 1999, Mazik *et al* 2005, Smith and Murray 2005, Wynberg and Branch 1997).

Fowler (1999) suggests that there are four groups engaged in bait digging. These include commercial collectors who regularly use the same stretch of coast; experienced local collectors who gather bait for their own personal use; inexperienced local or visiting collectors who are less likely to be concerned with managing local stocks; and commercial collectors who have only taken up bait digging for a short time and who are inexperienced and/or inefficient. He lists eleven possible ways of managing bait collection. These include; national or local/regional codes of conduct; participation in local management plans; prohibition or licensing of commercial activities or general licensing for all collectors; bag limits; zonation; closed seasons; closure of bait beds; improved retail sources; and fisheries legislation. However, he acknowledges that all of these can be of limited success due to difficulties of communication, especially with those who are less likely to be concerned with the long term management of the intertidal zone, and the problem of resources to educate and enforce.

Bait digging can be regulated by voluntary codes of conduct or by enforceable bylaws. However, they tend to have limited success due to commercialism and the ‘unaffiliated’ nature of participants. It is difficult to apply non-regulatory measures. Defra (2006d, ii) suggests that voluntary codes of conduct ‘which are well defined and with local support’ are preferable to regulation and enforcement. However, control through bylaws can be successful, although they need to be locally focussed and flexible.

Examples of bait digging codes of conduct include those drawn up for the Solent European Marine Site (Solent European Marine Site undated), the Fowey Estuary (cited in Smith and Porter 2003) and Poole Harbour (Poole Harbour Steering Group undated).

Some codes of conduct, for example the North Eastern Sea Fisheries Committee’s (undated) *Intertidal Fisheries Code of Conduct*, specifically identify that archaeological sites can be damaged by bait digging and one of the guidelines of the code is to ‘Avoid disturbance to archaeological sites’. However, this assumes that archaeological sites have, firstly, already been identified and, secondly, would be easily recognisable to those collecting bait.

The impact of bait digging on archaeology is unclear and there is little quantifiable evidence available. It is undeniable that bait digging would be extremely damaging if carried out on archaeological sites, but the evidence for this damage seems mostly anecdotal. For example, Tomalin (1997, 50 and forthcoming) cites bait digging on a semi-commercial scale on the Wootton-Quarr coast of the Isle of Wight as being destructive to archaeological remains in the intertidal zone. Unquestionably, if the areas favoured by bait diggers coincided with those where archaeological sites survived, the damage to the archaeological resource would be great, but in more than fifteen years of working in the same stretch of the coastal zone, I have yet to see more than one or two worked flints that have been disturbed by bait digging, and no bait digger's holes have been seen in the areas of highest archaeological potential.

4.4.6 Biological/chemical processes

The effects of biological and chemical processes on archaeological material in the intertidal zone has received little attention compared with fully marine sites (see for example Ferrari and Adams 1990, Palma 2005) or terrestrial wetland archaeological sites (in particular the monitoring of water levels/saturation, e.g. Chapman and Cheetham 2002, Holden *et al* 2006, Brunning 2007a and b, Lillie and Smith 2007, Lillie *et al* 2008).

On the Isle of Wight, research into the physical, biological and chemical processes affecting the preservation of waterlogged wooden material in the intertidal zone was undertaken as part of the Wootton-Quarr project and for a Masters dissertation (Simpson 1994 and forthcoming, a and b). This included monitoring at three locations at extreme low water, in the mid-shore zone and just above high water. Piezometers were used to assess the dissolved oxygen, redox potential and pH of water within the sediments. Sampled stakes were assessed for attack by micro and macro-organisms (fungi, bacteria, and marine borers) in both their exposed and buried parts. The moisture content, specific gravity and hardness of posts were also tested.

Although the potential for biological and chemical processes to cause damage to the intertidal archaeological resource was identified in *England's Coastal Heritage* (Long and Roberts 1997, 46), this has not been picked up on by most Rapid Coastal Zone Assessment Surveys. It is easy to see that there are more obvious threats, and indeed it could be said that the damage caused by biological and chemical processes is to some extent a by-product of other more obvious processes such as erosion and changes to beach morphology.

The RCZAS for the Scilly Isles (Johns *et al* 2004) recognised the damage caused by marine borers and bacterial and fungal activity, but only in relation to marine timbers. During a programme of monitoring in the Blackwater Estuary, Essex, Murphy sampled timbers from a structure primarily to assess whether there were quantifiable differences in condition between exposed and buried components (Murphy 2004). He looked at percentage water content, signs of physical erosion, especially the presence or absence of bark, the degree of induration by iron sulphide, the colour of replaced tissue assuming changes from black to red following exposure to oxygen, evidence of boring organisms and colonisation by other plants and animals, and evidence of gross distortion and fissuring. He concluded that although it was evident that some of these processes were occurring, it was difficult to assess the relative significance of each, recommending 'further studies in contrasting environments' (ibid 30). This echoes the statement made in *England's Coastal Heritage* that 'Not only are many of the biological, chemical and physical processes responsible for damage to the resource poorly understood, but the range of local site processes makes simple predictions at a national level almost impossible' (Long and Roberts 1997, 44).

In the past few years it has been identified that the effects of coastal erosion and climate change are likely to lead to increasing numbers of archaeological sites being exposed in the intertidal zone where their survival cannot be guaranteed. Attention has now started to focus on assessing the potential of more benign wetland environments for reburial of organic archaeological remains which have been recovered as a cost effective means of storage and preservation (Hogan *et al* 2006, Simpson pers comm; Simpson and Edmunds 2009).

4.4.7 Ship wash

Ship wash includes both the generation of waves caused by movement of ships through water and propeller-induced turbidity in the water column. The wave magnitude is related to speed of vessel, size and displacement of vessel and the distance between the vessel and the feature of interest.

The effects of ship wash can lead to three problems, namely intertidal erosion of estuaries, re-suspension of sediments and aeration of water column. However, little research has been undertaken into the scale of these problems (UK Marine SACs Project 2001).

Probably the most controversial effect of ship wash is its contribution to intertidal erosion. It is difficult to establish a connection between the two because the marine system is so variable and also because of the lack of research and supporting data. The composition of the shoreline and the distance between the navigation channel and the shore is important, as is the depth of water. The susceptibility of the shore to erosion is increased around an exposed point of land in a narrow river, and is affected by the steepness of the shore gradient, the water level, and if a high level of boating activity is concentrated near shore.

On the Isle of Wight concerns about erosion grew following the introduction of larger ferries on Wightlink's Portsmouth to Fishbourne route in the early 1980s. Local people became aware of falling beach levels around Wootton Creek, and archaeological material started to erode from the intertidal sediments, prompting a major archaeological survey (Tomalin 1995; Loader *et al* 1997).

Numerous studies into the effects of the larger ferries have been undertaken on behalf of the local authority, the ferry company, local residents, English Nature (now Natural England), and as student projects (e.g. Hydraulics Research Ltd 1980 and 1988, Robert West and Partners 1989 and 1990; Posford Duvivier 1994, Bray 2003, Garel *et al* 2008).

Perhaps unsurprisingly in view of their individual interests, assessments undertaken on behalf of the ferry companies generally find that their actions do not contribute to coastal erosion which they conclude is a natural phenomenon. Prior to the introduction of the larger ferries it was concluded that there was 'no evidence that points to a connection between land recession and operation of the present ferries' and that 'operation of the proposed larger vessels in the enlarged approach is likely to cause less disturbance by wave action and blockage effect' (Hydraulics Research 1980, 4).

A report commissioned by the local authority concluded that erosion in Wootton Creek 'can be attributed to a greater or lesser extent to the changes in ferry service' although 'it may be that the sediments within the creek have adjusted to the new hydrodynamic regime created by the changed ferry service', and found that the effects' could have been predicted and allowed for in advance' (Robert West and Partners 1993, 24-25). A second report on behalf of the local authority found a clear link between the dredging of the channel to accommodate the larger vessels, the wash generated by them and the lowering of beach levels stating that 'a large proportion of the problem is related to the dredged channel and the operation of the ferries' but were more cautious in apportioning blame ...'establishing a proportional damage between wind waves and ship generated waves is open to much interpretation' (Posford Duvivier 1994, 6).

Local residents are convinced that there is a direct link between the wake from ferries and the increased erosion (Fishbourne Residents Group, undated). In the case of the Portsmouth-Fishbourne route, little monitoring was undertaken prior to the apparent increase in erosion following the introduction of the larger ferries, so it is extremely difficult to prove that the erosion has accelerated as a direct result.

In 2009 Wightlink introduced new, larger 'Wight Class' ferries on its route between Lymington and Yarmouth on the western side of the island, and similar concerns were voiced about the potential effects of these ferries on the extensive saltmarsh and mudflats which line the mouth of the Lymington River. Once again, the ferry company's stance was that erosion is a natural phenomenon and any potential contributory impacts could be mitigated by controlling ferry speeds within the harbour. They argued that the ferries were, in fact, more environmentally friendly than those which they replaced (Wightlink undated; ABPmer 2008).

Information gathered for Natural England found that the ferries were likely to contribute to loss of mudflats, recession of Chart Datum, recession of Mean Low Water, and deepening of the channel (H R Wallingford 2009), although this was challenged by Wightlink. The Lymington River Association questioned the conclusions of ABPmer, Wightlink's consultants, saying that their methodology 'contained serious errors such that their conclusions were misleading and should be set aside' and that 'Other evidence seemed to be based mostly on conjecture not backed up by evidence' (Lymington River Association 2008).

Other harbour user's concerns were directed more specifically at the effects of the wash from the ferries on their activities, for example yachting (Solent Protection Society 2008).

Having spent almost 20 years engaged in intertidal survey on the Isle of Wight, and in particular on the north east coast adjacent to the Fishbourne ferry terminal, I have seen plenty of evidence to suggest that the actions of the ferries do contribute to coastal erosion. Each time a ferry arrives or departs, water and sediment is sucked off the beach, only to rush back as the ferry passes (Fig. 4.3). During peak times ferries run to a strict half hourly timetable and there is little time for disembarking and reloading. The vessels travel at speed, although it has been noted that they reduce speed considerably when we have surveying equipment on the beach.

Figure 4.3 The wash created by the ferry approaching the terminal at Fishbourne (© IWCAHES)

An island community relies heavily on transport from the mainland on many levels, and on the Isle of Wight there is no alternative, with no fixed link and only very minor airports. In addition to environmental concerns such as the ferries' contribution to coastal erosion, many people are dissatisfied with the high costs and the level of service provided, and the ferry companies appear to pay little heed to their concerns, so much so that in 2009 the local Member of Parliament submitted evidence to the Office of Fair Trading in support of a full investigation by the Competition Commission.

4.4.8 Visitor impact

A report produced by Defra (2004a Appendix 1) lists a wide range of recreational activities which take place at the coast – on land, on the foreshore, and offshore - and their possible impacts. However, the effect of such activities on the historic environment is not mentioned, nor are any heritage agencies listed in the appendix of 'Authorities, agencies and other bodies' (Defra 2004a Appendix 2). Amongst the potential issues raised by trying to control the various activities, the report mentions problems of enforcement, of liaison when activities are carried out by individuals rather than organised groups, the potential for enforcement in one area to lead to the activity moving elsewhere rather than stopping, and the fact that codes of practice are likely to be ignored by the unscrupulous.

There is a miscomprehension amongst many people that no-one owns the beach and so they can carry out whatever activities they wish to. In reality approximately 55% of the foreshore plus most of the seabed out to the 12 mile territorial limit is owned by The Crown Estate with the remaining 45% under the ownership of statutory bodies, local authorities, port authorities, government departments, or in private ownership (The Crown Estate 2004b). On the Isle of Wight, the situation is yet more complex and a greater percentage of the beaches are privately owned. The National Trust owns large stretches of coast and leases further areas from The Crown Estate. The fact that a large percentage of the coast is covered by environmental designations should also offer archaeological sites some protection from damaging activities.

Direct visitor impact is a particular problem on soft, dune coasts and has been highlighted as one of the main threats to the archaeological resource in Wales and on Northumberland coast (Davidson 2002; Northumberland County Council 1994). The increasing popularity of the coast for recreation and tourism has led to significantly higher numbers of visitors. This too has meant a rise in the associated facilities such as car parks, toilets, food outlets, paths and roads. The RCZAS for the New Forest has identified the potential for increased visitor pressure as a result of the improved access to the coast proposed by the Marine and Coastal Access Bill (Wessex Archaeology 2010).

In my experience, visitor impact is likely to be more of a problem to terrestrial coastal sites than those in the intertidal zone since the more vulnerable intertidal sites such as timber structures tend to be on muddy coasts that are not attractive to visitors. They are often located towards the low water mark, whereas the majority of casual visitors remain nearer to the coastline.

The hostile environment in which many intertidal sites are found may limit the damage caused by large numbers of visitors but also reduces the opportunities for public dissemination and involvement. I have been involved in an annual low tide day walk at Wootton-Quarr, where visitors were taken to see some of the more accessible intertidal wooden structures and palaeoenvironmental deposits. Many local people were aware of the work that we had been carrying out and relished the opportunity of actually visiting the sites with us. The experience taught them about the difficult conditions posed by the intertidal zone but I am sure that some went away disappointed at the lack of visibility of the sites. Having seen our reconstruction drawings of the extensive fish traps and other structures, they had preconceived ideas of what they might see and were unprepared for wooden posts that hardly protruded above the sediment. The fact that the posts were not obvious to them also meant that some were damaged by trampling.

4.4.9 Ecological/vegetation changes

Loss of saltmarsh

Hughes and Paramor (2004) write of saltmarsh loss on a regional scale in southern England, which has generally been attributed to coastal squeeze caused by sea-level rise. However, they point out that, as well as migrating landwards, saltmarsh may develop vertically and may even extend seaward with rising sea-level if the rate of sediment accretion is sufficient. They suggest that other factors may be responsible for loss of saltmarsh. These include an increase in abundance of burrowing invertebrates such as the ragworm *Nereis diversicolor* which cause the loss of pioneer zone plants leading to sediment instability; increased wave or tidal action; and vulnerability caused by the loss of intertidal seagrasses leading to erosion in front of the saltmarsh. Pontee (2004) has considered saltmarsh loss in the Lymington and Western Yar Estuaries in relation to navigational dredging. He concludes that the patterns of erosion are symptomatic of many of the estuaries of Southern Britain and suggests that the driving factor is more regional in nature. He suggests the natural variation in the height of tides as part of the 18.6 year lunar nodal tidal cycle, or alternatively, the rapid expansion of *Spartina* marshes has created unstable morphodynamic systems within the estuaries which are still undergoing readjustment.

Spartina die-back

Prior to the nineteenth century, the native cord grass *Spartina maritima* formed a common component of saltmarsh flora. Problems arose with the introduction of a North American species, *Spartina alterniflora*, believed to have been introduced into Southampton Water via transatlantic shipping in the early nineteenth century. Hybridization between the two species occurred, creating an aggressive new species, *Spartina angelica*, which rapidly colonised the intertidal mudflats around much of the British Isles and northwest Europe. A second hybrid, *Spartina townsendii*, was first identified in the 1870s and this, too, spread rapidly, so that by the early twentieth century the native form, *S. maritima*, had virtually died out. The spread of the hybrid forms was assisted by deliberate planting, both to consolidate bare saltmarsh as a means of coastal defence and to raise levels prior to embankment.

The earliest report of *Spartina* die-back came in 1924 in Poole Harbour, but it was widespread by the 1950s, prompting several studies into its possible causes. These differentiated between die-back on the edges of channels caused by wave action (channel die-back), and in the lower parts of the marsh between (pan die-back). It was believed that pollution or a pathogenic organism might be responsible but this was ruled out. It was established that sediment in die-back marsh was highly anaerobic with a high ferrous sulphide content, and, according to Tubbs it was concluded that the cause was 'a combination of waterlogging caused by the slight ponding effect of the creekside levees and the very fine nature of the particles deposited on the marsh in the later stages of its vertical growth, exacerbated by the high organic content of the soils arising from initial *Spartina* decay' (Tubbs 1999, 89). Alternative hypotheses have cited genetic changes or physical erosion as contributory factors (Haynes and Coulson 1982; Nyman *et al* 1994).

4.4.10 Fishing/trawling

Fishing and trawling in the United Kingdom are regulated by Sea Fisheries Committees. It might be assumed that sea fishing would have little effect on archaeological sites in the intertidal zone, however, this is not the case in the Solent. Here, oyster trawlers are regulated by the Southern Sea Fisheries Committee and are licensed to operate up to the line of mean high water spring tides (Solent Oyster Fishery Order 1980). The effects of their operations have been observed on Quarr beach where sediments have been scoured by the dredge over a large area and well in from low water (Fig. 4.4). We have witnessed the damage that these have caused to wooden posts, and structures such as hurdle or brushwood trackways are unlikely to be able to withstand more than one pass of the dredge. At the same time, however, the Solent fishermen have been very willing to report any archaeological material that they have recovered during trawling.

Figure 4.4 Damage caused by trawling for shellfish in the intertidal zone at Quarr, Isle of Wight (© IWCAHES)

Studies have been undertaken to assess the effects of fishing on European marine sites, including their effects in the intertidal zone (for example Gubbay and Knapman 1999, Sewell and Hiscock 2005). These have found towed fishing gear such as oyster and scallop dredges and beam trawls to be damaging to the seabed to a varying extent depending on the nature of the substrate and the intensity of the activity (Fig. 4.5). They found that the dredges could disturb the top 10-15cm of muddy sediments, and their tracks could remain visible for several months in stable sediments. We have witnessed the tops of posts on an intertidal alignment having been snapped off or wrenched from a vertical position, and fragile structures such as hurdles would not be able to withstand such activity.

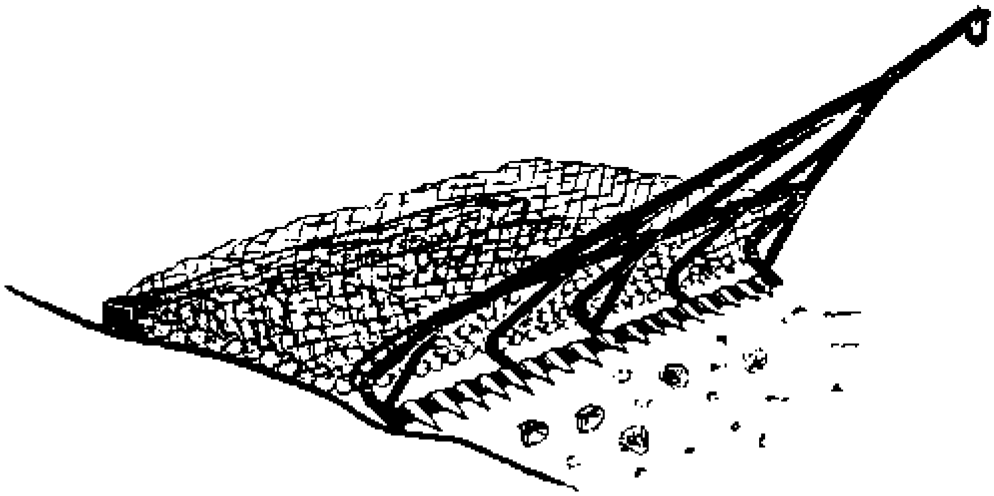

Figure 4.5 An example of a dredge for gathering oysters or scallops (from www.fao.org)

In 2004 there was an incident on Ryde Sands, on the north east coast of the Isle of Wight, where the collection of cockles using a pump scoop dredge caused damage to nationally scarce *Zostera* beds. This was in an area close to archaeological sites. Because of the area's status as a SAC and SPA the activity has been banned permanently (Defra 2004b; OPSI 2004).

4.4.11 Climate change and its relevance to coastal archaeology

Perhaps the most significant threat to the historic environment of the coast and one that may be either directly responsible for or a contributory factor towards many of the other hazards that it faces is climate change. The impact of climate change, and in particular the associated issue of sea-level rise on the historic environment, especially that of the coast, has become an increasingly urgent problem in the twenty first century. In 2002, English Heritage's *State of the Historic Environment Report* stated 'Climate change is an acknowledged threat to both the natural and historic environment' and will 'pose a challenge to a wide spectrum of the historic environment from coastal sites to veteran trees. Can we measure the likely impact and cost the necessary mitigation?' (Summary, 6). The same review in 2003 stressed the 'considerable uncertainty about the reliability of middle to longer-term climate change predictions, and as a result, the longer-term implications for the historic environment' (English Heritage 2003, 13), whilst in 2004, it was acknowledged that the effects of climate change would make the conservation and protection of heritage sites 'all the more difficult to achieve', and would be 'especially challenging at coastal sites'

(English Heritage 2004, 120). The report in 2007 described the impact of climate change on the historic environment as 'the most pressing debate in relation to environmental sustainability' (English Heritage 2007b, 50).

In 2008 the 'Heritage Counts' report featured a section on climate change, including a case study entitled 'Adaptation in the coastal context' (English Heritage 2008b). Here the significance given to heritage assets in the shoreline management process was described as being much weaker than that given to designated nature conservation sites, which have to be protected or equivalent habitats created. There is a greater emphasis in the report on the built heritage rather than archaeological remains and palaeoenvironmental deposits, and whilst it is stated that 'The role of volunteers can be hugely important here: actively involving people in organised monitoring and recording of the impacts of climate change, and then passing on that information to others, will be one of the best ways of managing the changes that are going to happen' (ibid, 12), how those changes will be managed is not explained.

Concerns about climate change led English Heritage to commission a scoping study to investigate the likely risks to the historic environment and to examine suitable mitigation and adaptation strategies (Cassar 2005, 4). Amongst the issues raised were: the 'irrevocable and dramatic loss of coastal sites' (p.23); the lack of management strategies and the fact that 'inevitable loss will probably require approaches to rapid investigation and recording' (p.26-27); coastal sites are amongst those most at threat, they are often of a type not found elsewhere and 'if they are not investigated before they are destroyed by climate change they will be lost forever in both in terms of physical reality and in terms of recorded archaeology' (p.32). The lack of data about the effects of environmental change and the resources for research and monitoring of sites and materials was highlighted (p.33). There was an acceptance that not all sites could be saved, but there needed to be the resources available to record those of lesser significance, although the question of how this would be funded was raised. Coastal loss and flooding was likely to have a devastating effect on coastal sites, but protection measures could create problems on another stretch of coastline. The study concluded that a coordinated approach should be taken, with English Heritage playing 'a significant part in the broader planning processes of the Environment Agency with priority given to recording rather than attempting to preserve many sites', (p.43), but again the problem of funding was raised.

This study does not appear to take a full and realistic account of the wide range of archaeological and palaeoenvironmental sites at the coast, particularly not the most vulnerable intertidal features. The suggestion is that sites would either be preserved or, if that was not possible, they would be fully recorded. In reality, I think there is an acceptance that it is inevitable that a large percentage of sites will be destroyed; securing the resources to identify these, let alone to adequately record them before they are destroyed, is more of an issue. Peter Murphy has said 'in practice, the availability of funding will be the main factor determining the scale of what can be done' (2009, 189).

The seriousness of the threat to the historic environment from climate change is reflected in the number of seminars and conference sessions that have been organised, for example by the Council for British Archaeology (CBA), the Institute for Archaeologists, the Historic Environment Advisory Committee for Scotland, and CoastNet (for details see CBA undated). English Heritage has published a statement on climate change and the historic environment in which it describes climate change as 'one of the most important and urgent problems facing us today' (English Heritage 2008c, 1).

In June 2009, climate change projections until the year 2080 were launched (UK Climate Projections 2009c). The projections covered seven 30-year time periods from 2010 to the end of the twenty first century and included a quantification of recent trends as well as future projections. Unlike previous studies, advances in the quality and quantity of data available also allowed a quantification of uncertainty.

The key findings from the UKCP09 projections suggest that for the south east of England by 2080:

- the increase in winter mean temperature is likely to be between 1.4°C and 5.7°C.

- The summer mean temperature is likely to have increased between 1.4°C and 8.1°C.
- The change in winter mean precipitation is likely to be between 4% and 67%.
- The change in summer mean precipitation is likely to be between -57% and 13%.
- The change in annual mean precipitation is likely to be between -7% and 9%.
- Sea-level rise in London is predicted to be between 30.5cm and 43.3cm by 2080.
- However, when combined with inferences drawn from evidence from ice cores, deep ocean sediments and corals, a 'low probability, high impact range for sea level rise' around the United Kingdom, known as the High-plus-plus (H++) scenario (Lowe *et al* 2009, 33) suggests a rise of between 93cm to 190cm.

4.4.12 Summary of the threats to the coastal archaeological resource

Coastal heritage is faced by a wide range of threats, both natural and anthropogenic. However, to a large extent, the risk to the archaeology of the coast is dependent on the nature of the archaeological remains and the nature of the coast (for example geology, exposure to wind and waves). One of the problems of dealing with the stability of archaeological sites on the coast is that they are subject to episodic events which are unpredictable in their occurrence and magnitude. Attempts have been made to define stretches of the coast in terms of the importance of their archaeology and the level of risk which it faces, but so many sites are poorly understood that it becomes difficult to assess their significance. It becomes rather a vicious circle when limited resources have to be assigned to record the most deserving sites but the importance of so many sites cannot be ascertained because their function is not obvious and they cannot be dated without funding for scientific dating.

4.5 Ranking and prioritisation

4.5.1 Ranking

For more than ten years there has been ongoing discussion about the merits of ranking archaeological sites on the coast for the purpose of prioritisation for SMPs and coastal defence. It was recognised in Wessex Archaeology's (1999) study of the use of historic environment data in SMPs that both those commissioning and those preparing SMPs wished for sites to be prioritised or given some value so that the same cost-benefit equations that are used for other coastal assets could be applied when appraising strategic defence options. The Wessex Archaeology survey concluded that historic environment sites should be treated as intangible assets, but that a system for prioritising sites which was comparable from region to region should be developed. It accepted that archaeological curators might be reluctant to prioritise sites because the coastal HERs were so incomplete, and stressed that, due to the nature of the resource, this might remain the case even following detailed survey. Therefore, rather than putting a value on individual sites, it was instead suggested that stretches of coastline should be assigned a value, rather than simply identifying 'hotspots of high potential surrounded by large areas of indeterminate potential' (ibid, 52).

Historic Scotland did not include the ranking of sites in its brief drawn up for the Scottish Coastal Assessment Surveys for several reasons. These included the problems of recognition and categorisation of sites, of comparing totally different site types, and the need to view sites in their landscape context rather than as individual, isolated points on a map. There were also considered to be the 'philosophical and pragmatic problems' that the sites' 'interest and importance depend on what happens to be visible at the time of inspection, on the survival of related archaeological and palaeoenvironmental evidence in the area, and on modern (and possibly evanescent) research interests' (Ashmore 2003, 4).

Most surveys which have attempted to prioritise the coastal historic environment have assigned values to particular lengths of coast according to the potential significance of their archaeological resource in relation to the level of threat to that resource (for example Northumberland County Council 1994, Van de Noort and Davies 1993, Bell *et al* 2000, Davidson 2002, Wessex Archaeology 2004b), rather than to individual sites.

An European Commission LIFE project carried out by the Isle of Wight Council's Centre for the Coastal Environment and partners, entitled *Coastal change, climate and instability* (McInnes *et al* 2000) investigated the ranking of archaeological and palaeoenvironmental sites which could assist the study of coastal change in various European study areas, including the Solent. Sites were ranked on a scale of 1-3 according to whether they held evidence pertaining to sea-level change, environmental change, climatic change, and temporal continuity. Scores were also made according to cultural amenity value, visible amenity value and fragility.

An indication of the current status of the site was made (i.e. extant, destroyed, information needed, recovered), and the coastal policy, coastal context and coastal type was noted. It was concluded that this system successfully identified sites that could contain information pertinent to measuring the scale and pace of coastal change, although how this success was tested is not stated. It was also noted that it proved necessary to emphasise to fellow archaeologists that the scoring system was intended to 'assess the potential scientific value of a site to the study of coastal change. Most certainly, they should not be used as an indication of potential cultural importance' (McInnes *et al* 2000, 7.55.) However, if even fellow archaeologists needed to be reassured of this, the wisdom of presenting such statements of the relative importance of archaeological sites to those with less relevant knowledge seems questionable.

This system of scoring archaeological and palaeoenvironmental sites for their contribution to an understanding of coastal change has been developed further in a project undertaken by the Hampshire and Wight Trust for Maritime Archaeology on behalf of SCOPAC. This study emphasised that the purpose of scoring was not to assess the importance or the archaeological or cultural value of a site, but to 'lay a relative value on the potential of each site to provide scientific information that may be beneficial to practical decision-making in the long-term management and protection of the coastline (Hampshire and Wight Trust for Maritime Archaeology 2006, 34).

A similar scoring system to that used for the LIFE project exercise was applied, with an additional score for those sites for which insufficient data were available. The scores for evidence of sea-level change, environmental change, climate change, and running chronology were thus 1 (not enough data available to score); 2 (low); 3 (medium) and 4 (high). Four levels of fragility were recorded: 0 (excavated or lost); 1 (not enough data available to score); 2 (stable); 3 (progressive erosion); 4 (imminent loss). Non-scoring criteria were applied to 'help provide a physical and managerial context' (ibid, 38). These were: site validation (extant remains, below-ground remains, below-ground sediments, destroyed, information needed, submerged remains, riverine feature, recovered); coastal policy (do nothing, hold the line, advance the line, managed realignment, retreat the line); coastal context (marine, intertidal, above high water, saltmarsh, cliffs, other); and coastal type (dune coast, hard coast, soft coast, submerging coast, accreting coast, estuarine coast, hard defended coast, eroding coast, riverine).

The exercise was applied within ten study units in the SCOPAC area including both rural and urban areas with a variety of physical characteristics. Four positive outcomes from the project were listed (ibid, 155). These included: the creation of a searchable database which could consider the archaeological and palaeoenvironmental resource against a number of coastal management issues; the ability to review a large dataset against a set of criteria; identification of individual sites of high potential; and identification of the types of sites that can provide information on coastal change. Negative outcomes were perceived to be the lack of detail in the information provided, including Ordnance Datum heights, coastland type and coastal management unit, and the fact that only a single line, summary description was requested from the HERs; the scoring needed to be undertaken by an experienced archaeologist; and sites were considered in isolation, without relating them to others nearby. It was observed that some sites may have received a low score but may have assumed more significance if their group value had been considered.

4.5.2 Monitoring

Most statements about the threat to the coastal archaeological resource are made from limited observations, possibly just a single visit to a site. There is a need for data covering a much longer timescale and most surveys recommend a programme of monitoring. Sites need to be visited repeatedly, in different conditions at various times of the year and at varying states of the tide.

4.6 Quantifying heritage loss in the coastal zone

Few studies have attempted to quantify the loss of the coastal heritage resource. The reason for this is largely because the recording of coastal archaeology is really in its infancy and resources have been concentrated on making a preliminary record of sites.

In the area of the Gwent Levels in the Severn Estuary, observations had been made regarding erosion rates and vulnerability of archaeological and palaeoenvironmental features but there was a lack of quantitative data. Limited interrogation of historic maps and aerial photographs allowed some average rates of recession to be calculated but it was felt that 'more detailed and qualitative as well as quantitative assessments of erosion can only be achieved with the help of an accurate base map which does not exist for many intertidal areas' (Neumann 2000, 319).

Chapman *et al* (2001) attempted to quantify rates of erosion and heritage loss in two areas of the intertidal zone of the Humber Estuary which were archaeologically rich, North Ferriby and Melton. They used vertical aerial photographs, published surveys and recent DGPS measurements, to plot the lateral erosion of the intertidal peat shelf over a period of 53 years. The reason for their study was that although intertidal environments containing well preserved organic deposit had become well known as being valuable sources of archaeological and palaeoenvironmental material, at the same time the management of such sites was problematic. Sites were located in a dynamic environment with inherent problems of accessibility, the unpredictable nature of the processes acting on intertidal archaeological sites, and the fact that the erosion that revealed the sites was also destroying them. However, there was little information about the scale and rate of erosion, and those figures that were available were usually broad-brushed estimates applicable to larger units of coastline. Threats to the coastal archaeological resource had been highlighted but its management had not been addressed.

Chapman *et al* argued that the only way to manage archaeologically rich but vulnerable coastal landscapes was by regular monitoring, and that a method of quantification of coastal erosion on a scale that was relevant to archaeological features was needed. Whilst shortcomings in the methodology that they used were identified, such as the problems of variable accuracy and resolution of the data used and the large interval of time between the individual periods of monitoring, the process was able to quantify rates of erosion and their variability over short distances. This would appear to be an effective method of monitoring and quantifying erosion at the coast, providing data are available for a relevant timescale, and the erosion edge that is being measured is unambiguous. The technique is also only of use for measuring lateral erosion.

The Essex coast monitoring survey (see Chapter 3) successfully used DGPS, vertical aerial photographs and modern and historic mapping to assess erosion and patterns of change in the coastal zone, but found the quantification of vertical erosion to be more problematic (Heppell 2004). Sites in the intertidal zone were often inaccessible and inhospitable, making it impractical to transport survey equipment, transfer bench marks or even to set up site datums in a suitable place. This is a problem that we have also encountered on the Wootton-Quarr coast, where we had considerable problems establishing survey stations. The accuracy and longevity of stations in the intertidal zone could not be relied on and the rapidity of coastal recession in many places meant that even on the coast edge above the high water mark, survey points rarely lasted more than one season. The increasing availability of survey grade GPS should help to rectify this problem.

The Isle of Wight Beach Monitoring project was a five-year programme similar to that carried out in Essex. It aimed to revisit the Wootton-Quarr coast monitoring changes to previously recorded sites, to carry out limited enhanced recording of those sites, and to record newly exposed sites (Loader 2008). The survey included a two-yearly theodolite survey of the beach adjacent to the ferry terminal at Fishbourne, together with general walk-over surveys, sampling and additional recording. The survey was only moderately successful; possibly because it tried to juggle both monitoring and more detailed recording, and also because inadequate provision was made for the dating and analysis of archaeological sites that needs to accompany such a project.

The work was carried out by a team of two, which worked well for general survey but was inadequate for more detailed recording, particularly when combined with the logistical problems of transporting equipment and trying to get tasks completed within a single low tide period. Also, with limited funding the beach was only visited once or twice a month which meant that a considerable amount of the time available was spent on re-familiarisation and actually re-locating sites. An additional disadvantage of infrequent visits was that work was timetabled for what appeared to be the lowest tides, whereas in reality the tides are not so predictable and can be affected by weather conditions such as wind direction and atmospheric pressure. There were many occasions when the tide stayed up and sites did not uncover, and conversely there must have been numerous times when the tide was lower than predicted but we were not on site to exploit it.

4.7 Conclusion

It is undeniable that the archaeology of the coastal zone is important, poorly understood, and under threat. Whilst monitoring can give an indication of the 'destruction timetable' of individual sites and areas (Tomalin forthcoming), it is almost giving a best-outcome-scenario and cannot account for the unpredictable, catastrophic events which can completely destroy sites which were apparently not threatened. There need to be mechanisms in place to deal with the sites that are most vulnerable. In some ways, monitoring is almost a delaying tactic, a much cheaper option than detailed recording and analysis. I have heard it said at a recent seminar that intertidal archaeology is the ultimate rescue archaeology, and is a matter of recording and recovering material, then thinking about its significance later. Whether carried out by volunteers or professional archaeologists, monitoring of coastal archaeological sites needs to be supported by the means to deal with archaeological material to an appropriate standard.

5 The local background

5.1 The Isle of Wight

5.1.1 Location

The Isle of Wight, a diamond-shaped island of approximately 38,000 hectares, is located off the south coast of England. It is separated from the mainland by the Solent, a narrow stretch of water at maximum 6km wide (Fig. 5.1).

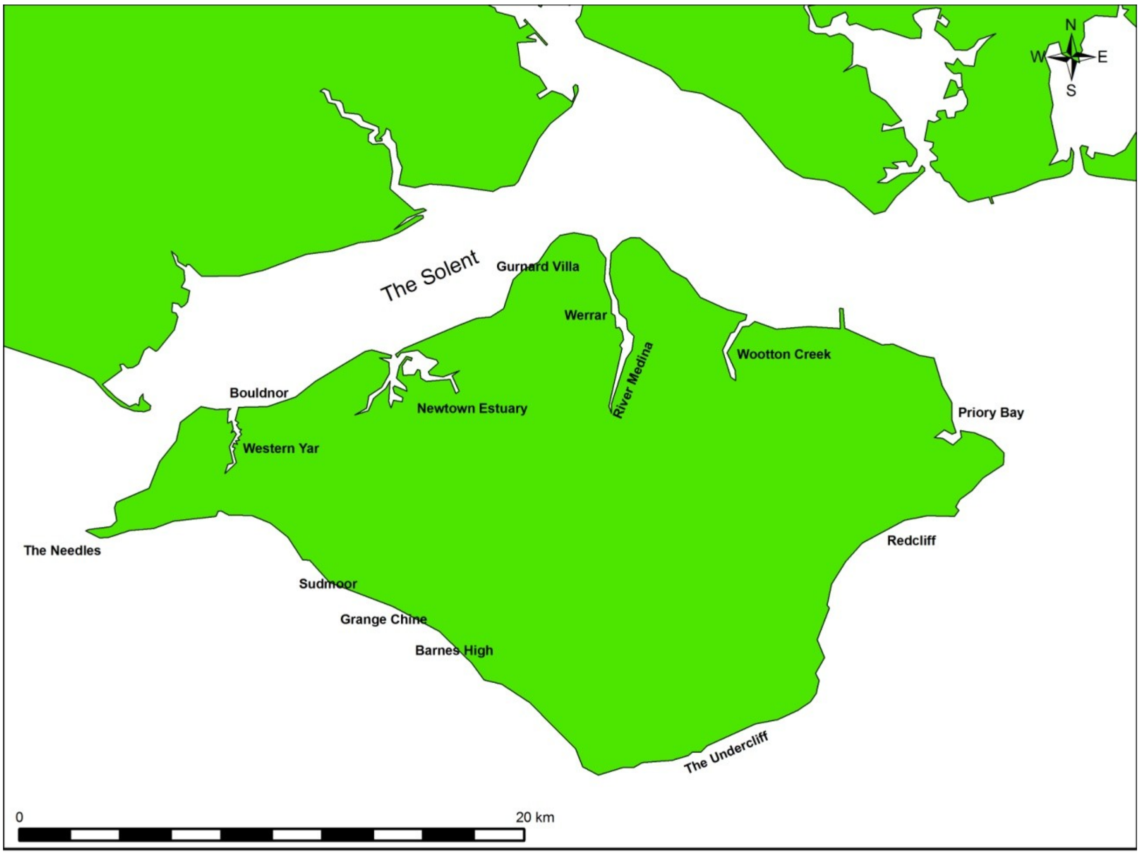

Figure 5.1 Locations mentioned in Chapter 5

Geologically and topographically complex for a small area, it has been described as a microcosm of southern England (e.g. Frazer 1990, 8 and 12), or 'all of lowland England in miniature' (Isle of Wight AONB Partnership 2004, 7). For this reason it can be regarded as an ideal study area, and from an archaeological perspective, the fact that it is an island, cut off albeit by a very narrow stretch of water from the mainland, makes it 'a distinct archaeological entity and provides an easily defined area which might allow specific archaeological problems to be answered' (Basford 1980, 8). It is particular suited to a study of the archaeology of the coast, firstly as a result of its varied coastal geomorphology; secondly because of the variety of ongoing coastal processes; and thirdly because of its wide-ranging and well-documented archaeology.

More than 90% of the island's coast is designated under European environmental legislation (Isle of Wight Centre for the Coastal Environment, 2009) (Table 5.1 and Fig. 5.2).

Table 5.1 Isle of Wight coast environmental designations

Designation	Approx. length of coastline (km)
SSSI	60
SAC	76
SPA	26
Ramsar	26
AONB	60
Heritage Coast	45

5.1.2 Geology

The Isle of Wight forms part of the Wessex-Channel Basin (Insole *et al* 1998). The geology of the island is composed of a succession of Cretaceous to early Oligocene formations with some remnant Pleistocene deposits. Two asymmetrical anticlines, the Brighstone Anticline and the Sandown Anticline, collectively known as the Isle of Wight Monocline, bring the oldest rocks to the surface.

In the southern part of the island an almost unbroken sequence of ten formations, from the Wealden Group to the Upper Chalk, is present. The oldest, the Wealden Group, is made up of two units; the Wessex Formation, comprising non-marine mudstones and sandstones, and the Vectis Formation, composed of siltstones and mudstones. The Wealden Group outcrops in a small area around Sandown in the south east and there is a more extensive outcrop on the south-west coast of the island. However, most of the southern part of the island is composed of Lower Greensand. Within this four formations are present, comprising Atherfield Clay, Ferruginous Sands, Sandrock, and Carstone.

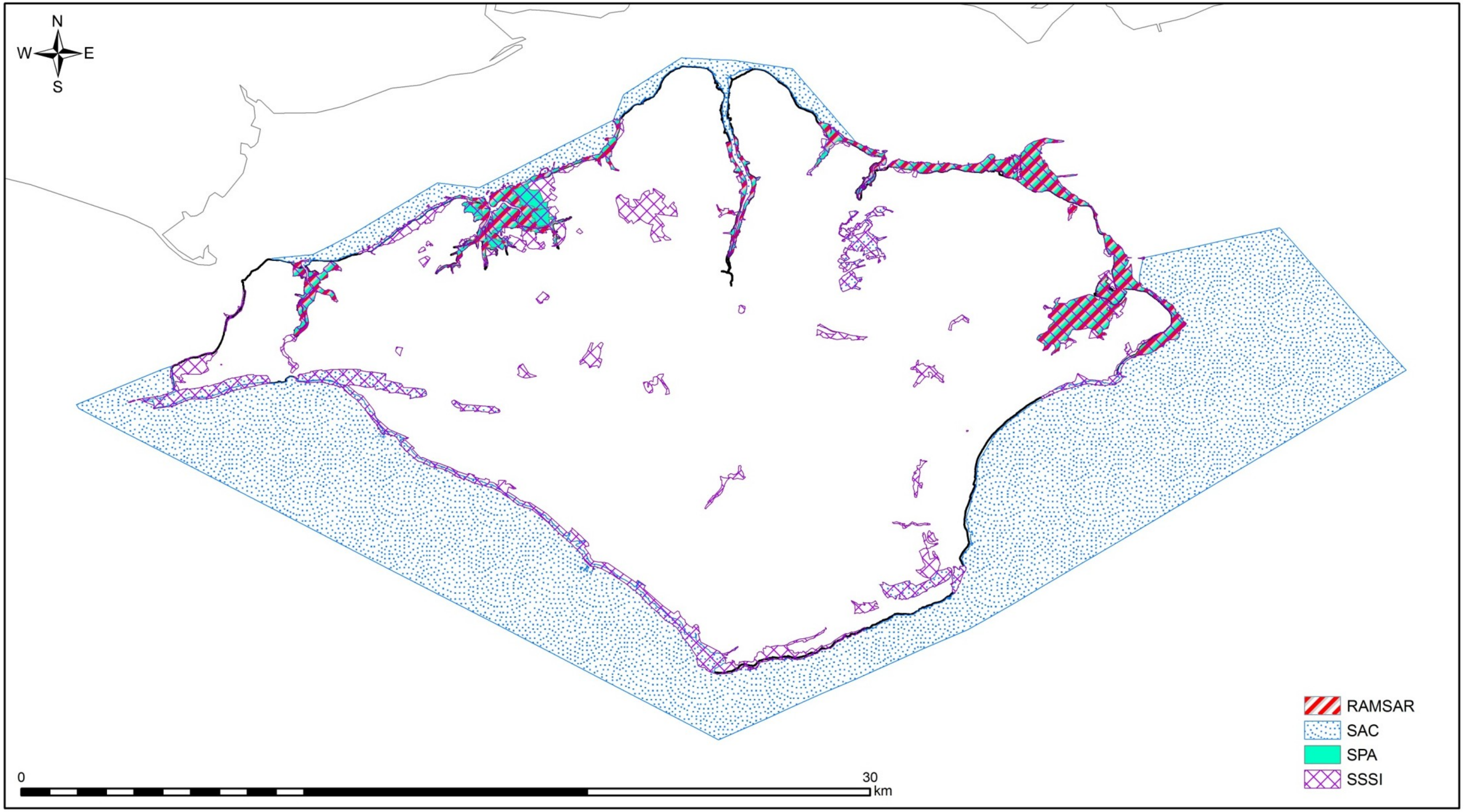

Figure 5.2 Isle of Wight environmental designations (©Natural England copyright 2011)

The Gault Clay is formed from a sequence of dark blue-grey silty muds. These sediments are responsible for much of the land movement which takes place, particularly on the south coast of the island. Above this, the Upper Greensand is composed of glauconitic siltstone or fine grained sand and sandstone with bands of calcareous and siliceous concretions.

The most distinctive feature of the Isle of Wight's geology is the central, west-east running central chalk spine, which separates the Cretaceous rocks of the south of the island from the younger, Tertiary deposits to the north (figs. 5.3 and 5.4).

The Chalk Group is a very thick sequence of grey-white limestones which are formed from the skeletal remains of minute planktonic algae (Coccolithophoraceae). The chalk includes bands of nodular and tabular flint, concretions grown within sediment after its deposition from silica derived from sponge spicules, diatoms and radiolarians. On the Isle of Wight the Chalk Group is divided into two formations; the Lower Chalk and the White Chalk.

The Lower Chalk has a higher clay content than the White Chalk. It is grey in appearance with rhythmic bedding. It is made up of four members – Glauconitic Marl, chalk Marl, Grey Chalk and Plenus Marls.

The White Chalk contains much less clay than the Lower Chalk and consists of white pure limestones with thin marl seams. It includes seven Members, the Ranscombe Member, St. Margaret's Member, Broadstairs Member, Newhaven Member, Culver Member, Portsdown Member, and the highest, which is only present at the western end of the island, the Studland Member. These are subdivided by the presence/absence of marls, the occurrence of nodular chalk, and bedding style.

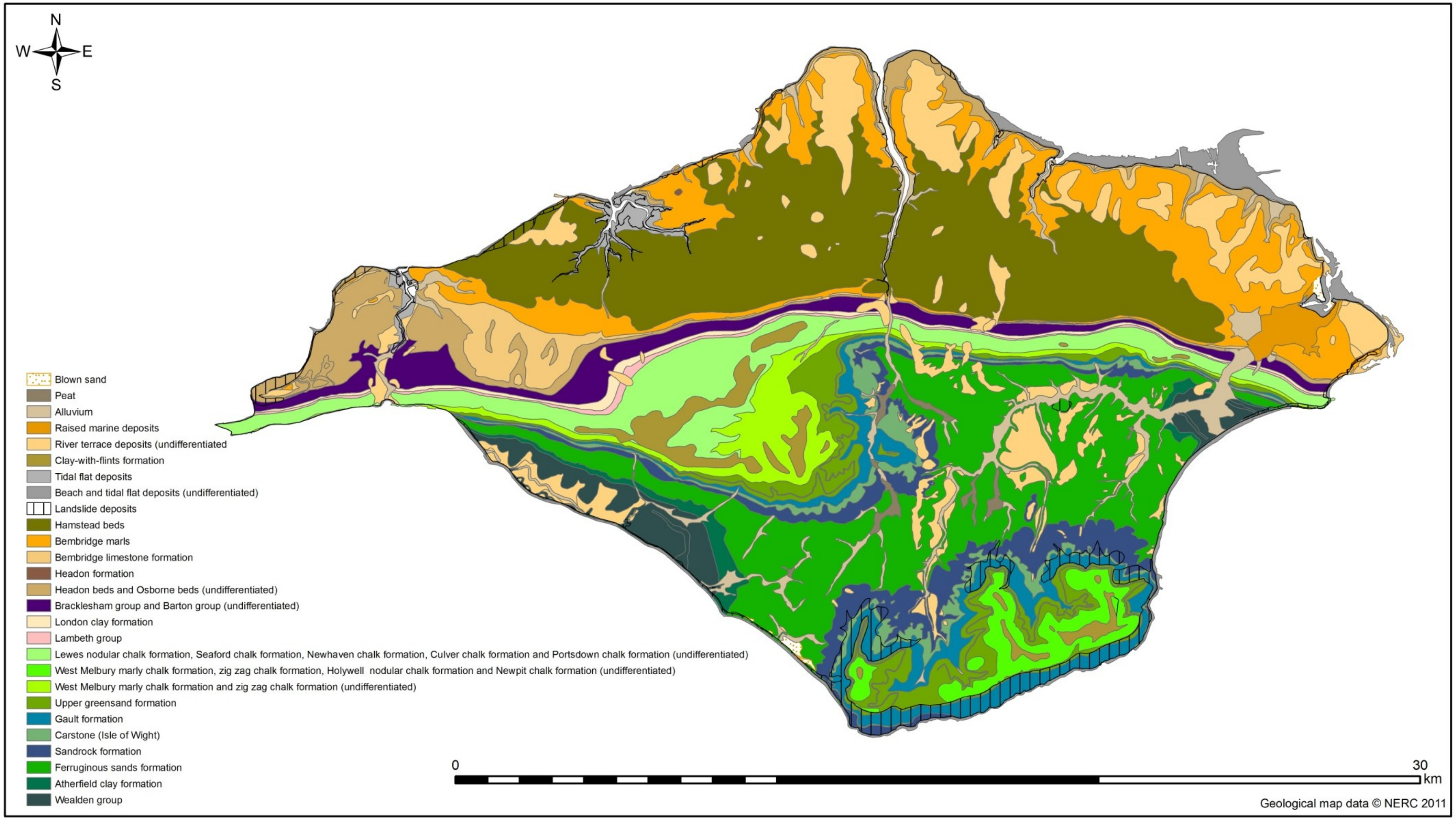

Figure 5.3 The geology of the Isle of Wight

Figure 5.4 Oblique aerial photo looking north eastwards from the Needles (© IWC)

To the north of the chalk ridge is a *c* 650m thickness of Palaeogene sediments dominated by muds which were laid down during alternate marine transgressions and regressions. They are vertical or dip sharply northwards immediately north of the chalk outcrop, whilst further to the north the strata are flat. The succession from late Palaeocene to earliest Oligocene comprises fourteen formations: Reading Formation, London Clay, Bracklesham Group (Wittering, Earnley Sand, Poole, Marsh Farm, Selsey Sand, Branksome Sand), Barton Group (Boscombe Sand, Barton Clay, Chama Sand, Becton Sand), Solent Group (Headon Hill Formation and Bouldnor Formation, separated by Bembridge Limestone).

The deposition of the Bouldnor Formation was followed by a long period of uplift and erosion. Folding on the Isle of Wight Monocline probably started in the Eocene and culminated in Miocene. This was followed by a period of erosion which created the landscape as seen today. This latest stage is poorly understood, and few of the resultant superficial deposits have been dated.

The Late Pliocene and Pleistocene saw a period of extreme climatic changes. During the cold stages, when sea level was low, the Solent River and its tributaries were as much as 46m below current sea level. The last glacial period, the Devensian, created periglacial conditions which encouraged the development of Head (produced by the downslope movement of weathered bedrock and drift by a mixture of solifluction and downwash) and Brickearth (primary or reworked loess).

During the interglacial periods, sea level was as high as or higher than present. Several different types of deposit formed locally. These include the Steyne Wood Clay (Holyoak and Preece 1983; Preece *et al* 1990), the Newtown Complex of intertidal mudflats (Munt and Burke 1986), and the Bembridge Raised Beach, an Ipswichian barrier beach (Preece *et al* 1990, Wenban-Smith *et al* 2005). Less well understood are the Older River Gravels, formerly known as Plateau Gravels, and River Terrace Deposits which were laid down as valley fills. There is little agreement whether these are marine or fluvial deposits.

The final breach of the chalk ridge between the Isle of Wight and the Dorset coast took place, it is believed, in the late stages of the Pleistocene or in the early Holocene (see section 5.3.1 below), leading to the formation of the island as we know it today.

5.2 Local coastal geomorphology

The Isle of Wight has a complex and varied coastal geomorphology but is lacking hard rock which makes it vulnerable to coastal erosion throughout (McInnes *et al* 1998). Certain areas, in particular the Undercliff, are key sites internationally for understanding coastal landforms and processes, and as such are relatively well researched (see for example Hutchinson 1987 and 1991, Hutchinson *et al* 1991, Bromhead *et al* 1991).

The first Isle of Wight SMP defined six Coastal Process Units, each representing a stretch of coast which was independent of its neighbours with regard to geology, geomorphology, and natural processes such as wind, waves and tidal currents (Halcrow & partners 1997 vol 2, 2.2). The six Process Units were (Fig. 5.5):

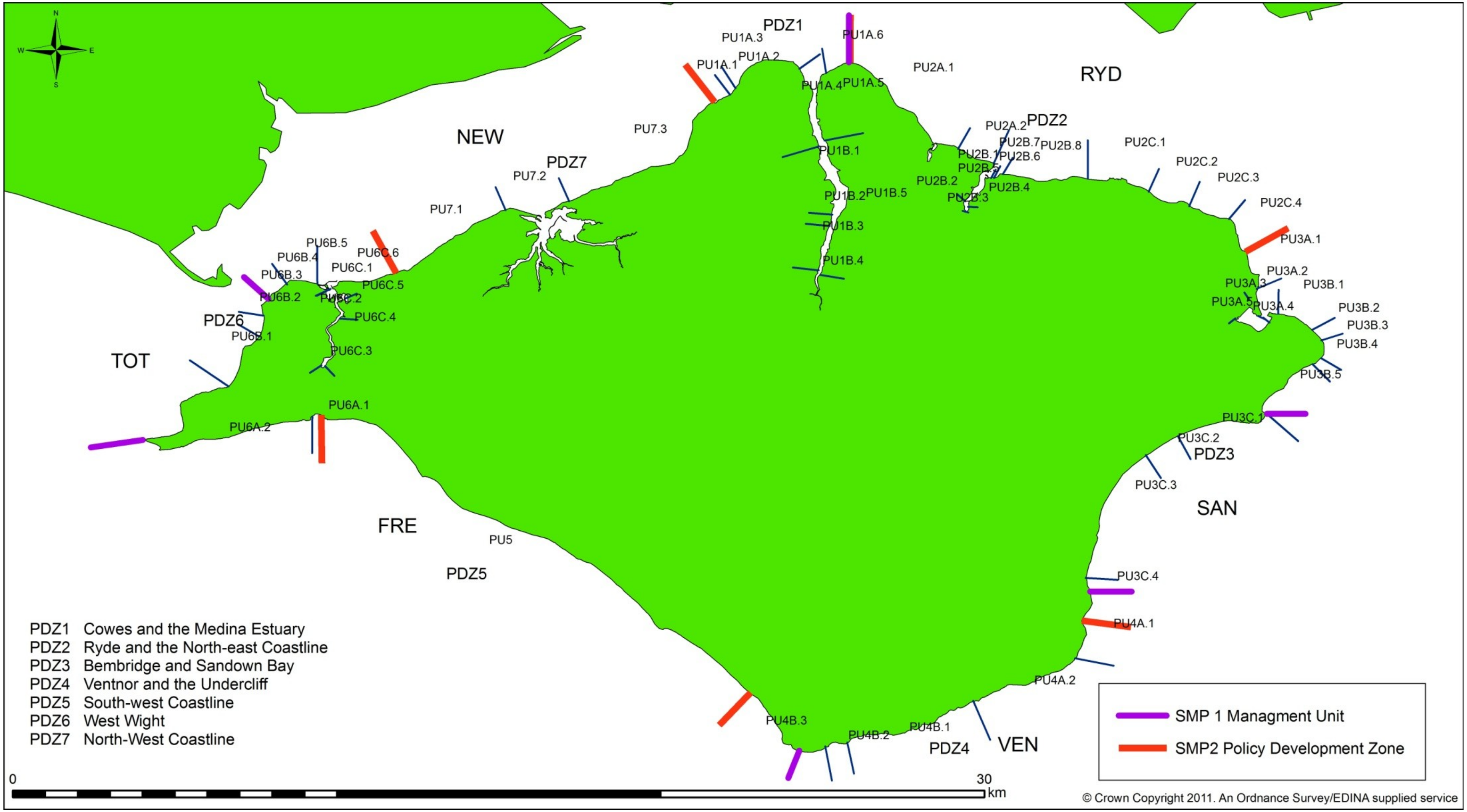

Figure 5.5 Isle of Wight SMP1 Management Units and SMP2 Policy Development Zones and Process Units (from Halcrow & Partners 1997 and Isle of Wight Council et al *2010)*

SAN - South east coast, from Culver Cliff to Dunnose/Horse Ledge (Sandown Bay).

VEN – South east coast, from Dunnose/Horse Ledge to St. Catherine's Point (Undercliff).

FRE – South west coast, from St. Catherine's Point to The Needles.

TOT – North west coast, from The Needles to Cliff End and Fort Albert.

NEW – North west coast, from Cliff End and Fort Albert to Old Castle Point, East Cowes.

The SMP revision divided the Island's coast into seven Policy Development Zones (PDZ), which it defined as 'a length of coastline with a particular character defined in the SMP for the purpose of assessing all issues and interactions to develop management scenarios'. For the final definition of policies these zones were then further divided into Policy Units and Management Areas (Isle of Wight Council *et al* 2010, xii).

Although their boundaries differ, the seven Policy Development Zones largely correspond with the original Process Units, with the addition of a unit covering the Medina Estuary. They are (Fig. 5.5):

PDZ1 Cowes and the Medina Estuary

PDZ2 Ryde and the north east coastline

PDZ3 Bembridge and Sandown Bay

PDZ4 Ventnor and the Undercliff

PDZ5 South-west coastline

PDZ6 West Wight

PDZ7 North-west coastline

PDZ1 Cowes and the Medina Estuary

Stretching from Gurnard in the west to Old Castle Point, this PDZ includes the towns of Cowes and East Cowes together with the Medina Estuary, with Newport at its navigable head (Fig. 5.6).

Figure 5.6 The River Medina looking northwards towards the Solent (© IWC)

PDZ2 Ryde and the north east coastline

This unit is delimited by Old Castle Point at the mouth of the Medina Estuary in the west and Horestone Point in the east. It is a low energy coast with both estuarine and marine influences. Much of the coastline comprises low, gently sloping cliffs. The coastal geology on the north east coast is composed predominantly of Oligocene clays and silts, capped locally by Pleistocene gravels. Interbedded Bembridge limestone outcrops in places and forms intertidal ledges which offer some protection from marine erosion but they also act as minor groundwater reservoirs which can exacerbate the erosion of the less resistant clays. As a result much of the coastal slope is actively eroding (Fig.5.7). Both basal marine erosion and mass movement are present. The coastline is especially vulnerable during conditions of marine erosion. It is thought that the effects of future climate change are likely to accelerate toe erosion and reactivate landsliding.

Figure 5.7 Typical view of the undeveloped coast of PDZ2 (Ryde and the north east coastline) at Quarr

The north east coastline forms the southern margin of the former Solent River system which was inundated by rising sea levels in the mid- to late Holocene (see below), but only small remnants of the once extensive Pleistocene river gravel terraces remain. Compared with their mainland counterparts, these deposits are poorly understood.

Tidal currents in the eastern Solent are less rapid than in the west and so clays, silts and fine sands are the predominant mobile sediments. It appears from mineralogical analysis that sediments may be transported into the eastern Solent from the south eastern coast of the Island (SCOPAC 2003a). Some of this sediment is deposited on Ryde Sands (Fig. 5.8).

Figure 5.8 The town of Ryde viewed at low tide from Ryde East Sands

Eastwards of Ryde Sands the coast is open to waves generated in Hayling Bay and from the English Channel, generating moderate wave action from a predominantly east or south-east direction. The extensive sand flats that have accumulated at Ryde give some shelter to the foreshore to their west, and here the prevailing waves are generated in Southampton Water and the eastern Solent. The coast is subject to low energy wave action, mainly from the north west. Tidal currents do not greatly affect the coastline except at the entrance to Wootton Creek. Here, rapid currents generated by the flow of water through the narrow entrance interrupt littoral sediment transport and cause local circulation effects and associated changes in coastal configuration. Along much of the north east coast foreshore steepening is evident, often accompanied by recession of MHW.

The SMP revision predicts potential erosion over the next 100 years of up to 111m within this zone if undefended.

PDZ3 Bembridge and Sandown Bay

PDZ3 extends from Horestone Point to Luccombe and includes the floodplain of the Eastern Yar, which meets the coast in this zone, at Bembridge Harbour and Yaverland.

At Horestone Point and Priory Bay, the coastline comprises wooded cliffs up to *c* 40m high and subject to periodic slumping. The mouth of the Eastern Yar Estuary at Bembridge is protected by sand spits. Bembridge Foreland is the most easterly extent of the Island. Moving southwards, Culver Cliff forms a more resistant chalk headland. Sandown Bay developed as a result of the marine erosion of the Wealden and Lower Cretaceous clays and sands, whilst the more resistant chalk of Culver Cliff and the boulder aprons of the Undercliff landslides developed as headlands as erosion progressively enlarged the bay.

Despite being geologically similar to the south west coast, Sandown Bay is relatively sheltered from waves generated by the prevailing south westerly winds, although large waves can occur associated with easterly gales within the English Channel. The frontage comprises cliffs of up to 100m height falling to below sea level at Yaverland where the Eastern Yar River has been truncated by coastal recession. In the past shoreline recession released large quantities of predominantly sandy sediment, which created and replenished the beaches within the bay and was also transported elsewhere. However, as the seaside resorts of Sandown and Shanklin developed from the Victorian period onwards, coastal defence structures including sea walls and promenades, timber and concrete groynes, were constructed (Fig. 5.9). These have altered the pattern of sediment transport, with cliffs no longer contributing sediment to the beach. It has been estimated that the sediment shortfall from this source is 18,000 – 36,000 m^3a^{-1} (Halcrow 1997).

Figure 5.9 Sandown Bay looking towards Yaverland, Redcliff and Culver Cliff

The construction of groynes has resulted in accretion of the upper foreshore whilst sediment has been lost from the lower foreshore and the intertidal zone has steepened. However, the exposure in 2008 of timber groynes which were shown on mid-nineteenth century Ordnance Survey maps but which had not been visible in living memory suggests that, in places, beach levels are also falling in the upper foreshore (Fig. 5.10). While the Sandown-Shanklin frontage is now completely protected, a zone of narrowing beaches and intertidal steepening has migrated eastwards and accelerating cliff retreat is recorded beyond the defences at Yaverland and Redcliff.

The predicted ‘without defences’ shoreline indicates a retreat of up to 156m over the next 100 years in Whitecliff Bay, whilst potential slope reactivation of 130m is predicted in Priory Bay. Erosion of the Yaverland frontage puts an extensive area of the Eastern Yar Valley at risk from flooding.

Figure 5.10 Falling beach levels at Yaverland, August 2008 which revealed timber groynes shown on mid-nineteenth century Ordnance Survey mapping but which had not been seen in living memory

PDZ4 Ventnor and the Undercliff

This PDZ comprises the Undercliff, formed by massive ancient landslides and subject to continuing renewed instability. Luccombe Chine and Chale Terrace form the boundaries of this unit.

Formed within the lower Cretaceous and Chalk outlier of the Island's south downs, the Undercliff is the result of the operation of marine erosion on a gently south eastward dipping interbedded sequence of clays and weak sandstones capped by Upper Greensand and Chalk (Fig. 5.11). Deep-seated rotational failures within the lower parts of the Gault have produced large blocks of Upper Greensand and Chalk which progress downslope to produce the steep rear scarp. A mid slope scarp is frequently formed in the Gault Clay and a second degradation zone of compound slides occurs as detached units more further downslope and new failures occur. Marine erosion cuts into the toe of this zone.

Figure 5.11 The Undercliff with Ventnor in the distance

The landslides form a zone approximately 500 to 750m wide, fronted by sea cliffs between 10 and 80m high. They are prone to instability, particular where coastal erosion at their foot has occurred. Historically, the most active zones are at the extreme eastern and western ends of the Undercliff at Luccombe and the Landslip, and Blackgang.

Beaches in the Undercliff are generally formed of landslide material. The stability of the coast is dependent on the protection given by the debris aprons against marine erosion. Retreat of MHW in the twentieth century has caused foreshore steepening which ultimately leads to cliff failures. Foreshore steepening together with accelerated cliff erosion and steepening of the coastal slope indicates that the unit is subject to an aggressive phase of toe erosion that could threaten the stability of large areas of the Undercliff.

The 'without defences' model suggests recession of the cliff top of between 27 and 91m in the next 100 years, but also with the risk of significant landslide reactivation due to coastal erosion and groundwater conditions.

PDZ5 South-west coastline

The South-west coastline PDZ is defined as a high energy, geologically controlled eroding cliff coast with a sequence of both exposed and pocket beaches. It extends from Chale Terrace in the south east to Freshwater Bay in the north west (Fig. 5.12).

A sequence of Cretaceous strata, from the Upper, or White Chalk to the Vectis and Wessex formations of the Wealden Group, is exposed in this unit, comprising a wide variety of lithologies of variable consolidation and permeability. The unit has narrow beaches of shingle in the south, and sand and shingle in the north but these are not stable and do not provide significant protection to the cliff toe.

Figure 5.12 The south west coast looking north west from Blackgang towards the Needles

The presence of deeply-incised coastal valleys known locally as ‘chines’ (Flint 1982; Leyland and Darby 2008) is a feature of the south west coast. These may represent the remnants of tributaries of a proto-Western Yar river system since destroyed by rapid coastal erosion, and were created by streams with enough energy to cut down through the soft cliffs as opposed to flowing over the cliff as a waterfall.

The coast is exposed to the high to moderate energy of Atlantic swell waves, with a maximum fetch in excess of 5000km. Relatively minor promontories provide a degree of subdivision but there are no major headlands.

Historic trends indicate a retreating coast, although rates vary both spatially and temporally. The foreshore is steepening, and the profiles of many of the cliffs too appear to have steepened, indicating a possible future acceleration of cliff top recession.

Predicted ‘without defences’ evolution of the coast indicates continuing erosion of up to 120m over the next 100 years.

PDZ6 West Wight

The West Wight PDZ6 runs from Freshwater Bay to Bouldnor, and includes the Yar Estuary at Freshwater Bay and Yarmouth.

This north-west facing coast has been formed by erosion following the breaching of the former Needles-Purbeck ridge (see section 5.3.1 below). It is bounded by the resistant chalk of Tennyson and High Down to the west, with the rest of the coast comprising poorly consolidated Tertiary sands, silts and clays. Headlands occur where limestones outcrop to form ledges on the foreshore and these have been accentuated by the construction of forts and associated coast protection structures from the mid-nineteenth century onwards (Fig.5.13).

The coast is open to waves generated within Christchurch Bay and the English Channel, with refracted waves from the north east Atlantic. The nearshore zone is affected by strong currents generated within the Hurst Narrows, although their impact on beach stability is not known.

Figure 5.13 PDZ6 (West Wight) viewed from Headon Warren towards Fort Albert

The profile at Headon Hill has been significantly flattened by rapid cliff top retreat which has helped create a boulder apron which offers some protection to the cliff toe, but cliff profile trends are smaller elsewhere in the process unit. In Totland Bay and at Warden Point, continued maintenance of coastal defences is required in order to prevent reactivation of instability within the cliffs. The coast is exposed to rapid tidal currents and open sea waves between Fort Albert and Fort Victoria.

Predicted ‘without defences’ coastal evolution indicates continued erosion, with the retreat rate increasing northwards to Fort Albert. SMP2 suggests a potential erosion rate of 48m over the next 100 years at Alum Bay and Headon Hill (Fig. 5.14), increasing to the north to *c* 80m at Totland, Colwell and Fort Albert, whilst the low-lying historic town of Yarmouth is under threat from flooding.

Figure 5.14 Alum Bay and Hatherwood Point

PDZ7 North-west coasline

PDZ7 stretches from Bouldnor in the west to Gurnard in the east and takes in the Newtown estuary and the inlet of Thorness Bay. This is defined as an estuarine coast backed by high eroding cliffs. The unit has an undulating coastal topography with major landslide systems developed on the higher points. The Newtown Estuary is a former tributary of the Solent River which was drowned during the Holocene Transgression (Fig.5.15).

Although the coast is relatively sheltered, tidal currents are quite complex and vary spatially, with some locations subject to strong flow and others to weak flow and it is likely that sediment exchange occurs between the mobile banks of the western Solent and the shore.

Figure 5.15 The Newtown Estuary looking south east from Hamstead

As a result of tidal asymmetry, ebb currents are of greater velocity and lesser duration than the corresponding flood currents, causing net seaward flushing of coarse bedload currents and net input of suspended sediments into inlets and estuaries. Tidal inlets thus form important transport boundaries that define process units. There is a trend for sedimentation within the creeks and saltmarshes, with by far the majority of sediment having a marine or estuarine origin.

Cliff profiles have tended to flatten as a result of cliff top retreat exceeding that of MHW, possibly reducing instability. However, rapid MLW recession has led to a narrowing and steepening of the lower foreshore which will probably result in increased erosion from the beach and cliff toes. This may make the possibility of cliff top failures more likely, and increase the erosion of landslide debris from the foot of more active cliffs. The waves and tidal currents within the western Solent remove eroded material and as a consequence, upper beach sediments are scarce.

The predicted ‘without defences’ evolution of this process unit shows a trend of cliff/slope erosion and flooding of low-lying land. Cliff retreat is predicted at between 130m at Bouldnor down to *c* 50-70m around Thorness Bay, Cowes and Gurnard.

5.3 The local archaeological and palaeoenvironmental background

5.3.1 The Solent River and the separation of the Isle of Wight

Early research regarding the island’s coast came from a largely geological perspective and was concerned to a high degree with speculation about when the Isle of Wight became an island. The history of this research has been reviewed in some detail by Tomalin (2000a and 2001), but is summarised here.

Much of the early discussion about the formation of the Isle of Wight arose from the speculations of William Camden, who, in *Britannia* first published in 1586, raised the question whether the Isle of Wight could be equated with the island of Ictis. According to the Sicilian historian Diodorus Siculus writing in the first century BC, Ictis was an island which was accessible by wagon at low tide and to which ingots of tin or tin ore were taken to be traded on to Gaulish merchants. Although there are far more likely contenders closer to the source of British tin, such as St Michael’s Mount or Mount Batten, this theory was still taken seriously in the late nineteenth and early twentieth century (Kell 1866, Reid 1905) and is even given some credence today by more imaginative local researchers.

More serious debate about the formation of the Isle of Wight and the Solent began in the nineteenth century. The similarity between the chalk outcrops of the Needles and those of Handfast Point on the Isle of Purbeck was noted by Thomas Webster, Charles Lyell and William Fox, who concluded that the two must have been linked at some time (Englefield 1816, Lyell 1830-1833, Fox 1862). Fox believed that a channel, the Solent River, had flowed eastwards behind this chalk ridge, providing a means by which the Frome, Stour, Piddle and Avon Rivers drained into the sea.

A further source of discussion was when had the Wight-Purbeck ridge been breached and whether it had been a gradual or a catastrophic event. There has been little agreement on this matter, and Velegrakis *et al* (1999) provide a summary of the various postulated time scales for this event. These range from the Late Pliocene (Reid 1902), through mid-Pleistocene (Reid 1915; White 1921; Green 1946), the Flandrian Transgression (Everard 1954; Keen 1975; Allen and Gibbard 1993; Bellamy 1995) to the Devensian (Wright 1982; Nicholls 1987).

Many of the early interpretations which suggested the presence of a major river channel crossing Poole and Christchurch Bay, entering the Western Solent and exiting via the Eastern Solent, were based on geological extrapolation, borehole and excavation data, and more recently the offshore extrapolation of thalweg gradients from terrestrial terraces (Dix 2001). However, in the past thirty years, seismic surveys have contributed greatly to the understanding of the general morphology of the Solent River. In the 1970s marine geophysical surveys carried out by Southampton University proved the existence of palaeochannels in the Eastern Solent and at the mouth of Southampton Water beneath Calshot Spit (Dyer 1975). The course of the palaeochannel was also traced to the south of the Isle of Wight, where it joined other palaeovalleys associated with the former course of the Seine (Larsonneur *et al* 1982, Hamblin and Harrison 1989).

Work by Velegrakis in the 1990s in Poole and Christchurch Bays identified seven palaeovalley complexes to the west of the Isle of Wight, three of which had breached the Wight-Purbeck ridge prior to the Holocene Transgression, although the nature and timing of these events remained inconclusive (Velegrakis *et al* 1999, 83). The same survey also showed that, unlike the Eastern Solent, there was no evidence here of an incised west-east flowing channel related to the Solent River. Two alternative explanations for this have been proposed; either that it represents a segmented drainage pattern with a dominantly southerly flow, or it is due to polycyclic erosion during transgressive and regressive phases which has removed evidence of previous sea-level lowstands (Velegrakis *et al* 1999; Dix 2001). Dix (ibid) indicates that the second option was favoured by Velegrakis, whilst Tomalin supported the first, suggesting that differences between deep sediment cores taken at Yarmouth and Newtown may indicate that the two became subject to marine conditions at different times (Tomalin 2000a, 2001). This, he suggested, may indicate that a land bridge had persisted between the mainland and the Isle of Wight somewhere in the area between Yarmouth and the Newtown Estuary, a similar theory to that expounded by Clement Reid at the beginning of the twentieth century (Reid 1905).

5.3.2 The archaeological background

One of the earliest references to the excavation of an archaeological site threatened by coastal erosion on the Isle of Wight was published in the *Journal of the British Archaeological Association* in 1865. At a meeting of the Association in March of that year, the Reverend Edmund Kell announced the discovery of a Roman building on the eroding cliff top at Gurnard on the north-west coast of the island (Fig. 5.16).

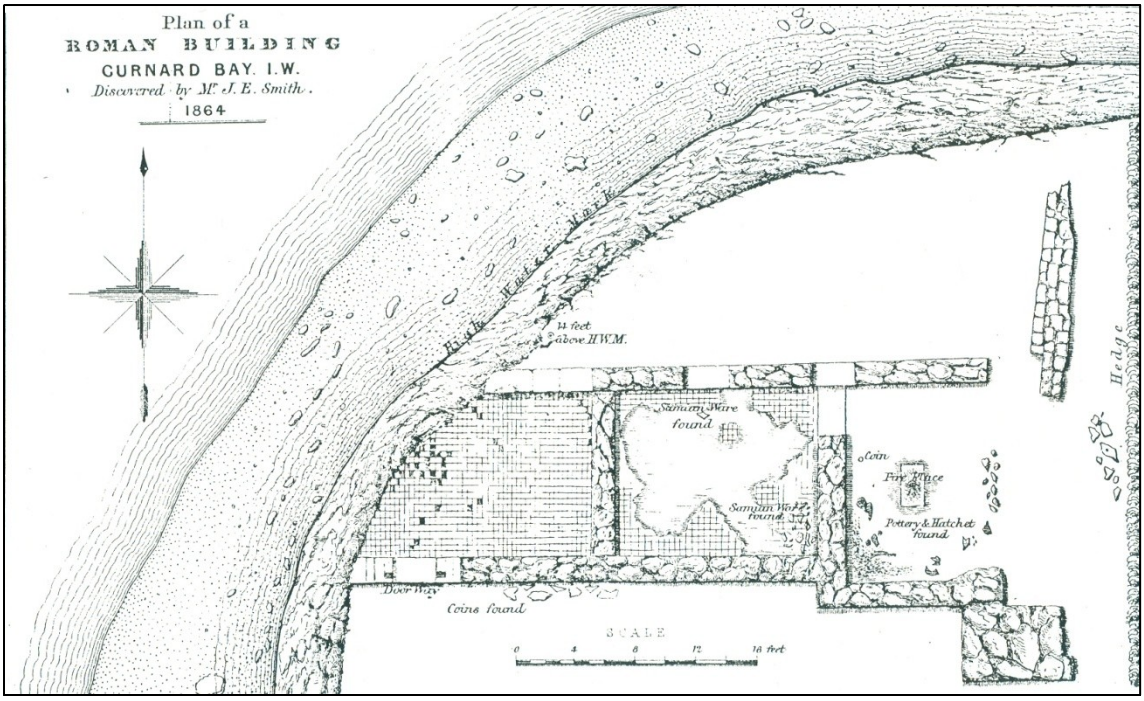

Figure 5.16 Plan of Gurnard Roman Villa (© IWCAHES)

The site was being excavated by Edwin Smith, a local fossil collector, but few details were known about his excavation until 1986, when the god-daughter of Smith's grand-daughter donated a manuscript to the Isle of Wight County Record Office (Motkin 1990). This was an account of his excavation which he had written in 1883. It described how he had uncovered a Roman building, 70 feet in length, with tessellated pavements, a hypocaust and bath. By the time Smith wrote his account, the site had been almost completely lost to coastal erosion.

During the late nineteenth and early twentieth century local antiquarians were active around most of the Isle of Wight's coast. The first Palaeolithic implements to be found on the island came from the beach at Bembridge and are possibly associated with the Bembridge raised beach deposits (Wymer 1999). At Priory Bay on the north east coast (Fig. 5.17), Professor E.B. Poulton collected Palaeolithic implements from the shore during the 1880s, and eventually traced them to exposures in the cliff face (Poulton 1909).

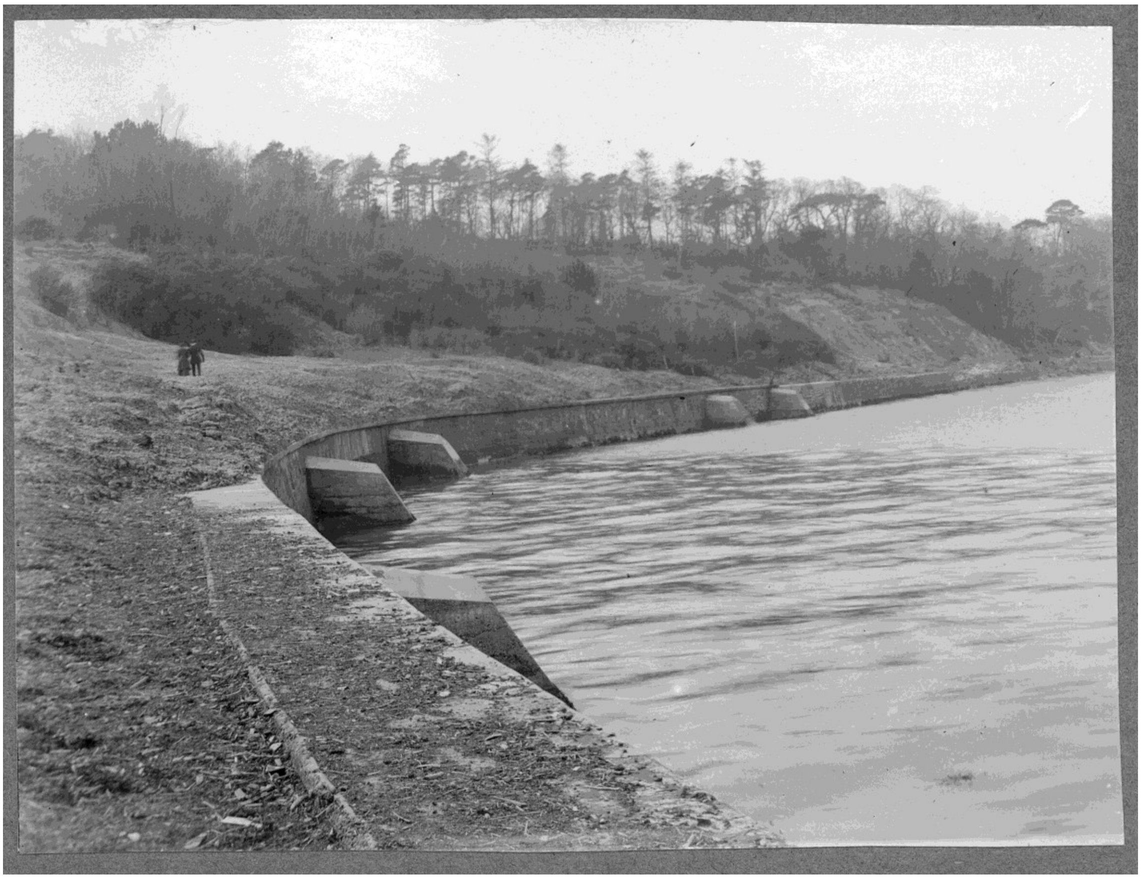

Figure 5.17 View of Priory Bay (c1920s) from the manuscripts of Hubert Poole

Priory Bay remains the most prolific Palaeolithic site on the island, with hundreds of worked flints having been recovered. Material displayed various degrees of abrasion, prompting some researchers to suggest that two assemblages were represented (Samson 1976). It was not until 1986 that serious attempts were made to record material *in situ* at the top of the cliff (Preece and Scourse 1987). At this time, a section approximately 1.75m wide was examined during a Nature Conservancy Council site clearance programme and an abraded bifacially flaked implement was recorded *in situ* in coarse gravel (Loader 2001).

In 2001, English Heritage funded further investigations at Priory Bay, including topographic survey, limited machine trenching inland of the cliff, and more extensive clearance of the cliff section (Wenban-Smith 2003). This latter excavation produced abraded artefacts within fluvial gravels overlain by colluvial/solifluction deposits containing both derived and very fresh material, some in mint condition. Uncertainty still remains whether the Priory Bay deposits are of marine or fluvial origin and how they relate to the nationally important Bembridge raised beach deposits some 3-4km to the south of Priory Bay (Preece *et al* 1990, Bridgeland 1999, Bates *et al* 2004).

The site was further examined as part of the Aggregates Levy Sustainability Fund-supported project *Palaeolithic Archaeology of the Sussex/Hampshire Coastal Corridor*, when samples for OSL dating were taken (Schwenninger *et al* 2006). These produced dates between *c* 365k BP (OSL-5; x-1564) and *c* 40k BP (OSL-1; x1560) (Wenban-Smith *et al* 2009). Further excavation was planned, but was postponed amid concerns about the effects of further section clearance on adjoining properties (Tony Tutton, National Trust Isle of Wight Property Manager pers. comm.). However, the excavations carried out to date have merely confirmed that the deposits at the top of the cliff are the source of the material found on the beach. There remain unanswered questions about the extent and correlation of the implement-bearing sediments and whether the mint-condition material comes from undisturbed palaeo-landscapes. The site is under threat from rotational slumping and marine erosion (Fig. 5.18).

Figure 5.18 Priory Bay as it appears today, with the remains of the sea wall seen in Poole's photograph

Fieldworkers such as H.F. Poole, G.W. Colenutt and H.E. Pritchett regularly examined the whole length of the north coast and its estuaries, and by the 1920s a significant number of lithic implements had been recovered from the intertidal zone. This prompted Hubert Poole, who was at one time the honorary curator of Carisbrooke Castle Museum, to comment on the distribution of Mesolithic flint picks concentrated between high and low water mark on the north coast: 'How far this may be due to organised search in this particular area is difficult to say, but it is an interesting speculation as to whether their distribution may point to the submergence of the old land surface on which the men who made the implements had their hunting grounds' (Poole 1929, 657).

Poole also recorded stratified deposits containing burnt and worked flint of Mesolithic and Neolithic date in the intertidal zone and eroding low cliff face at the mouth of the Newtown Estuary on the north west coast, and at Werrar on the west bank of the River Medina (Fig. 5.19).

Figure 5.19 The intertidal site at Werrar on the River Medina (H.F. Poole manuscript)

At Werrar, the excavation of clay in the intertidal zone for brickmaking revealed an occupation site where hearths were dug into an old ground surface which was sealed by estuarine silts. Worked flints including picks, microliths, burins, scrapers, knives, cores and waste flakes, were recovered from the same level (Poole 1936). Poole believed the assemblage to be purely Mesolithic, but it was not until 2007 that Poole's site was relocated and palynological samples were retrieved (Scaife unpublished). This confirmed Poole's interpretation of the site as a prehistoric land surface, overlain by organic sediments.

The south west coast of the island was also a focus for the attention of the early antiquarians, who recovered flint implements and recorded hearths from gravels and organic layers exposed in the cliff face (Fig. 5.20; Poole 1936). These could be related to the course of an ancient, truncated tributary of the Western Yar River, itself a former tributary of the Solent River (Clifford 1936; Scaife 1987). Many of the lithics were believed to be Upper Palaeolithic or Mesolithic in date, but there are few diagnostic pieces and a recent reassessment has found none to be unequivocally of that date (unpublished correspondence in Isle of Wight HER).

Figure 5.20 Photograph of the cliff section in Brook Bay from H.F. Poole's notebooks

In 1927, Gerald Dunning excavated a Bronze Age cremation cemetery at Barnes High, on the south west coast. Eleven urns set in a rough circle and containing cremations were recorded. Sherds from additional urns were recovered from material that had already fallen from the cliff face, indicating that the urnfield had probably extended southwards. The site was subsequently rapidly destroyed by coastal erosion (Dunning 1931). Cliff falls further to the west on the same stretch of coast also exposed the remains of a Late Iron Age/Early Roman occupation site comprising three huts and a stone-lined well at Sudmoor. Excavations were carried out in the 1930s (Dunning 1935, Sherwin 1939, Hookey 1951) and the site was reported as having been lost to coastal erosion by the 1950s (IWHER 11), although pottery sherds and other material can still be observed in the cliff face and adjacent field.

Throughout the late nineteenth and early twentieth centuries, material was also collected from midden deposits which were being revealed by cliff falls in the Undercliff area between St. Catherine's Point and Bonchurch. These contained material ranging in date from the Late Bronze Age to the medieval period (IWHER; Sherwin unpubl., Dunning 1935 and 1939, Poole and Dunning 1937, Poole 1940). Associated palaeoenvironmental deposits were later analysed and dated (Preece 1986, Hutchinson 1987). This work produced radiocarbon dates of 3350-3080 cal BC (SRR-1813; 4490±40BP) and 2580-2290 cal BC (SRR-1947; 3960±50BP) for two recumbent trees protruding from the apron of landslide debris at St. Catherine's Point, and a date of 3800-3000 cal BC, (BM-1737; 4700±140BP) for a sample of charcoal from an organic lens in the cliff face at Binnel. This same feature has produced sherds of Beaker pottery during more recent fieldwork (Loader and Basford 2000; Backhouse-Fry pers. comm.). The radiocarbon dates and associated artefacts provide an indication of the chronology of the processes which created the present topography of the Undercliff.

Figure 5.21 Erosion at Chapelcorner Copse (from Colenutt 1938). Photographs taken between September 1910 and January 1912

The impact of coastal erosion on the coastline of the Isle of Wight was noted by G.W. Colenutt in 1938 (Fig. 5.21). He discussed the erosive processes operating on different parts of the island's coast and suggested possible causes, stressing in particular the effects of the removal of shingle from the beaches (Colenutt 1938).

The 1970s saw the development of maritime archaeology in the Solent, but with attention focussed on the investigation of shipwrecks such as the Mary Rose (Rule 1983), and, off the Needles, the Campen (Larn 1985) and the Assurance and Pomone (Tomalin *et al* 2000). Limited excavation was carried out on cliff top sites threatened by coastal erosion, for example at a multi-period site comprising a Mesolithic to Bronze Age flint working and early Roman saltworking site at Redcliff, near Sandown (IWHER 1125, IWHER 1126; Tomalin 1990). At Grange Chine, on the south west coast (IWHER 1873), an eroding Roman occupation site was recorded, and attempts were made to calculate the rate of erosion on this stretch of coast since the Roman period (Basford 1980). A survey of the island's archaeology published in 1980 estimated that 25% of the known archaeological sites and finds were located on or near the coast, and it also recognised the considerable threat posed to the coastal archaeological resource from coastal erosion (Basford 1980). However, although a small number of fieldworkers continued to report material from the island's beaches, the potential of the coast, in particular the intertidal zone, was largely ignored until the late 1980s.

At this time, the Isle of Wight County Archaeological Service began to receive reports of Roman pottery and wooden posts which were being revealed by falling beach levels near to the Sealink (now Wightlink) car ferry terminal at Fishbourne, on the north east coast (Fig. 5.22). Prompted by these discoveries, and amidst mounting local concerns about erosion around the mouth of Wootton Creek which appeared to have accelerated following the introduction of larger car ferries, Sealink provided funding for an archaeological survey. This was followed by further funding from English Heritage, and the study area was extended.

The Wootton-Quarr survey was an intensive survey of approximately 6km of the Isle of Wight's north-east coastline between Wootton Creek and Ryde Pier, which preliminary survey had shown to be archaeologically and palaeoenvironmentally rich and which seemed to be threatened by natural and humanly induced erosion (Tomalin *et al* forthcoming). This survey was amongst the first to adopt the 'seamless' approach advocated by English Heritage (Roberts and Trow 2002), and although largely concentrated on the intertidal zone, it included studies of the maritime zone and a hinterland zone extending approximately 6.5km inland to the Island's median chalk ridge.

Figure 5.22 Fishbourne Beach at the mouth of Wootton Creek with the Wightlink ferry terminal in the centre (© IWCAHES)

The project involved a multi-disciplinary team who investigated both the archaeological and palaeoenvironmental aspects of the survey area. More than 150 individual sites and structures were recorded in the intertidal zone. These ranged from find spots of Palaeolithic handaxes to post medieval timber structures. Scatters of burnt and worked flint of late Mesolithic/early Neolithic character including numerous microliths and picks, and large amounts of debitage were located on the firm ground on the edges of palaeochannels. Trackways and platforms of Neolithic and Bronze Age date, constructed from hurdles, brushwood and split timbers, were recorded at extreme low water. Extensive peat and submerged forest deposits were surveyed and sampled, producing a preliminary sea-level curve for the Solent (Long and Scaife forthcoming) and a dendrochronological sequence of 3600 BC to 2557 BC (Hillam forthcoming).

Numerous post settings were recorded and dated but their function often remained unclear as no analogies could be found (Darrah and Loader forthcoming). Both longshore and cross-shore post alignments were recorded and radiocarbon dated to the Late Bronze Age, Iron Age, Roman, early medieval and medieval periods. The most extensive structure was a longshore alignment at current mean low water, stretching discontinuously for *c* 1.25km. This produced radiocarbon dates of *c* AD 600-800, but its function is open to question. Scatters of Roman and medieval pottery, with a large proportion of imported wares, were recorded at Fishbourne, Quarr and Binstead.

The survey was followed by a five year programme of less intensive monitoring of the Wootton-Quarr coast (Loader 2008). During this period, sites that had previously been recorded were monitored and newly revealed structures were recorded. This monitoring exercise established that in the upper half of the intertidal zone sand and gravel banks were mobile, with sites being covered and then revealed again, but in the lower part of the intertidal zone, stripping of sediment seemed to be more general, with as much as 30cm of silt being removed since sites were first surveyed (see below, Chapter 7.5.2).

At a similar time as the Wootton-Quarr survey, work began on the submerged site of Bouldnor Cliff, to the east of Yarmouth on the north west coast of the Island. This site had first been identified in 1976 after fishermen reported dredging up timbers, and preliminary recording was undertaken in the late 1980s by a team funded by the Manpower Services Commission (MSC). However, with limited funding, it was not until the late 1990s and 2000s that detailed survey and analytical work could be carried out. Bouldnor was selected as one of 23 palaeoenvironmental study areas in Great Britain, France and Ireland to be examined under the auspices of a European Union LIFE project coordinated by the Isle of Wight Council's Centre for the Coastal Environment. Entitled *Coastal change, climate and instability*, the project had three aims, the first of which was 'to demonstrate the value of using archaeological (palaeoenvironmental) evidence to predict the nature, scale and pace of coastal change' (McInnes *et al* 2000, i.6).

Work at Bouldnor Cliff comprised geophysical survey carried out by the University of Southampton's School of Ocean and Earth Science, diver survey by the Hampshire and Wight Trust for Maritime Archaeology, and environmental analysis of recovered samples (Scaife 2000). More than 7m of sediment were recorded, comprising three peat layers intercalated with silty clays (Momber 2000). At a depth of -11.5m OD a peat platform with recumbent trees and tree stumps extended from the base of the cliff. One of these timbers was radiocarbon dated during the Wootton-Quarr project to 6430-6120 cal BC (GU-5420; 7440±60 BP) (Long *et al* forthcoming).

Further survey work at Bouldnor has identified stratified worked and burnt flints of a very similar character to those recovered during fieldwork on Quarr Beach (Momber 2004; Tomalin 2011). Work was consequently focussed to locate more accurately the source of the flintwork and to record the site before it is lost to coastal erosion (Momber *et al* 2009). In addition, a programme of scientific dating produced a 285-year dendrochronological sequence which wiggle match radiocarbon dating placed at 6280-6240 cal BC to 6000-5960 cal BC at 95% probability (Momber *et al* 2011).

The Wootton-Quarr project was followed by a rapid survey of the Isle of Wight's entire coast and estuaries; the Isle of Wight Coastal Audit. This survey took place at the time when English Heritage was developing its methodology for Rapid Coastal Zone Assessment Surveys (English Heritage 1999). Consequently, similar techniques were used but the methodology had not been fine-tuned. The survey identified areas of high archaeological potential/threat, but also stressed the limitations of this type of rapid survey, and the fact that so little was known about most of the sites that had been identified; indeed approximately 20% could not even be dated (Loader and Basford 2000). This has made it extremely difficult to justify why sites should be preserved or recorded when responding to planning or coastal management proposals, and to prioritise which sites or areas should receive attention should funding for further work be available. The fact that a relatively large amount of money was allocated to the Wootton-Quarr survey before a rapid assessment of the rest of the coast had been carried out has led to an assumption that that area has had its share of funding (Fulford and Champion 1997, 232), despite the fact that other parts of the Island's coast may be of equal importance and vulnerability.

To help remedy this shortcoming, a programme of targeted radiocarbon dating was consequently funded by English Heritage, with the aim of feeding enhanced data into the revision of the SMP (English Heritage 2006d; Loader 2006). For this project, areas which had been identified as being archaeologically rich but vulnerable to coastal erosion during the Coastal Audit were revisited, sites were relocated and samples taken. Although some sites, particularly those which had been identified in the eroding cliff face, had succumbed to coastal recession, 15 sites, including palaeoenvironmental deposits, hearths, fish weirs, stake alignments, and other timber structures, were sampled and produced dates ranging from the early Mesolithic to the early post medieval period (Loader 2009).

5.4 The wider relevance of the Isle of Wight's coastal archaeology

The Isle of Wight is an ideal location for a study of coastal archaeology, but equally it is representative of the range of sites and conditions which can also be encountered on the south coast of England and beyond. A wide variety of sites are found on the island's coast, ranging from Palaeolithic working floors to twentieth-century military installations. Sites are located in the intertidal zone, the cliff face and the terrestrial coastal zone and represent a broad range of activities.

The island's coast includes relatively hard chalk cliffs, soft, friable cliffs, and coastline with wide intertidal foreshore. Much of the coast is undefended and covered by natural environmental designations, but there are also stretches of developed coastline with substantial coastal defences. As a result of the island's location and configuration there is a range of coastal processes operating on different parts of the coast. As a consequence, archaeological sites are faced by a variety of threats, and with a range of management options put forward by the Isle of Wight SMP. Based on all of these factors a representative sample of stretches of coast has been selected for detailed study. These will be further described in the following chapter.

6 Methodology

6.1 Choice of detailed study areas

6.1.1 Overview of study areas

Six areas of the Isle of Wight's coastline have been selected for detailed study (Fig. 6.1). These have been chosen because they are felt to be representative of the range of geomorphological settings found both on the island and more widely on the south coast of England and beyond. They comprise both stretches of undefended coast and areas with substantial coastal defences. The selection includes chalk cliffs, soft, eroding cliffs, open coastline with wide intertidal foreshore, and an estuarine location. All are known to include a variety of archaeological sites in the intertidal zone, the cliff face and the terrestrial coastal zone, which are faced by varied and different levels of threat, and with a range of management options recommended by the Isle of Wight SMP.

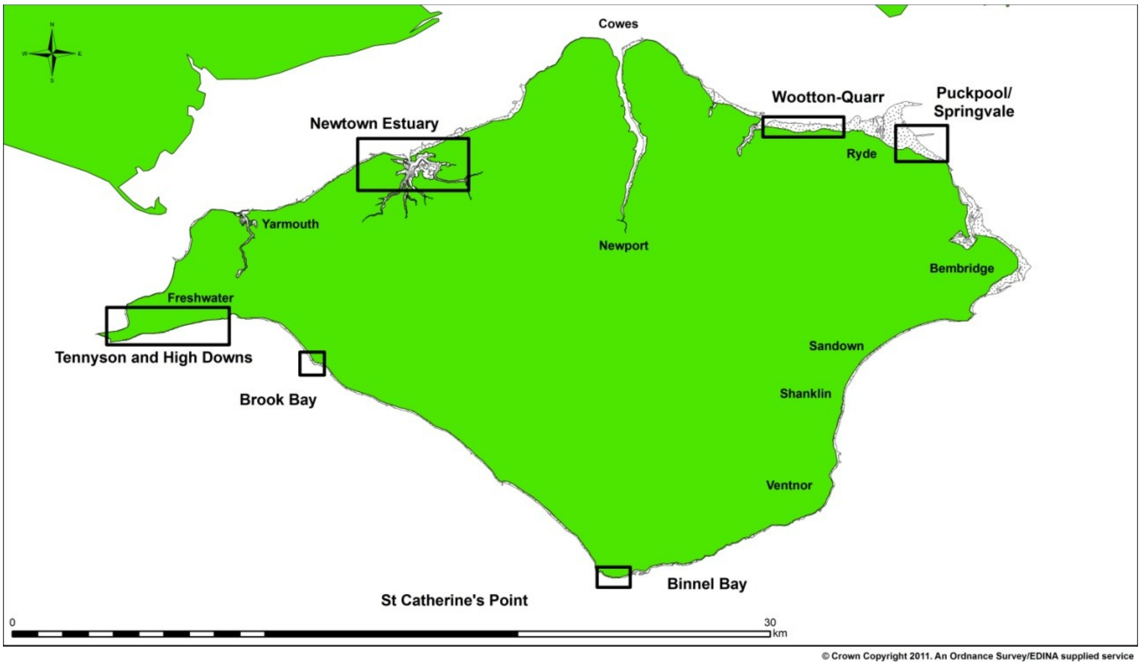

Figure 6.1 The study areas

6.1.2 Tennyson Down and High Down

The chalk cliffs of Tennyson Down and High Down form the westernmost outcrop of the island's median chalk ridge, stretching for some 5.5km between Freshwater Bay and the Needles. The cliffs rise steeply westwards from the low-lying Freshwater Bay to a maximum height of *c* 150m OD at Tennyson's Monument. This stretch of coastline is relatively resistant to erosion (Fig. 6.2 and 6.3).

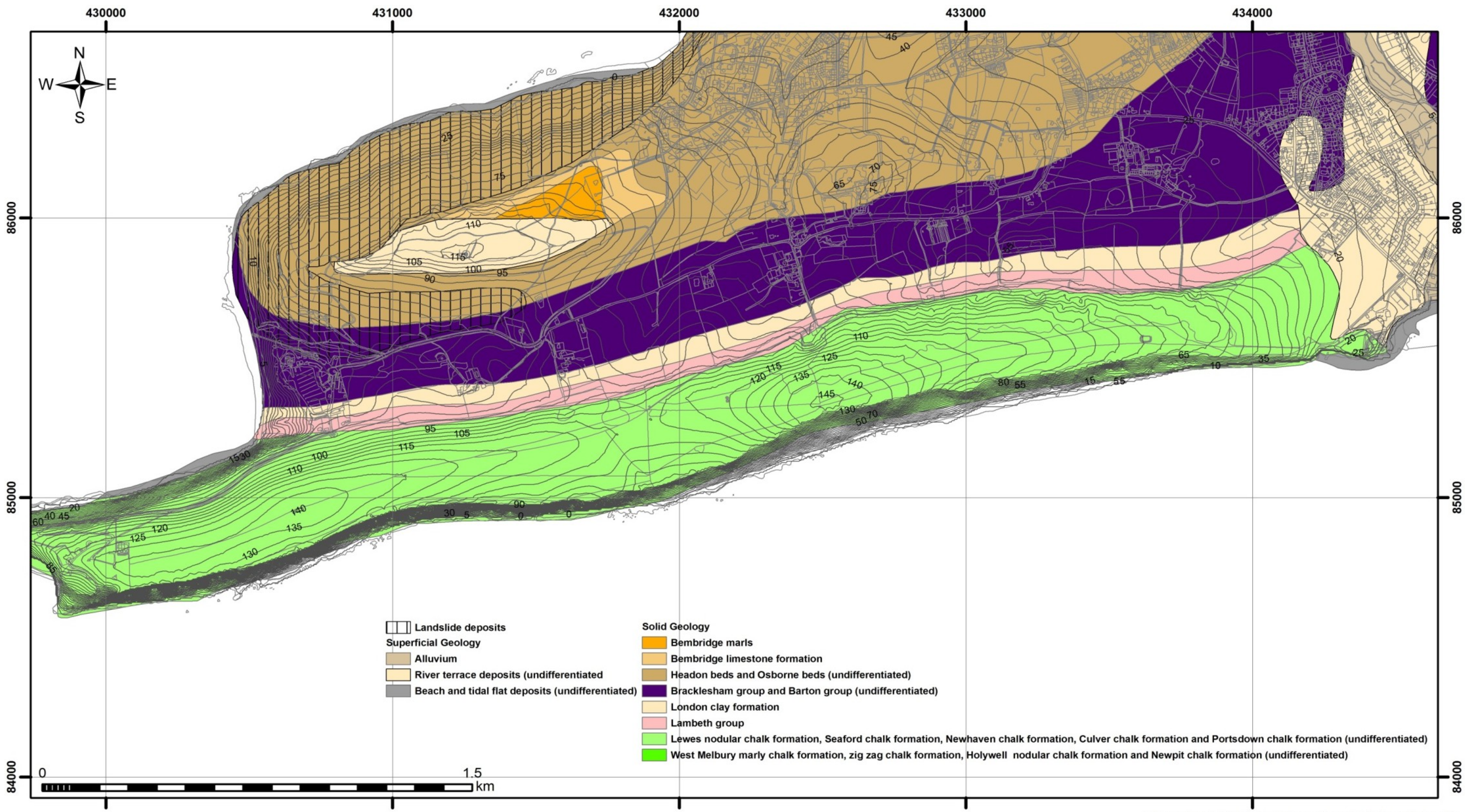

Figure 6.2 Ggeology and contours in the Tennyson Down and High Down study area

The original SMP's predicted retreat was only 15m over 75 years (Halcrow 1997), but this figure has been revised for the SMP revision to 40m over 100 years (Isle of Wight Council *et al* 2010). Erosion is fairly even along this frontage, although the coast is subject to episodic cliff falls, most of which are quite minor, but occasionally more substantial amounts of material fall.

Figure 6.3 Freshwater Bay, Tennyson Down and High Down viewed from the south

The chalk cliffs are fronted by a wave-cut platform with very little accumulation of beach material, and the intertidal zone is largely inaccessible. On the cliff top, a strip of downland approximately 300m wide is rich in archaeological features. These include a Neolithic mortuary enclosure (Fig. 6.4), Bronze Age round barrows, an undated sub-circular enclosure which has been truncated by coastal recession, and nineteenth century and World War II military installations including a series of trenches sited to prevent enemy landings from the air (see Fig. 7.18a). These can still be traced on the ground as a number of irregular banks and ditches. The downs were a favourite haunt of Alfred Lord Tennyson, whose residence, Farringford lies near the coast, and a memorial to the poet is presently some 20m from the cliff edge at the highest point. The western end of the down was the site of a golf course in the late nineteenth century, and there are numerous earthworks relating to this phase in its history.

Located within the Isle of Wight AONB and the Tennyson Heritage Coast, the downs are owned by the National Trust. The area forms part of the Headon Warren and West High Down Site of Special Scientific Interest (SSSI), and the Isle of Wight Downs Special Area for Conservation (SAC).

Figure 6.4 Mortuary enclosure on Tennyson Down (© IWCAHES)

6.1.3   Brook Bay

Brook Bay is located on the south west coast of the island .The geology of the Brook Bay study area comprises clays, shales, marls and sandstones of the Wealden Group (Fig. 6.5). The diverse geological structure leads to a disparity in erosion style and rate, with recession by semi-rotational slides, block failures, and mudflows which are caused not only by marine erosion but also by overland flow, gullying and shallow sliding (SCOPAC 2003b). The presence of outcrops of more resistant bedrock which are slower to erode gives rise to minor headlands such as that at Hanover Point (Fig. 6.6).

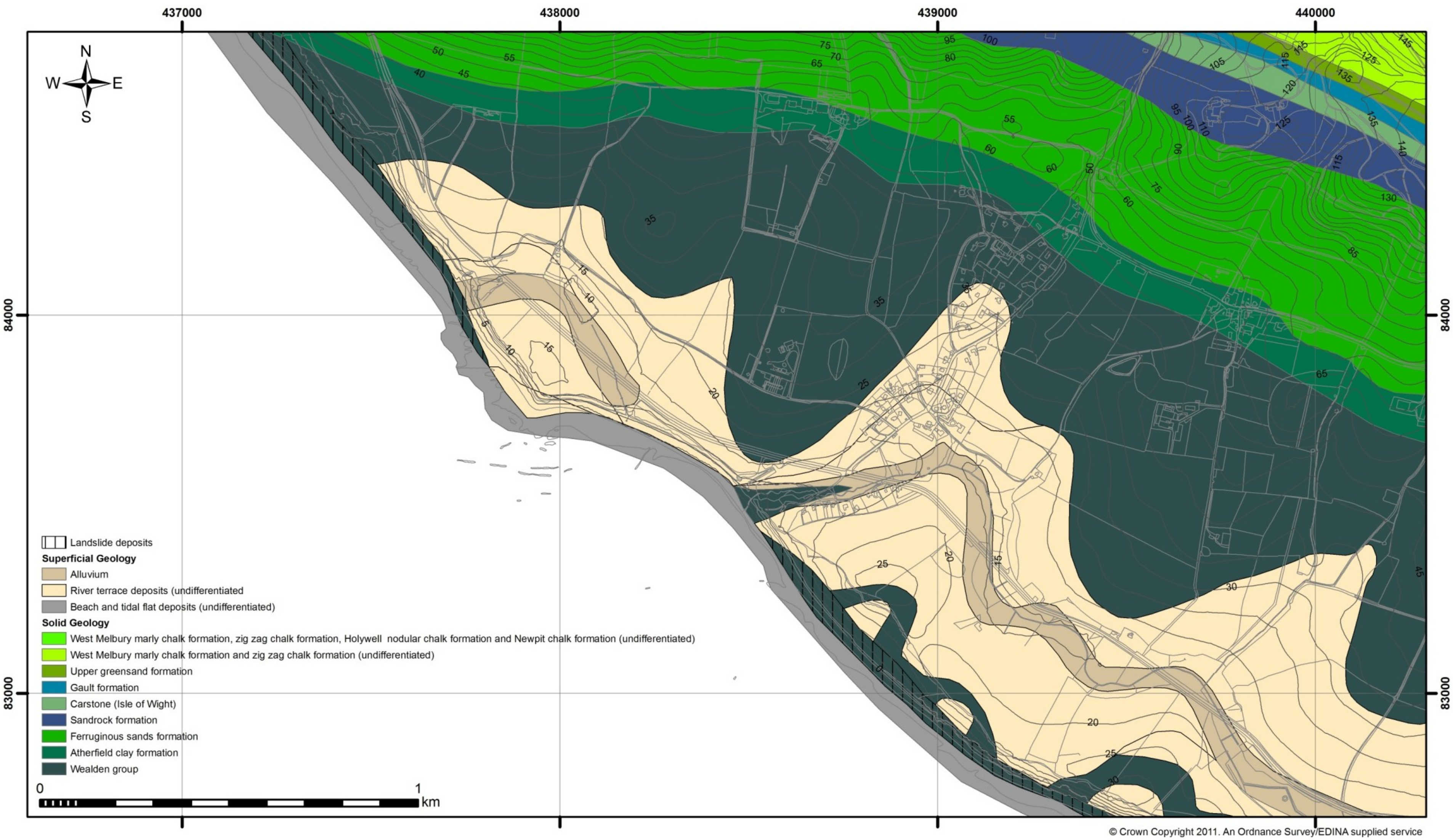

Figure 6.5 Geology and contours in the Brook Bay study area

Erosion of the cliff face is rapid. The first round SMP indicated that there were few reliable measurements of erosion rates but suggested that cliff recession could be as much as 1.5m per annum. The figures in the SMP revision are even lower and predict a total loss of 80m over 100 years for the coast between Atherfield and Compton Chine. Having witnessed erosion along this coast over several years this figure does seem rather a conservative estimate.

Figure 6.6 Brook Bay looking south east from Hanover Point

A particular feature of the island's south west coast is the occurrence of 'chines' (White 1921; Flint 1982; Leyland and Darby 2008). Chines are dynamic features which can develop and decay relatively quickly. They are narrow ravines formed by streams with enough energy to cut through the soft cliffs rather than flowing over the edge as a waterfall. The most dramatic of these is Whale Chine but two examples, Brook Chine and Churchill Chine (Fig. 6.7), are located within the study area.

The intertidal zone is exposed to the full effects of the prevailing south westerly winds and waves, and consequently little archaeological material survives here, but sites are continuously being revealed and then destroyed in the eroding cliff face.

Figure 6.7 Churchill Chine viewed from the beach

The sediments at the top of the cliffs in Brook Bay comprise fluvial gravel deposits and valley brickearth, and it is associated with these deposits that archaeological and palaeoenvironmental features have been recorded. Archaeological sites have been recorded from at least the early twentieth century when antiquarians collected lithics, and recorded hearths, palaeoenvironmental deposits and a Bronze Age urn cemetery (Poole 1936, Clifford 1936, Dunning 1931). The remains of a further possible Bronze Age cemetery were excavated in 2001 after a walker on the beach noticed an inverted urn containing a cremation truncated in the cliff section at Hanover Point (IWHER 4033; Basford and Loader 2000).

In 1993, a pit containing burnt material was identified in the face of the south eastern arm of Churchill Chine, overlain by a lens of fire-cracked flint (figs. 6.8 and 6.9). Samples were taken from the lens of fire-cracked flint (context 2), the fill of the pit (context 22) and the underlying palaeoenvironmental deposits (context 20). Radiocarbon dates were obtained as follows (Table 6.1).

Table 6.1 The results of radiocarbon dating from deposits at Churchill Chine (IWHER)

Context 2 (lens of firecracked flint)			
SUERC-15509	charcoal (*Corylus* sp.)	3855±35 BP	2470-2200 cal BC
SUERC-15510	charcoal (Pomoideae)	3840±35 BP	2470-2150 cal BC
Context 22 (pit)			
SUERC-15507	charcoal (*Corylus* sp.)	3890±35 BP	2480-2210 cal BC
SUERC-15508	charcoal (*Ilex* sp.)	3790±35 BP	2340-2060 cal BC
Context 20 (palaeoenvironmental deposits of the Western Yar tributary)			
SUERC-15505	hazelnut shell	9185±35 BP	8540-8290 cal BC
SUERC-15506	hazelnut shell	9100±35 BP	8330-8250 cal BC

Figure 6.8 Hearth revealed in the section of Churchill Chine, photographed in 2001 (© IWCAHES)

Figure 6.9 The same feature photographed in 2010 following erosion after an exceptionally cold, wet winter

In 2005, radiocarbon dates of 2040-1920 cal BC, 3632±21 BP (KI25780) and 1980-1880 cal BC, 3583±22 BP (KI25781) were obtained for a fragment of hurdle which fell from the face of Churchill Chine (Fig. 6.10).

Figure 6.10 Hurdle from Churchill Chine (© IWCAHES)

Archaeological and palaeoenvironmental sites within the survey unit are associated with a former tributary of the Western Yar, itself a tributary of the Solent River (see section 5.3.1), which has been truncated by cliff recession (Fig. 6.11).

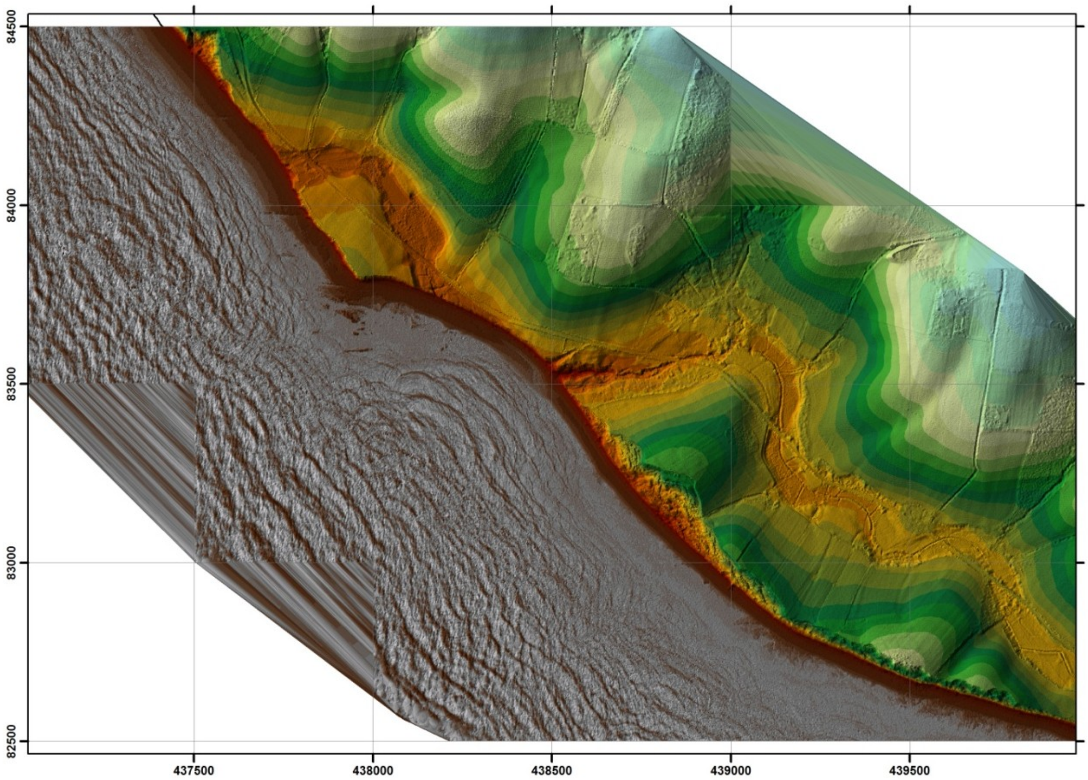

Figure 6.11 LiDAR image showing the course of the former Western Yar tributary, Brook (data courtesy of Channel Coastal Observatory)

The cliffs along the entire south west coast are subject to unpredictable and potentially catastrophic falls and mudslides. In Brook Bay, heavy rain and snowfall together with freezing temperatures over the winter of 2009-2010 triggered a landslide which threatens the Military Road, the main route between Freshwater Bay and Chale (Fig. 6.12; Isle of Wight County Press 2010). An extensive programme of enhancement to drainage landward of and alongside the road has been put in place in an attempt to prolong the life of the highway.


Figure 6.12 Brook Bay looking north west. Taken 6 March 2009 and 28 February 2010

Brook Bay forms part of the Tennyson Heritage Coast, and is within the Isle of Wight AONB, the Compton Down to Steephill Cove SSSI and the South Wight Maritime SAC. It is also within the South-West Isle of Wight Geological Conservation Review (GCR) site and is locally designated as a Regionally Important Geological and Geomorphological Site (RIG). Most of the bay is owned by the National Trust.

6.1.4 St. Catherine's Point (Rocken End to Binnel Bay)

The coastline from Binnel Bay to Rocken End forms the south west end of the Undercliff, a landslide complex stretching for approximately 12km on the island's southern coast (Fig. 6.13).

Figure 6.13 St. Catherine's Point and the Undercliff (© IWCAHES)

The Undercliff comprises an inner cliff of Upper Greensand and chalk fronted by a complex of irregular terraces and scarps created by deep-seated rotational and translational slippage, largely within the Gault deposits (Fig. 6.14).

Seaward of these an apron of debris material composed of Upper Greensand and Chalk, possibly of periglacial origin, gives some protection against marine erosion, but attrition of this apron leads to the reactivation of landslips. Within the study area erosion is more active to the west, around Rocken End. This is thought to be because this area is more exposed to the prevailing winds and the also because the debris apron is less extensive (Hutchinson 1987).

The timescale of the formation of the Undercliff is confusing, but a possible sequence has been postulated by Hutchinson (1987, 132).

During the Devensian glacial stage, periglacial activity produced a large amount of fine debris, burying any remaining Ipswichian coastal landslides and forming debris accumulations over the exposed former seabed. Gradually, these accumulations would have become exposed to marine erosion caused by post glacial sea-level rise. This erosion eventually removed the Ipswichian and Devensian features and cut into *in situ* cliff strata, forming a now buried shore platform and former sea cliff. It is suggested that the height of the landward part of the platform (*c* 9m below present mean sea level) dates it to around 7000-8500 years ago. Continuing marine erosion triggered a new phase of major landsliding which buried the landward portion of the shore platform and pushed the high tide mark seaward. At St. Catherine's Point the debris from this landsliding reached a thickness of approximately 13m.

During the ensuing period of relative stability, a soil horizon developed on the surface of the debris apron, and several decimetres of tufa accumulated above it. This was followed by further instability, indicated by some slope debris within which fallen timbers which have been radiocarbon dated are present (Preece 1986; see below). This debris was subsequently buried by a few decimetres of slopewash.

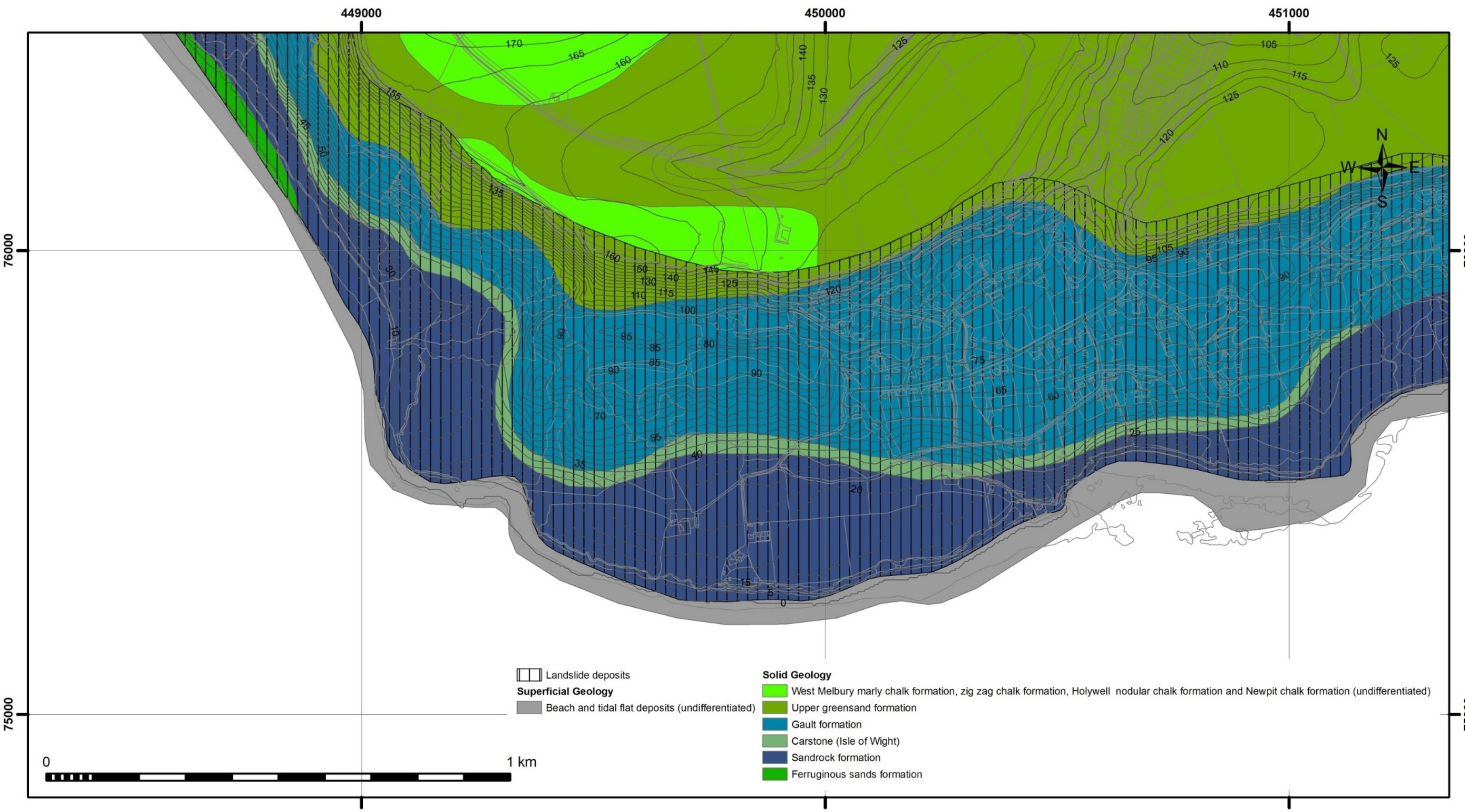

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Figure 6.14 Geology and contours in the St. Catherine's Point study area

This instability was followed by a second major phase of landsliding. This might have been due to the effects of unloading following the first phase of activity which caused the clay strata within the cliff to swell and soften, or it may have been caused by climatic deterioration in the Iron Age. A further major landslide produced the ridges which are now present between the inner cliff and the debris apron (Fig. 6.15).

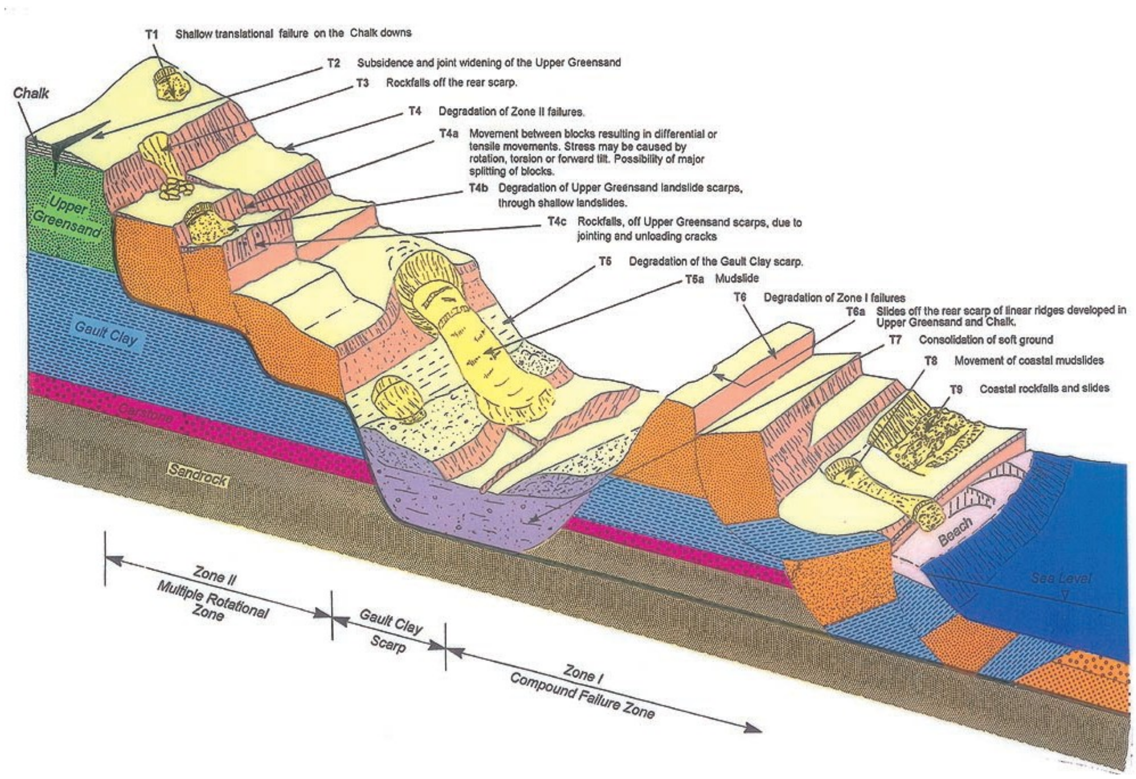

Figure 6.15 Schematic diagram of landslides at St. Catherine's Point (from McInnes et al *2000)*

Since the early twentieth century, archaeological and palaeoenvironmental material has been recorded both on the ridges and on the debris apron. A thirteenth century midden was excavated on one of the terraces above St. Catherine's Point in 1928 (Dunning 1939), whilst material from the apron debris includes late Iron Age/Roman middens adjacent to St. Catherine's lighthouse, the skeleton of a girl approximately twelve years old of unknown date which was found face down in a pit (Fig. 6.16), and a medieval midden at Watershoot Bay which was first recorded by Gerald Dunning in 1965 (IWHER 712). A local fieldworker is reported to have collected material from a Beaker settlement eroding from the cliff face adjacent to St. Catherine's Lighthouse (Allen 2005), although this material has not been reported to the local archaeological service.

Despite the area's relatively hostile environment, extensive areas of ridge and furrow are visible on the debris apron.

Figure 6.16 The excavation of the skeleton of a girl aged c12 years from the cliff top at St. Catherine's Point (© IWCAHES)

The lighthouse was constructed between 1838 and 1840 in response to the wreck of the Clarendon off Blackgang in 1836 (Fig. 6.17). It replaced two earlier lighthouses, the first dating from the fourteenth century and the second, which was never finished, from the seventeenth century. These were built high on the downs and were not successful, being regularly shrouded in mist. The lighthouse at St. Catherine's Point was the location of one of the Ordnance Survey's network of active GPS stations, but in autumn 2001 it was noticed that the grid coordinates for the station had moved. Monitoring confirmed that other stations in the network had remained in a constant position, whilst between September 2000 and March 2001 the lighthouse had moved southwards by more than 9cm. It was established that this movement was directly related to periods of excessive rainfall (Ordnance Survey 2009).

Figure 6.17 The eroding cliff adjacent to St. Catherine's Lighthouse

In the late 1970s and 1980s, palaeoenvironmental deposits in the Undercliff were examined in an attempt to locate buried ground surfaces and organic material suitable for radiocarbon dating (Preece 1986; Hutchinson 1987). Fallen trees located approximately 9m below the surface within the apron material exposed in the cliff face at St. Catherine's Point were radiocarbon dated to 3350-3080 cal BC (SRR-1813; 4490±40BP, *Taxus*) and 2580-2290 cal BC (SRR-1947; 3960±50BP, unidentified wood).

At Binnel charcoal from a dark lens approximately 6m down in the cliff face within the debris apron was radiocarbon dated to 3800-3000 cal BC, (BM-1737R; 4700±140BP). This same horizon also produced a faunal assemblage including bones of red deer, pygmy shrew, red squirrel, dormouse, bank vole, field vole, bird, frog/toad, and snake (Preece 1986, 194). Deposits described as middens had first been identified here in 1923, when excavations were carried out by a Dr Burrows of Southsea (IWHER 693). Gerald Dunning also investigated the site from the late 1920s to the 1960s. He recorded four middens, containing pottery of Late Bronze Age to Roman date (Fig. 6.18; G. Dunning notes and photographs in IWHER back up file).

When the same section was examined during the Isle of Wight Coastal Audit in 1999, a sherd of beaker pottery was recovered from the horizon identified by Preece and in 2009, further beaker sherds were reported (Delian Backhouse-Fry pers. comm.).

Figure 6.18 Landslip deposits at Binnel Bay photographed by Gerald Dunning in 1938 (© IWCAHES)

In the 1880s, a German industrial chemist, Theodore William Spindler, retired to the Undercliff and had ambitions to turn his estate at Old Park into a fashionable marine resort. He started by constructing a sea wall in Binnel Bay (Fig. 6.19). However, the scheme was unsuccessful; the structure was battered by the full force of the waves and soon became undermined. Today, little remains of the sea wall and groynes, but their depiction on mapping provides a useful indication of erosion rates since their construction (figs. 6.20 and 6.21).

Figure 6.19 The construction of 'Spindler's Harbour' at Binnel Bay (from McInnes 2006)

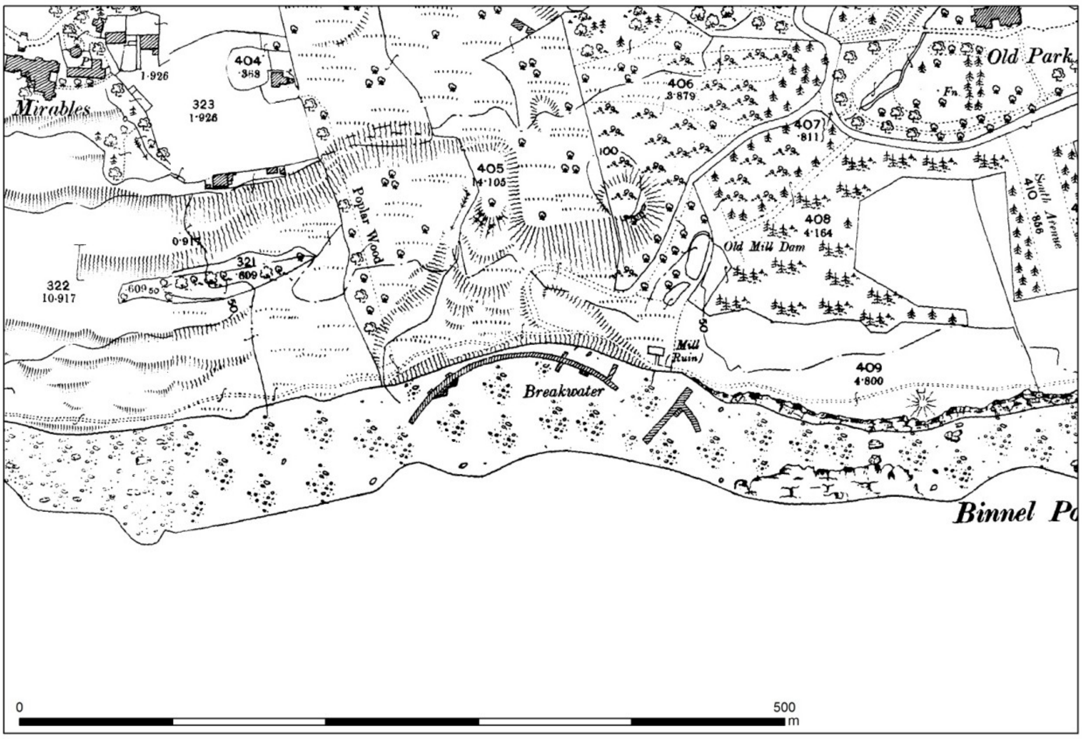

Figure 6.20 'Spindler's Harbour' at Binnel Bay shown on 1898 Ordnance Survey map

Figure 6.21 The remains of 'Spindler's Harbour' at Binnel Bay, 2007

The Undercliff is backed by a sheer inner cliff which rises to a height of *c* 160m OD. At Gore Cliff, above St. Catherine's Point, a major landslide which took place in 1928 has exposed the face of the cliff which is composed of Upper Greensand topped with Lower Chalk. The chalk in the cliff section is overlain by a thickness of just over 3m of hillwash. In the 1930s a local collector recovered a Roman brooch of second century style from the basal levels of this hillwash at a depth of *c* 3m. This hillwash is said to have derived from a slope which must have existed on the southern, seaward side of the present cliff (Preece 1980; 1987).

Between St. Catherine's Point and Binnel Bay lies Reeth Bay and Puckaster Cove. Rock armour sea defences were constructed here together with an extensive drainage system in 2004 (Fig. 6.22) in an attempt to reduce the instability of this stretch of coast which is backed by a residential area.

Figure 6.22 Rock armour in Reeth Bay

The Undercliff at St Catherine's Point is owned by the National Trust, whilst the coastal strip to the east is in private ownership. It is part of the Compton Down to Steephill Cove SSSI, and the South Wight Maritime SAC.

6.1.5 Puckpool/Springvale (Ryde East Sands)

Puckpool and Springvale are located on the north east coast of the island, to the east of Ryde. This is a defended coast with a wide intertidal zone which forms the eastern part of Ryde Sands.

The geology in this study area comprises Bembridge Marls and Headon and Osborne Beds with alluvial deposits in the low-lying area behind Seaview Duver (Fig. 6.23). Outcrops of Bembridge Limestone on the foreshore are more resistant to erosion.

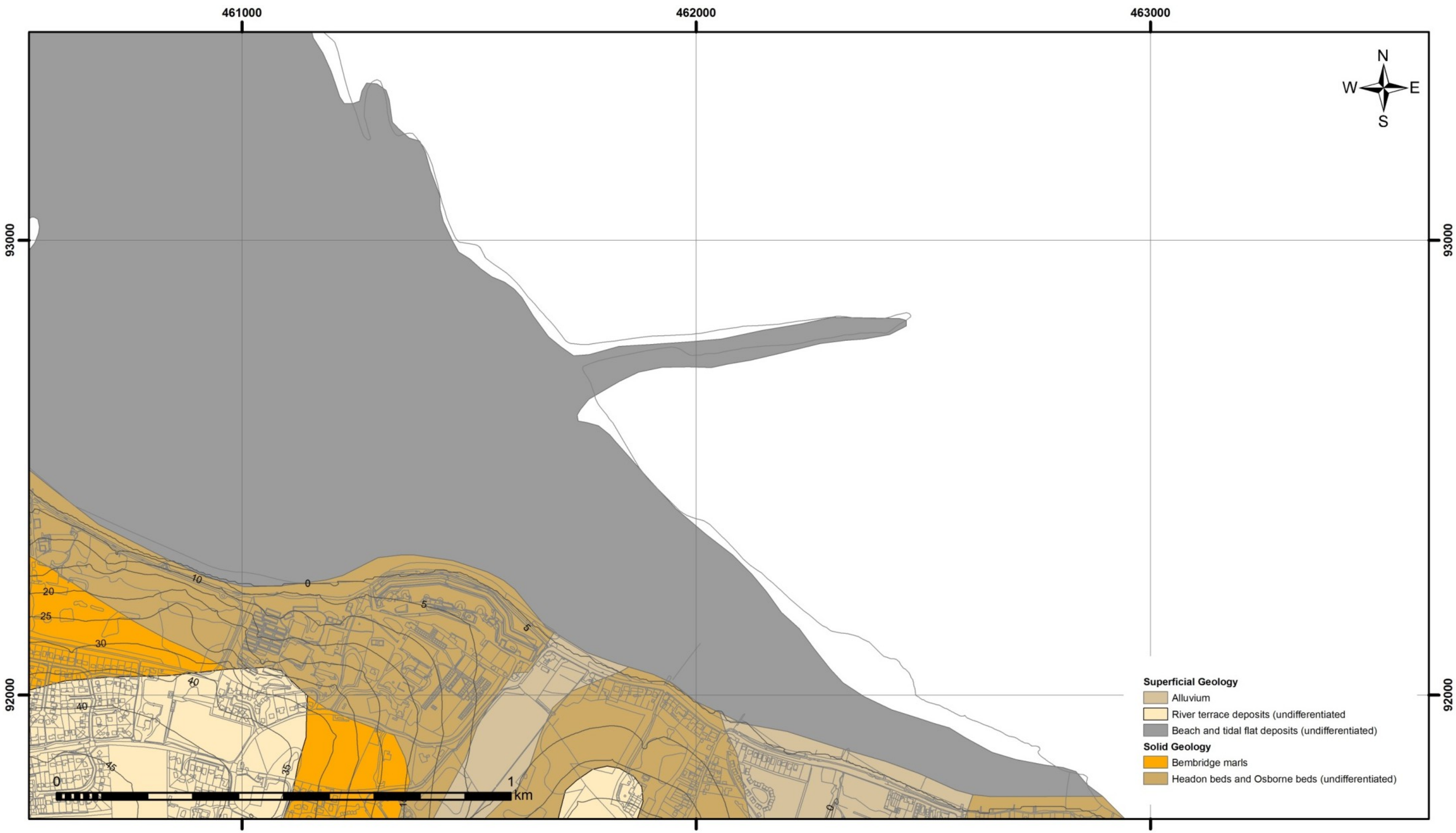

Figure 6.23 Geology and contours in the Springvale study area

It is unclear when the extensive sandflats started to built up; a chart of 1693 appears to show a large expanse of sand (Greenville Collins 1693), but the author Henry Fielding in *A Voyage to Lisbon* published in 1755 speaks of his ship calling at Ryde, which was inaccessible during low tide phases because of the mud. This suggests that the sands were not so extensive at that time:

> *Between the sea and the shore there was, at low water, an impassable gulf, if I may so call it, of deep mud, which could neither be traversed by walking nor swimming; so that for near one half of the twenty-four hours Ryde was inaccessible by friend or foe. But as the magistrates of this place seemed more to desire the company of the former than to fear that of the latter, they had begun to make a small causeway to the low-water mark, so that foot passengers might land whenever they pleased.*

The presence of large coastal fish traps constructed of stone on the Isle of Wight is unique to this location. The reason for this is unclear; there are other locations with a similar combination of an extensive, gently sloping, intertidal zone and readily available raw materials where it might be expected that comparable structures might be found. Both V-shaped and curvilinear traps have been recorded (Fig. 6.24).

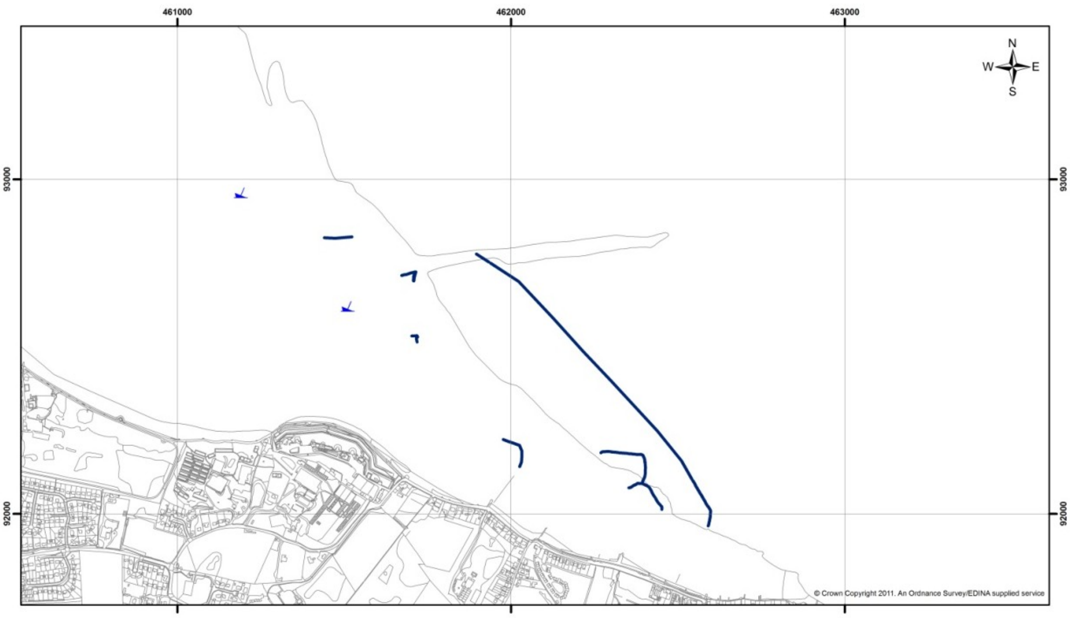

Figure 6.24 Intertidal features at Springvale

English Heritage provided funding to recover samples for radiocarbon dating (Loader 2009). No timbers were found in association with the curvilinear features, but wooden components of a V-shaped fish trap (IWHER 3576; Fig. 6.25) have been dated to the Saxo-Norman period (GrN-31048: 900±BP, cal AD 1040-1210 andSUERC-15817: 870±BP, cal AD 1040-1260).

Figure 6.25 V-shaped stone fish-weir at Springvale

A substantial but poorly understood structure also on this stretch of coast is a long linear feature constructed of limestone rubble and posts stretching north-westwards for more than 1km. The seventeenth century local diarist John Oglander wrote of a harbour here: 'there belonged in those days [sixteenth century or before], to St Helens and Barnsley 50 sayle of shipes off Nettlestone Pointe, by acte, a myle into the sea, they had made a good harbour by casting up of the beach on both sydes, to be sene at this day' (Oglander Commonplace book). It was thought that this structure may have formed the remains of this feature. However, posts from the alignment were also submitted for radiocarbon dating and produced dates in the seventh to ninth centuries (GrN-31047:

1235±15 BP, cal AD 690-865, and SUERC-15516: 1240±35 BP, cal AD 670-890).

It is possible that the post alignment pre-dates the stone structure, or the ‘harbour’ has an earlier origin than previously thought. Archaeological investigations in advance of coastal defence works suggested that the structure ran along the seaward edge of a north-westerly trending palaeochannel which, it was suggested, had been accessible until the medieval period (Wessex Archaeology 2004). Alternatively, the structure might represent the remains of a large fish trap, although no evidence of a device for trapping the fish has been recorded and it is unclear how the structure would have related to the smaller curvilinear and V-shaped fish traps.

Substantial coastal fish traps of similar date have been recorded in the Blackwater Estuary in Essex (Strachan 1998), and Bridgewater Bay in Somerset (Crowther and Dickson 2008), although these structures are more obviously fish traps. On the Isle of Wight, some 6km to the west of Springvale at Wootton-Quarr, another substantial linear structure, has been radiocarbon dated to the late-sixth to eighth centuries (see section 6.1.6 below; Tomalin *et al* forthcoming). This longshore alignment again does not have an obvious trapping apparatus and it is questionable whether the structure can be interpreted as a fish trap. Whatever the function of both of these structures, their construction necessitated a reasonably large and organised work force.

Other features in the intertidal zone include longshore post alignments, wrecks, and palaeoenvironmental deposits. Roman material including pottery, coins and briquetage has recently been recovered, suggesting that the context containing this material is becoming increasingly vulnerable to erosion, although the source is yet to be identified.

There has in the past been an assumption that Ryde Sands act as a sediment sink and are prograding (Harlow 1980, cited in SCOPAC 2003a) but archaeological features on Ryde East Sands have been seen to be progressively uncovering. This is possibly due to episodic events, for example winds from the northeast can remove sediment; it may be associated with the lateral movement of an intertidal spit, or it may be the result of recent coastal defence works at Seaview Duver. The assumption that the Sands are continuing to accrete has also been questioned in the revision of the Isle of Wight SMP (Isle of Wight Council *et al* 2010). There is a need to monitor this stretch of coastline over a longer time frame.

The Puckpool/Springvale intertidal zone forms part of the Ryde Sands and Wootton Creek SSSI, the Solent and Southampton Water SPA, and the Solent and Southampton Water Ramsar site.

6.1.6 Wootton-Quarr

The Wootton-Quarr study area is also on the northeast coast of the island and extends for approximately 4km from the Fishbourne ferry terminal in the west to Ryde pier in the east. The geology of the Wootton-Quarr study area is composed of Oligocene clays, silts and limestones, comprising Bembridge Marls and Headon and Osborne Beds, with a band of more resistant Bembridge Limestone outcropping at intervals on the coast, where it provides some resistance to coastal erosion (Fig. 6.26).

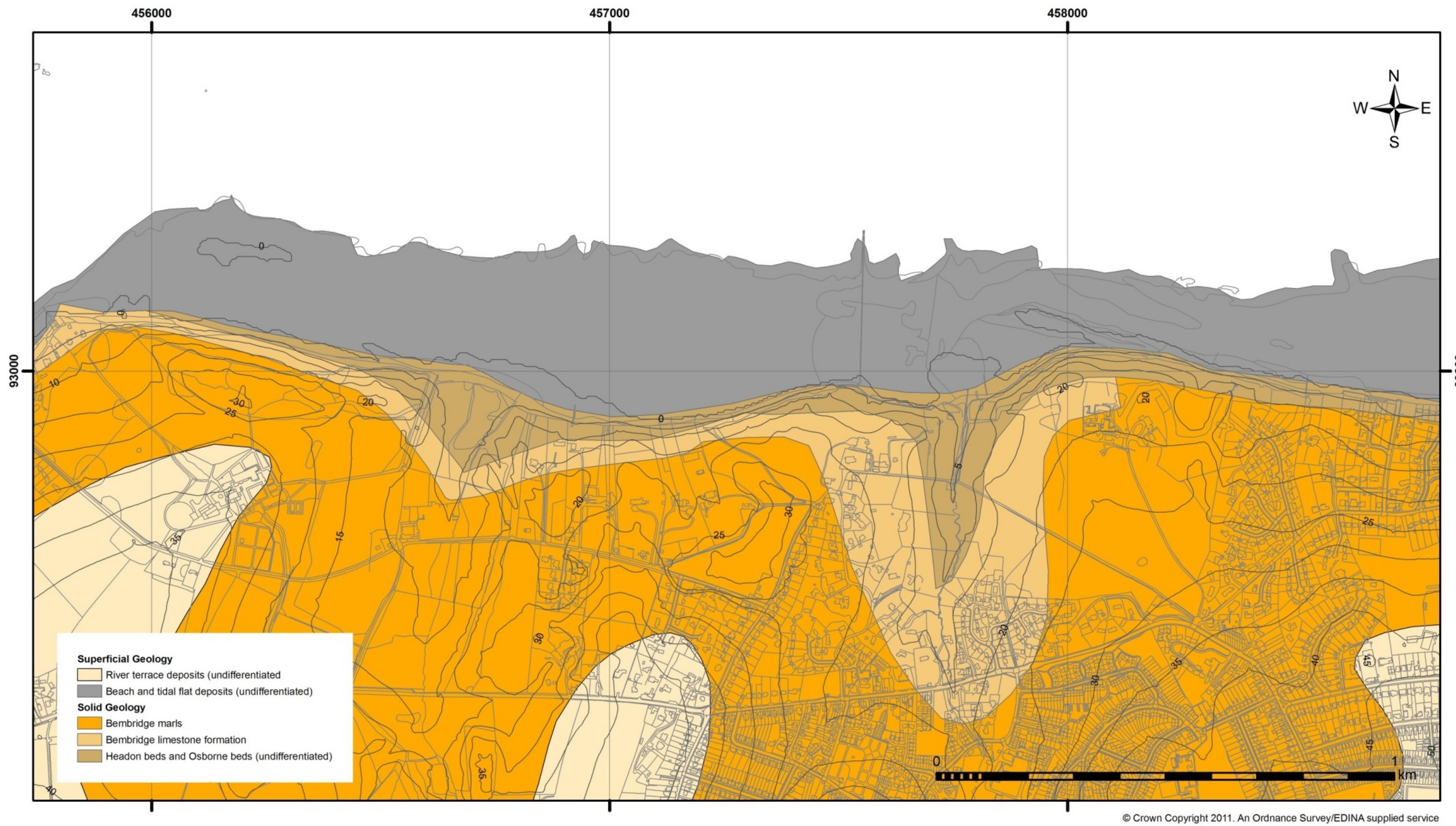

Figure 6.26 Geology and contours in the Wootton-Quarr study area

Central in the study area is the modern Benedictine Abbey of Quarr, which has to its east the remains of a medieval Cistercian abbey (Fig. 6.27).

Figure 6.27 The Wootton-Quarr study area. The remains of the Cistercian abbey are in the centre of the photograph (© IWCAHES)

This stretch of coast was subject to an intensive archaeological survey during the 1990s (Tomalin *et al* forthcoming; Loader *et al* 1997). This survey came about after a number of sherds of Roman pottery were found on the beach at Fishbourne. The site was visited and numerous timber structures were noted. At the same time concerns were expressed about increasing erosion at Fishbourne which local residents believed to be linked to the introduction of larger car ferries. Firstly Sealink and then English Heritage funded archaeological survey including an integrated programme of environmental analyses and radiocarbon and dendrochronological dating (Tomalin *et al* forthcoming). A wide range of archaeological and palaeoenvironmental sites were recorded over a 27 month period.

The earliest artefacts found on the Wootton-Quarr coast were two Palaeolithic handaxes. However, the most prolific prehistoric finds were lithic scatters of

Late Mesolithic/Early Neolithic date comprising both worked and burnt flint which were recorded adjacent to the palaeochannels that crossed the beach at Quarr and Binstead. More than 100 picks and tranchet axes, 70 microliths, a variety of other implements and many thousands of pieces of debitage were recovered.

More than 150 post settings comprising both groups and alignments were recorded. The earliest structure, a post setting of unknown function, was radiocarbon dated to 4040-3710 cal BC, (5100±60 BP; GU-5251), and the recovered post still had moss adhering to the bark. Neolithic trackways of both hurdle and brushwood construction were noted at extreme low water where recording was hampered by their inaccessibility. Other structures were found to date from the Early and Later Bronze Age, Iron Age, Roman, medieval and Post medieval periods. It proved surprisingly difficult to assign a function to many of the structures. Some, such as Structure K20, (Fig. 6.28a) resembled the V-shaped anchor post settings for small basket fishtraps but analogies for others could not be found, although they were of quite distinctive and frequently repeated designs (Fig. 6.28b and c).

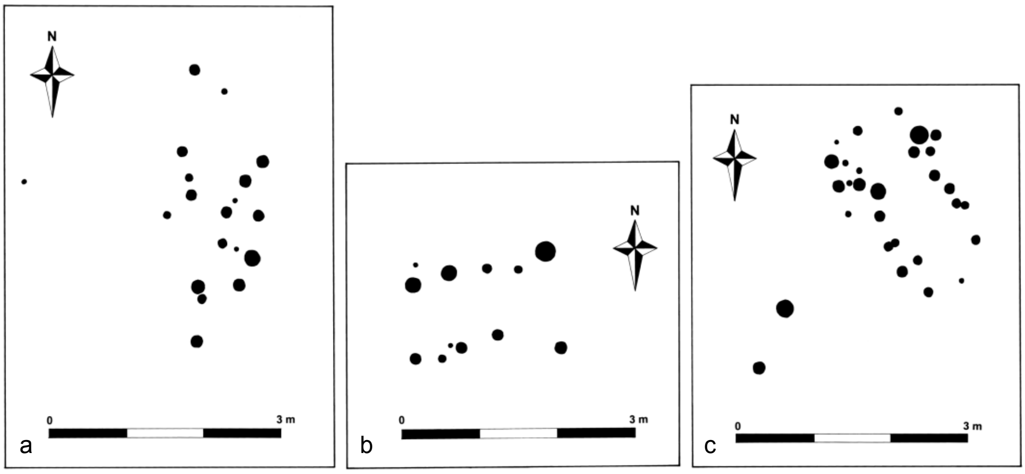

Figure 6.28 Structures K20, B49 and B66 from the Wootton-Quarr intertidal zone (© IWCAHES)

The most substantial feature recorded was a non-continuous longshore alignment stretching at low water for 1.25 km (Fig. 6.29). Posts from individual sections of the alignment were radiocarbon dated and produced dates in the sixth to eighth centuries[1]. The function of the alignment was not established. No horizontal timbers or traces of hurdling were found associated with the structure. If the structure was a fish weir there was no evidence of a trapping device. An examination of the wood technology by Richard Darrah suggested that a large group of people had been involved in shaping the timbers, none of which were worked with the proficiency of a craftsman. Although tool signatures were recorded none were matched between the individual sections of the alignment (Darrah and Loader forthcoming).

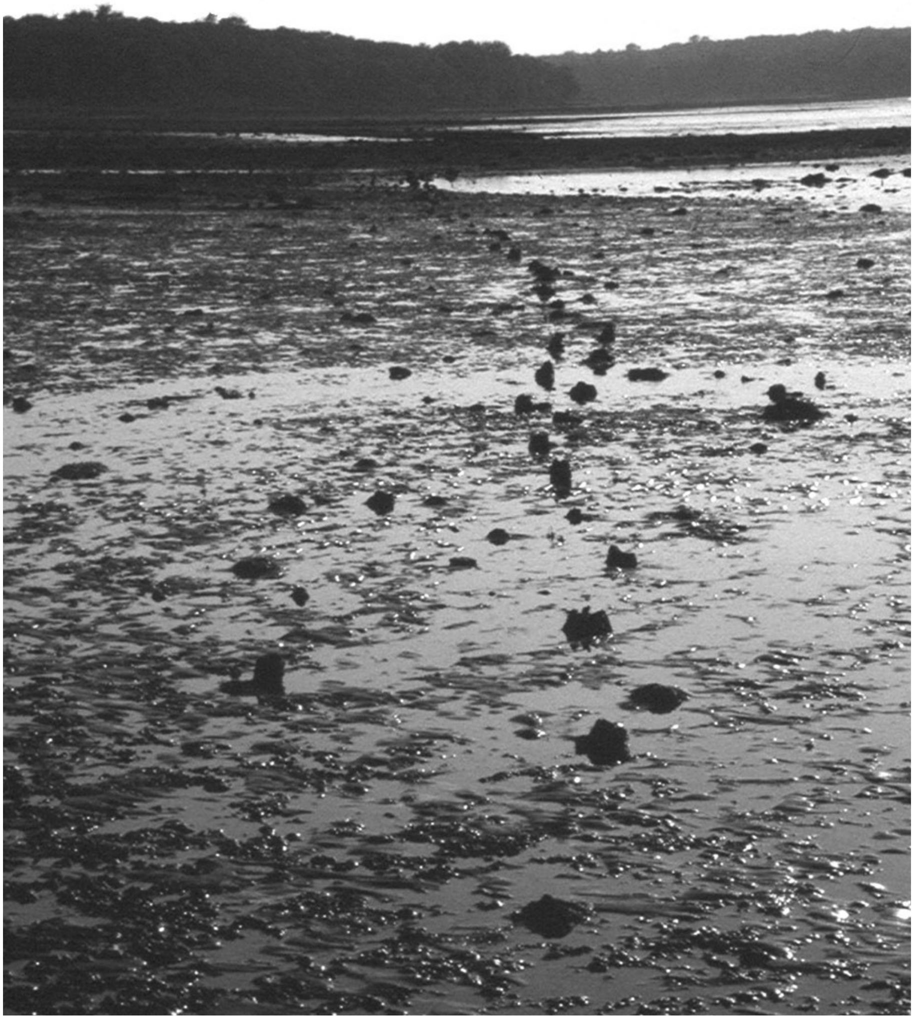

Figure 6.29 Saxon intertidal post alignment at Binstead (© IWCAHES)

A further line of posts, structure P103, was recorded some 700m to the east, and this also produced consistent radiocarbon dates (cal AD 630-790; GU-5592; 1320±50 BP and cal AD 540-670; GU-5411; 1450±50 BP).

[1] (cal AD 590-710 (GU-5597; 1380±50 BP; Q137); cal AD 540-680 (GU-5256: 1420±50 BP: Q14); cal AD 600-780 (GU-5254; 1350±50 BP; K15); cal AD 600-770 (GU-5255; 1350±50 BP) and cal AD 600-770 (GU-5591, 1370±50 BP; K16) and cal AD 560-690 (GU-5400; 1390±50 BP; B17)

At Binstead a substantial V-shaped fish weir was radiocarbon dated to the Saxo-Norman period (GU-5399: cal AD 890-1040, 1040±50 BP and GU-5398: cal AD 810-1020, 1100±50 BP). It is thought that this structure might have served the workers who were employed in the limestone quarries which are found on the adjacent coast. Quarr limestone was highly prized and was used in many mainland buildings, including pre-Conquest churches Hampshire and East Sussex, Winchester Cathedral and the White Tower at the Tower of London (Westmore *et al* forthcoming; Tatton Brown 1980).

Artefact scatters composed largely of Roman and medieval ceramics were recovered from the beach at Fishbourne, Quarr and Binstead. These display significant evidence of trade, particularly with the south coast and the Continent. In the medieval period this trade would have been focussed on the abbey at Quarr, but the reason for the site's significance as a landing place in the late Iron Age and Roman periods is less obvious.

Figure 6.30 Eroding intertidal peat at Quarr

The Wootton-Quarr project sought to consider the archaeology of the intertidal zone in relation to its environmental context, and palaeoenvironmental analyses formed a significant aspect of the investigations (Fig. 6.30). These included studies of pollen, plant macrofossils, insects and diatoms. A 770-year dendrochronological sequence spanning the years 3463 – 2694 cal BC was obtained from fallen oak trees in the intertidal zone (Hillam forthcoming).

It is not just the intertidal archaeology that is under threat on the Wootton-Quarr coast. Erosion of the low cliff fronting the medieval Quarr Abbey revealed a twelfth century roof tile kiln associated with a phase of rebuilding at Quarr Abbey (Fig. 6.31). The kiln was subsequently excavated in 1993 before its destruction (Riall forthcoming). The ruins of the medieval abbey itself are now only *c* 210m from the eroding cliff line.

Figure 6.31 Excavation of the twelfth century tile kiln at Quarr in 1993. The structure has now been completely destroyed by coastal erosion (© IWCAHES)

The Wootton-Quarr coast falls partly within the Isle of Wight AONB, within the Ryde Sands and Wootton Creek SSSI, Solent and Southampton Water SPA, and Solent and Southampton Water Ramsar site.

6.1.7 The Newtown Estuary

The Newtown Estuary is located on the north west coast of the island between Yarmouth and Cowes. The estuary comprises a dendritic pattern of tidal creeks flooded during the Holocene transgression, with extensive areas of salt marsh and at low water, mud flats. The estuary mouth is protected by spits on its east and west sides. The eastern spit in particular is becoming increasingly subject to erosion and overtopping. The geology of the Newtown Estuary study area (Fig. 6.32) is composed mainly of the Hamstead Beds, Bembridge Marls and Bembridge Limestone formation. This gives rise to rotational slumping and mudsliding, particularly on the higher coastal slope to the west of the estuary.

Within the estuary is the failed medieval planned town of Newtown, which was founded in the thirteenth century by the Bishop of Winchester. It appears to have fallen into decline relatively quickly, partly due to economic circumstances, but the town was also all but destroyed during French raids in 1377. Much of the street pattern is still visible, partly within the fields or as green lanes (Fig. 6.33). In addition the boundaries of many of the burgage plots have survived as small paddocks. Around the core of the burgage plots there is extensive ridge and furrow surviving in many of the fields.

To the north of the medieval town an area of marshland was reclaimed from the sea between 1656 and 1768 (Fig. 6.33; Foss 2004, 73). It is thought that the primary purpose of the reclamation may have been either for salt production or the creation of extra grazing land. The unpublished Ordnance Survey of *c* 1794 shows salt pans inside the embankment. Aerial photographs reveal extensive evidence of ridge and furrow within the reclaimed marsh. It is unlikely that this land could ever have been successfully cultivated due to the continuing salinity of the soil, but instead the ridging might have been to encourage drainage for a pastoral regime. The sea wall was breached during the storm surges of 1953 and there was further damage during storms the following year; the reclaimed land consequently reverted to mud flats. The remains of the reclamation bank are still visible, constructed mainly as a clay bank with post revetment, but in places using drystone walling techniques. The area has since been colonised by salt marsh plants.

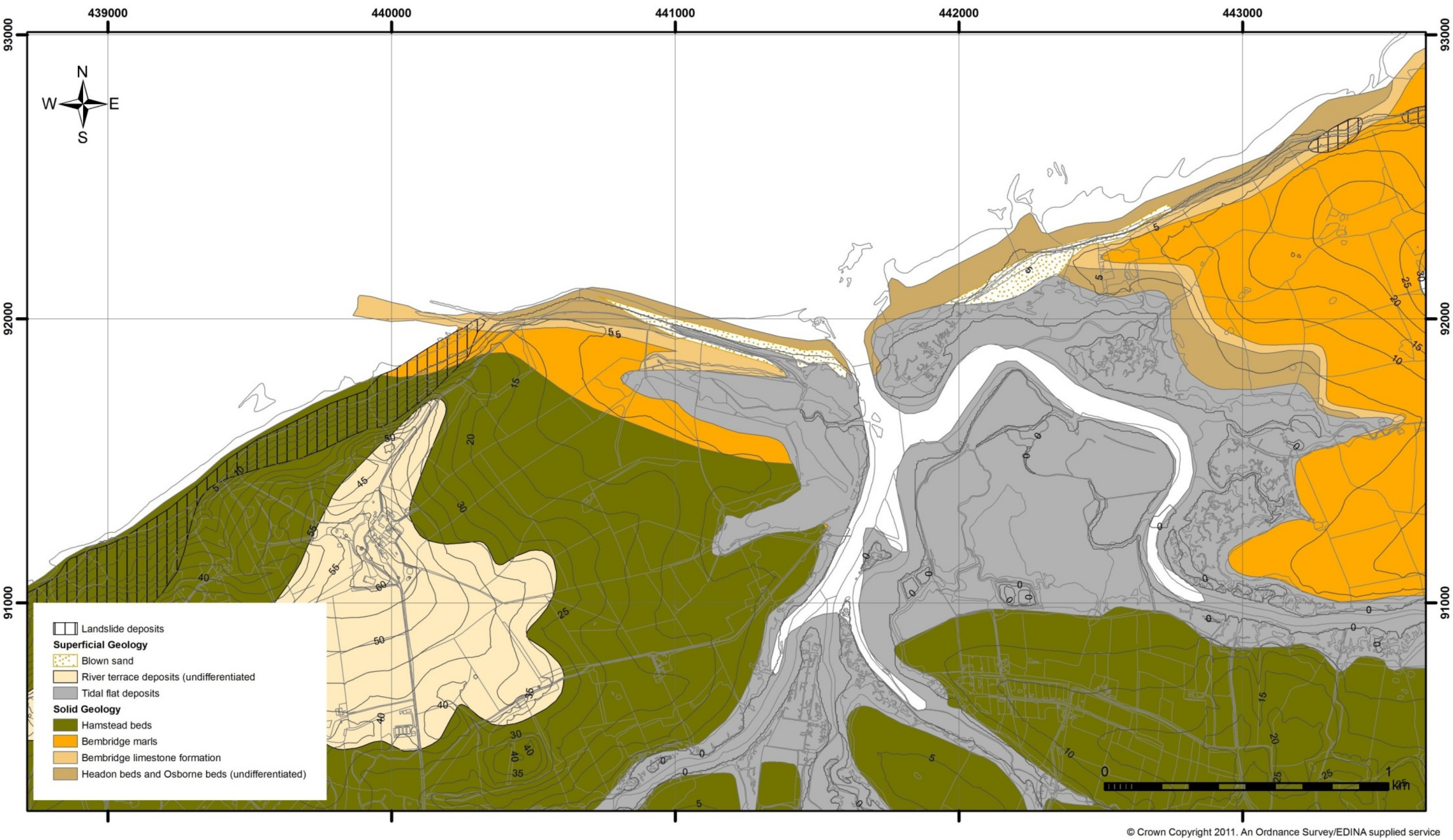

Figure 6.32Geology and contours in the Newtown Estuary study area

Figure 6.33 Aerial photograph of Newtown (© IWCAHES)

Whilst the medieval settlement focus is within the creek, evidence of prehistoric and Roman activity is found at the mouth of the estuary, particularly on the eastern spit. The local antiquarian Hubert Poole recorded stratified Mesolithic and Neolithic lithics on a buried land surface within the face of the spit (Poole 1936; Fig. 6.34). The site was visited during the Wootton-Quarr project and wooden structures including two corduroy platforms were recorded, one of which was radiocarbon dated (GU-5341, 2920-2500 cal BC, 4160±70BP). A palaeoenvironmental core sunk to a depth of -14.85m OD through the estuarine sediment provided evidence of sea-level rise and coastal change (Long *et al* forthcoming).

Figure 6.34 Newtown East Spit, from H.F. Poole's manuscripts (© IWCAHES)

The Isle of Wight Coastal Assessment Enhancement Project in 2008 provided a further opportunity to obtain radiocarbon dates for wooden structures on the spit (Loader 2009). Four structures, comprising three post alignments and one post group, were sampled (Fig. 6.35). The earliest, a post alignment, produced dates In the Neolithic period[2]. A longshore post alignment, IWHER 5398, was dated to 2200–1970 cal BC (GrN-31053, 3700±35BP; *Fraxinus* sp.) and 2290–2020 cal BC (GrN-31054, 3740±40BP; *Fraxinus* sp.). A third alignment produced less closely-matching dates of 110 cal BC – cal AD 1 (GrN-31051, 2050±15BP; Pomoideae), and cal AD 10–130 (GrN-31050, 1930±25BP; *Quercus* sp.). The difference in age might reflect either reuse or repair, a theory which was supported by the difference in character between the two posts (Fig. 6.36). The final structure, a setting of five posts was dated to 390–190 cal BC (GrA-37194, 2220±35BP; *Acer sp.*) and 360–175 cal BC (GrN-31052, 2185±20BP, Pomoideae).

[2] 2470–2210 cal BC (Sample no.1003602; GrN-31049; 3870±25BP; *Fraxinus* sp.) and 2300–2130 cal BC (Sample no.1003603(A), Salicaceae, SUERC-15818, 3770±40BP; Sample no.1003603(B) GrA-37196 replicate, 3820±35BP; Sample no.1003603, T' = 0.9, T'(5%) = 3.8, v = 1, 3798±26BP).

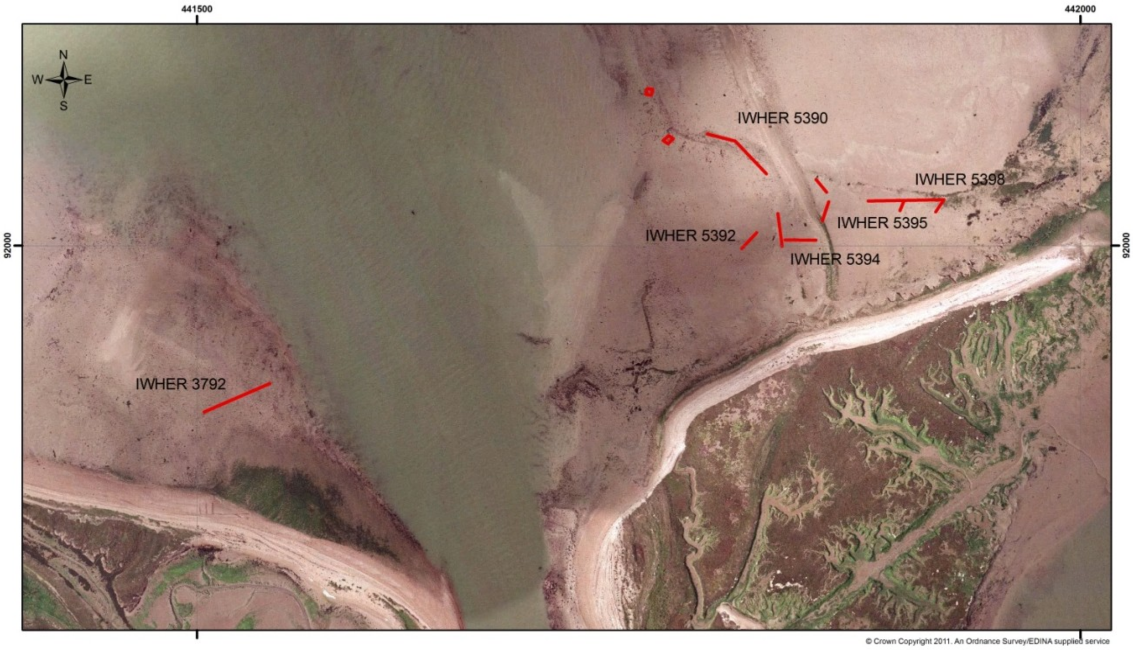

Figure 6.35 Intertidal wooden structures at the mouth of the Newtown Estuary

Figure 6.36 Sampled posts from post alignment IWHER 5398, Newtown East Spit (© IWCAHES)

At the mouth of the estuary on the western side, additional post alignments, peat deposits and lithic scatters have been noted but have not yet been scientifically dated or recorded in detail.

Much of the Newtown Estuary is owned by the National Trust. On the eastern side of the estuary lies the Jersey Camp ranges, owned by the South East Reserve Forces' and Cadets' Association. The estuary is located within the Hamstead Heritage Coast, and is protected by numerous environmental designations, being a Ramsar Site, SSSI, SAC, SPA and National Nature Reserve.

6.2 Assessment of means of measuring coastal change

The quantification of past shoreline change and prediction of future trends is an important aspect of coastal zone management, but it is acknowledged that there are many complex and interrelated factors acting on different timescales which contribute to coastal recession and accretion (Camfield and Morang 1996). In the past most researchers have used a combination of historic maps and aerial photographs, sometimes together with limited fieldwork, to make their predictions, believing that cartographic and photographic evidence is more objective than, for example, anecdotal evidence (Carr 1980). Most authors cite the same range of advantages and limitations to the use of both historic maps and aerial photographs.

6.2.1 Cartographic sources

The use of maps and charts for assessing coastal change has the advantage that they cover a longer timescale than other types of quantitative data such as photographs. They also should be reasonably objective and therefore more reliable than sources such as verbal accounts. However, there are many problems inherent to the use of cartographic sources. The earliest maps and charts are still only a few hundred years old, and the technical accuracy of both surveying and plotting can be questionable; it can be that the precision of the survey data is lower than that of the rates of change that are being measured. There may be a long time span between different maps or editions, and it is sometimes not noted whether stretches of coastline were resurveyed for later editions. Equally, maps have been amended sometimes without the survey date being changed (Carr 1980).

A further possible confusion is that the definition of the high and low water marks that are shown on maps and charts has changed over time. Ordnance Survey maps of England and Wales which were prepared prior to 1868 and all OS maps of Scotland show the high and low water marks of ordinary spring tides (Oliver 1993). However, since 1868, when the Poor Law Amendment Act specified that parish boundaries in England and Wales should be taken to the centre of rivers and to the low water mark, the high and low water marks of 'medium tides', defined as halfway between the spring and neap tides, have been depicted on Ordnance Survey maps. In the 1900s the 'ordinary, medium or mean' tides were 'generally surveyed or sketched at the fourth tide before the new and full moon' (Oliver, op cit, 72). By the 1930s, 'suitable dates' midway between neap and spring tides were selected on which to survey the high and low water marks. Winterbotham (1934) states that the high tide usually leaves a clear mark until the next high tide so can be surveyed with confidence, but the definition of low water mark 'cannot be vouchsafed to the same degree of accuracy'. Since 1945 the high and low tide marks have been surveyed from aerial photographs if ground survey would be difficult. Oliver (1993) concludes that it is very risky to use Ordnance Survey mapping for shoreline investigations at a scale less than 1:10560, whilst Carr (1980) also warns that when undertaking such investigations attention should be paid to the plotting accuracy of different map scales.

It is generally accepted that there is a need for data covering as long a period as possible when quantifying past shoreline change. However, as Carr (1980, 75) points out, long term records present an average; 'the sum but not the range of conditions that have been experienced'. They do not show the episodic nature of change at some locations, can provide no information on individual events or what might have triggered them (Rosser *et al* 2005) and it is difficult to relate short term to longer term trends. It has also been pointed out that past patterns of coastal erosion are the result of a unique combination of wave, weather and environmental conditions and are not necessarily an indication of future trends (Lee 2005, 89).

In addition to the problems of the definition and interpretation of mapped data, physical damage to paper maps, such as shrinkage, warping or damage can also cause errors, although these can to some extent be rectified.

6.2.2 Aerial photographs

Aerial photographic analysis can range from the use of uncorrected photographs to more precise measurements using computer rectified aerial or orthophotographs (Moore and Griggs 2002). One advantage of using aerial photographs is that they should be easy to interpret, although it can still be difficult to define the shoreline, for example the cliff edge may be rounded or obscured by vegetation (Moore and Griggs 2002). Inaccuracies can be increased by problems such as tilt and scale differences caused by the aeroplane's inability to fly at a constant altitude (Crowell *et al* 1991). Errors may be compounded by the inherent limitations of photography, such as lens distortion and other optical defects, and the stretching and warping of film and photographic paper, both during processing and subsequently (Thieler and Danforth 1994a). There may be relief displacement, creating distortion where higher than average features are displaced outwards from the centre of the image. The lack of land marks to assist in rectification of aerial photographs can be a particular problem in the coastal zone (Battiau-Queney *et al* 2003). This can be compounded when photographs which include a substantial area of sea are used. Control points are chosen on land, rather than being spaced across the whole area of the photograph, which can distort the resulting image (Thieler and Danforth 1994b). Seasonal changes can give false impressions and it is important to compare photographs taken at the same time of year, and not after extreme events such as storms.

The rectification of aerial photographs can also be of variable accuracy. The simplest rectification process, that of georectification, identifies a number of control points which are preferably sharp and unambiguous and matches them to the same features on a map. More accurately, orthorectification drapes the image over a digital elevation model which reduces the errors caused by relief displacement. Using larger scale aerial photographs can make it easier to identify control points, but at the same time this reduces the amount of control points visible in one image, and once again, these will be concentrated on the landward side of the photograph.

Thieler and Danforth conclude that 'Historical shoreline change studies are fundamentally limited by the accuracy of the techniques and materials used to acquire geographic shoreline position data… As long as historical maps and aerial photographs are used in shoreline change studies, there will be a considerable amount of technological error, on the order of several metres, present in shoreline position and rate-of-change calculations' (1994a, 562). In order to redress some of these inaccuracies, they devised two software packages. The first, the Digital Shoreline Mapping System (DSMS), enables pre-processing of aerial photographs to remove distortion errors, triangulation, and error analysis (Thieler and Danforth 1994b). The second, the Digital Shoreline Analysis System (DSAS), is a method of producing shoreline rates of change at user defined intervals along the coastline (ibid; Himmelstoss and Miller 2005), although the programme cannot be used to predict future rates of change.

6.2.3 Remotely sensed data

Airborne remote sensing

The use of remotely sensed data for determining coastal change has become more widespread in recent years. In the past, when only a limited amount of data was available, remote sensing had been relatively unsuccessful in the coastal zone (Cracknell 1999). Satellite data had been of poor spatial resolution and coverage was infrequent, while the use of aerial photographs only allowed small, accessible areas to be studied. However, in the past decade, advances in technology including GIS and LiDAR have enabled better quality data to be more readily available, and the processing of data is within the capabilities of most computer systems. Giordano and Gelpke (2003) highlight the potential of GIS in mapping coastal change, but also draw attention to the challenges of dealing with unknown positional accuracy and ‘fuzzy data’ when using this technology.

LiDAR

LiDAR is a remote sensing technique which uses laser pulses to measure distance. A pulsed laser beam is scanned from side to side from an aircraft and the time taken for each pulse to be reflected from the ground back to the aircraft is recorded and can be converted to a distance. High precision GPS is used to ensure that accurate position and altitude measurements for the aircraft are available. The density of data readings is dependent on the height and speed of the aircraft, the scanning angle, the scan frequency and the number of passes made by the aircraft (Devereux *et al* 2005), and will vary according to the purpose of data collection. A typical flying height of 1000m will produce data in a swathe of approximately 700m width, which is widely held to be ideal for surveys of the coastal zone (Channel Coastal Observatory, 2003a).

LiDAR is used by the Environment Agency to assess flood risk and to monitor coastal erosion (Environment Agency, not dated). The data collected by the Environment Agency is being made more widely available for other uses, both through licensing and through portals such as the Channel Coastal Observatory. This technique offers enormous potential, and has performed favourably in monitoring coastal change when compared with photogrammetric survey (Adams and Chandler 2002, Saye *et al*, 2005), but its effectiveness and accuracy is still being evaluated. It also has the disadvantage that the technique is relatively new, and therefore the available data do not cover the same sort of timescale that even aerial photography can offer. However, it is possible to use LiDAR in conjunction with photographs that have been scanned photogrammetrically and processed to extract digital elevation models (DEMs), as was carried out on the North Yorkshire coast to assess landslide hazards (Miller *et al* 2008). Here, the accuracy of both datasets was checked against a series of ground control points which had been surveyed by GPS.

Use of LiDAR in archaeological survey

LiDAR has been used in several landscape-scale archaeological surveys, notably those of the Stonehenge World Heritage Site (Bewley *et al* 2005), the Salisbury Plain Training Area (Barnes 2003), and Loughcrew, Ireland (Shell 2005). It has also been assessed for archaeological purposes alongside conventional aerial photography, for example during NMP projects covering the Mendip Hills AONB, the Savernake Forest and the Witham Valley, Lincolnshire (English Heritage undated d and e; Crutchley 2006) and the two techniques have been found to be complementary. The value of LiDAR lies not only in its ability to reveal upstanding archaeological remains but it has also been used successfully to map geomorphological and geoarchaeological features (Challis 2006). A further advantage of LiDAR over aerial photography is the ability to filter out features such as buildings or trees, making it ideal for use in woodland environments (Devereux *et al* 2005; Crow 2008). Its value as a tool for enhancing HER data with its ability to produce three-dimensional images which can easily be manipulated within a GIS has been recognised, although the high cost of data is seen as a disadvantage, which nevertheless may be overcome if LiDAR surveys are commissioned corporately rather than just for archaeological purposes (Challis *et al* 2008).

LiDAR has in the past had limited use in coastal archaeological surveys, although data from a 2 x 2km sample area were assessed for the RCZAS for the Severn Estuary (Mullin 2005). It was found that in the intertidal zone, although some new sites were identified, LiDAR was disappointing. This was explained by the resolution of the LiDAR data, the ground conditions at the time of survey, and the ephemeral nature of intertidal sites. However, it was felt that LiDAR could be particularly useful for monitoring sites in inaccessible or dynamic environments, and where aerial photographs had not previously been taken specifically for archaeological purposes (Truscoe 2008). LiDAR data were made available in JPEG format for the area of the North East Coast RCZAS but were not used, partly because most of the data were collected at high tide, but also because as it was felt that the resolution of the data in this format was insufficient to show any but the most robust archaeological features (Bacilieri *et al* 2008; Tolan-Smith 2008). The RCZAS for Donna Nook to Gibraltar Point did not examine LiDAR data but recommended a further phase of work incorporating fieldwork and aerial photographic analysis to NMP standard, including an assessment of LiDAR data for select areas (Buglass and Brigham 2007a). Previous use of LiDAR in a coastal archaeological context has been largely restricted to locating palaeoenvironmental features such as relict river channels (for example Brunning and Farr-Cox 2005). In Northern Ireland, the potential of LiDAR for coastal geomorphological and archaeological mapping is being assessed (McNeary and Westley 2010). Preliminary results suggest that the technique is not suitable for revealing archaeological features, but has high potential for mapping geomorphological features such as raised beaches and old river courses which might have been foci for human activity in the past.

Terrestrial photogrammetry

Terrestrial photogrammetry has been used as a more rapid ground-based method of gathering data and has the advantage that it can also provide additional visual comparative data. However, lens distortion, light conditions, and the steepness of the viewing angle can cause errors, particularly when measuring steep cliffs (Rosser *et al* 2005).

Terrestrial laser scanning

Terrestrial laser scanning (TLS) is now being used increasingly in the survey of landslide complexes, for mapping sand dunes, and in studies of cliff recession. According to Rosser *et al* (2005), its many advantages include speed and precision of data acquisition, the ability to survey hazardous and inaccessible locations, and relatively low cost. This means that surveys can be repeated regularly and when necessary. Unlike assessments of cliff recession made using maps or aerial photographs which usually only consider the movement of the cliff top and toe, this technique looks at the whole of the cliff face, and when compared with LiDAR, produces results at a much higher resolution (French and Burningham 2009). This creation of detailed surface images assists the interpretation of different types of cliff failure (Poulton *et al* 2006).

6.2.4 Ground survey

Traditional surveying methods, for example using total station theodolite, have been used both independently and as a means of ground-truthing results gained by other means, such as aerial photography or LiDAR. The most simple ground survey method is that carried out using a dumpy level. Whilst frequently used for archaeological survey, the equipment being cheap and easy to maintain, the technique has also been used to produce beach profiles during coastal monitoring programmes (Channel Coastal Observatory 2003b), when heights were measured along a pre-determined line. However, the results require considerable post-processing and errors are a particular problem on steeply sloping foreshores, where the equipment has to be moved and reset frequently.

The use of total station theodolite has proved invaluable for coastal survey, particularly because it produces three-dimensional measurements, and indeed, intertidal surveys such as that undertaken at Wootton-Quarr would have been virtually impossible without such equipment. The theodolite has a relatively long range, but this can be impeded by inclement weather conditions. It has also been said that the use of total station theodolite is hampered by the operational difficulties created by low light levels which is a problem in the coastal zone because survey needs to take place at low tide, often early in the morning or in the evening (Channel Coastal Observatory 2003b). Although undoubtedly this does slow down the process, personal experience has shown that this can be overcome reasonably successfully by the use of torches and two-way radios. We have encountered more difficulties through extreme cold causing the tripod legs of the theodolite to contract, or the buffeting of strong, gusty winds which moves the theodolite off-level.

GPS is now widely used for beach survey, being both accurate, and rapid and easy to use. It has the advantage that it can be used in most conditions although the equipment is perhaps less robust in the intertidal zone, having electronic components. Generally, the open coastal landscape is ideal for this type of surveying since an adequate number of satellites are usually visible, although patience may be required when surveying near cliffs.

The development of survey grade GPS and total stations with automatic tracking have simplified the process of surveying in the coastal zone, but in comparison with other methods ground survey has been said to be ‘rather crude and spatially restricted, labour intensive and require prolonged direct contact with potentially hazardous terrain’ (Miller *et al* 2008, 530).

Survey in the intertidal zone is particularly problematic since it is governed by tides, which means that the time available for fieldwork can be severely restricted. It can be difficult to complete surveys within one tidal window or even a block of suitable tides. As a result it is quite possible that storm events or even as little as a change in wind direction can alter the configuration of intertidal features mid-way through the survey.

One task of the Wootton-Quarr project and the Beach Monitoring project which followed was the biennial survey of the beach to the north east of the Fishbourne ferry terminal using total station theodolite (Motkin forthcoming; Loader 2008). The survey usually took place over between three to five of the lowest tides during the spring months and the methodology used was for the worker holding the prism to carry out traverses along the water line, following the tide as it went out and came back in, recording points at intervals of *c* 5m but more closely spaced where changes in relief were more marked. Each year's dataset was processed to create a digital terrain model which was then imported into to IDRISI software for manipulation. The results were illustrated using contour plots, hillshade diagrams and plots of level change, and the net volume loss and maximum cut and fill heights were calculated. Whilst the results unquestionably showed significant changes to the beach topography, identifying both falling beach levels and sediment being redistributed, the survey did not directly measure heritage-loss, and it could not be used to demonstrate the effects of changes in beach topography on specific, individual archaeological features. It has been estimated that the topographic survey covered less than 3% of the total Wootton-Quarr survey area (Loader 2008); to survey the whole of the project area using this method would not have been feasible.

6.2.5 Use of archaeological sites to predict coastal change

There have been some attempts to use archaeological data to predict rates of coastal recession, for example by examining fish traps in intertidal zone (Allen 2002, Momber 1991). However, Allen advises that caution should be exercised when using archaeological features for this purpose for several reasons. Erosion of the lower foreshore is continuous and it is likely that structures were originally more extensive than is now demonstrable. Structures such as fish traps could have been set up at some distance from the cliffline, which would exaggerate the apparent rate of cliff recession, although they may be a more useful indicator of the contemporary low water mark as they would by necessity have been accessible to empty on most low tides. They may have been in use over a long time and may have been repaired, thus sampled timbers may be later than the original structure, and the available dating evidence may be of variable quality. It is also possible that structures may not have been originally constructed in the intertidal zone, for example where they are located within palaeochannels.

6.3 Details of datasets used in this study and how they were processed

A list of the datasets used is found in Table 6.2 below.

6.2 Sources used in this thesis

Cartographic sources

John Speed 1611	www.iwight.com/library/record_office/images/Speed.jpg
Captain Greenville Collins 1693	www.geog.port.ac.uk/webmap/hantscat/html/h0106815.htm
Isaac Taylor's 1 inch to 1 mile map of Hampshire 1759	www.geog.port.ac.uk/webmap/hantsmap/hantsmap/taylor4/taylor4.htm
Ordnance Survey unpublished 6 inch to 1 mile 1793	IWHER
Ordnance Survey 1:2500 County Series First Edition (1862)	Digimap
Ordnance Survey 1:2500 County Series First Revision (1898)	Digimap
Ordnance Survey 1:2500 County Series Second Revision (1909)	Digimap
Ordnance Survey 1:2500 County Series Third Revision (1942)	Digimap
National Grid 1:2500 1943-1995 map edition (1976)	Digimap
Ordnance Survey MasterMap	Digimap

Aerial photography

RAF 1946	IWHER
BKS 1971	IWHER
Environment Agency (Meridian Airmaps) 1983	IWHER
Environment Agency (Aerofilms) 1997	IWHER
Environment Agency 2001	Channel Coastal Observatory
Environment Agency 2005	Channel Coastal Observatory

LiDAR

November 2004 (2m resolution)	Channel Coastal Observatory
November 2005 (2m resolution)	Channel Coastal Observatory
October-December 2007 (1m resolution)	Channel Coastal Observatory
February 2008 (1m resolution)	Channel Coastal Observatory
15-16 January 2009 (1m resolution)	Channel Coastal Observatory

Monuments

IWHER GIS monument data	IWHER
Scheduled monuments	services.english-heritage.org.uk/NMRDataDownload/
Listed Buildings	services.english-heritage.org.uk/NMRDataDownload/

6.3.1 HER data

Data for sites within a distance of 500m of the coast and within the intertidal zone were obtained from the Isle of Wight HER. Due to the circumstances and methods of recording the sites originally most sites are recorded as point locations rather than polygons and their extent cannot easily be assessed. Many sites are located to an accuracy of only 10 or 100m.

Archaeological sites and features discovered during the nineteenth and early twentieth century were originally plotted on to six inch to one mile Ordnance Survey maps which were maintained by the honorary curators of Carisbrooke Castle Museum (Fig. 6.37).

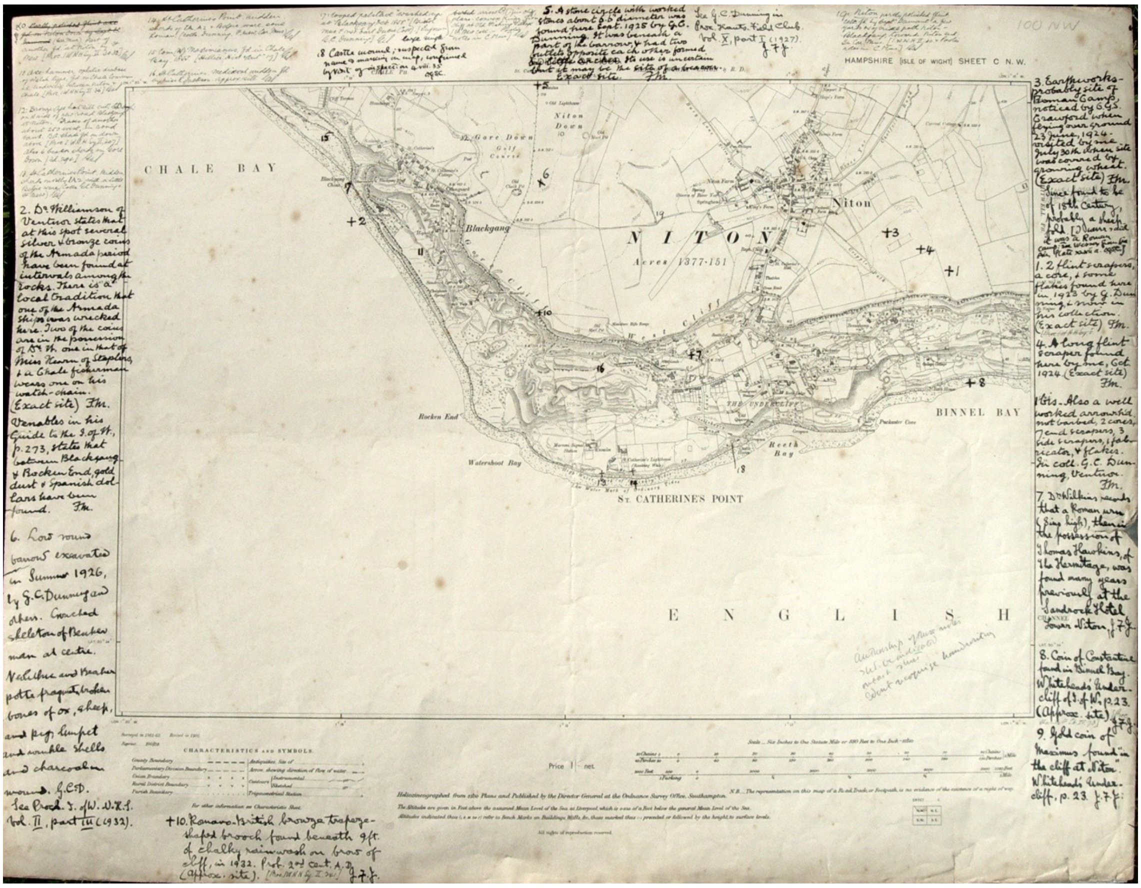

Figure 6.37 Carisbrooke Castle Museum record map of the area around St. Catherine's Point

When the Isle of Wight Sites and Monuments Record was established in the early 1980s these maps together with the national Ordnance Survey record cards formed the basis of the record and were used to estimate the locations of sites. This means that the recorded grid references are the result of an estimate made by the original compilers of the Carisbrooke Castle Museum maps followed by an interpretation of this estimate made some 50 years later by the SMR Officer using more recent maps. Sites on the Isle of Wight coast only started to be located with a reasonable degree of accuracy when, firstly, access to total station theodolite, and then GPS, became available from the very late 1980s onwards.

In order to create a shapefile with the relevant data behind it, a query was built within the HER database (HBSMR) to extract basic information which was then saved as an Access table. The table included the fields HER Number, Site Name, Description, Date, Eastings, Northings, Land Use, and Condition/date (see Appendix 2).This was then manipulated in ArcCatalog to create an ArcView shapefile of point data for sites that were within 500m of the coast or, to seaward, in the intertidal zone, whichever distance was greatest (Fig. 6.38). These data could then be interrogated within ArcMap.

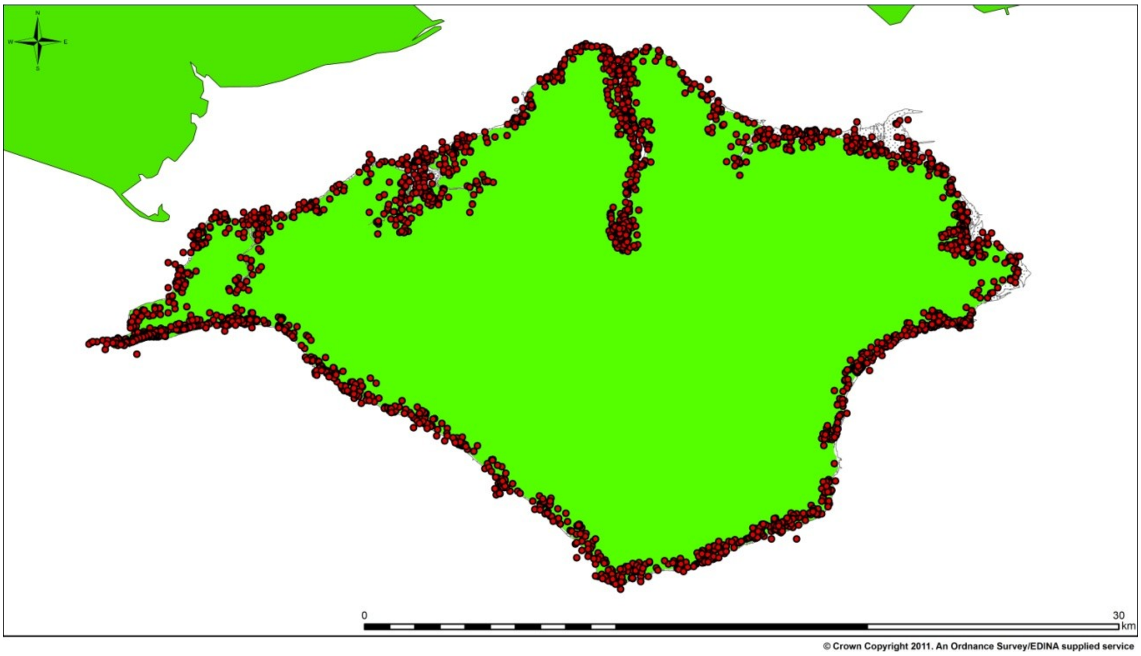

Figure 6.38 HER data within 500m of the coast, or to seaward, in the intertidal zone, whichever distance is greatest

6.3.2 *Survey data*

A limited amount of more detailed survey data were also available through the Isle of Wight HER. Some stretches of the coast, for example the Wootton-Quarr coast, had been surveyed extensively, whilst others had been examined during the Isle of Wight Coastal Audit and subsequent projects. As well as more detailed surveys of individual sites and structures, some features and limited stretches of coast had been surveyed repeatedly over several years (Loader 2008).

6.3.3 Cartographic sources

The Isle of Wight HER also holds a range of early maps from which a selection was made of maps which were either available digitally or which could be photographed and placed into a GIS. The aim was to assess whether there is any value in attempting to use such sources to quantify rates of coastal erosion and destruction of coastal archaeological sites.

Figure 6.39 John Speed's map of the Isle of Wight

The earliest map which was felt to show adequate detail was John Speed's map of the Isle of Wight, published as part of *The Theatre of the Empire of Great Britaine* dating from 1611 (Fig. 6.39). A digital copy of the map was downloaded from the website of the Isle of Wight Record Office.

In the late seventeenth century, Captain Greenville Collins was appointed to survey the coast of the British Isles by Samuel Pepys, who was Secretary to the Admiralty during the reign of Charles II. The resulting set of 48 charts, including one of the Isle of Wight and Hampshire coast (Fig. 6.40), was published as *Great Britain's Coasting Pilot* in 1693 (West 2008).

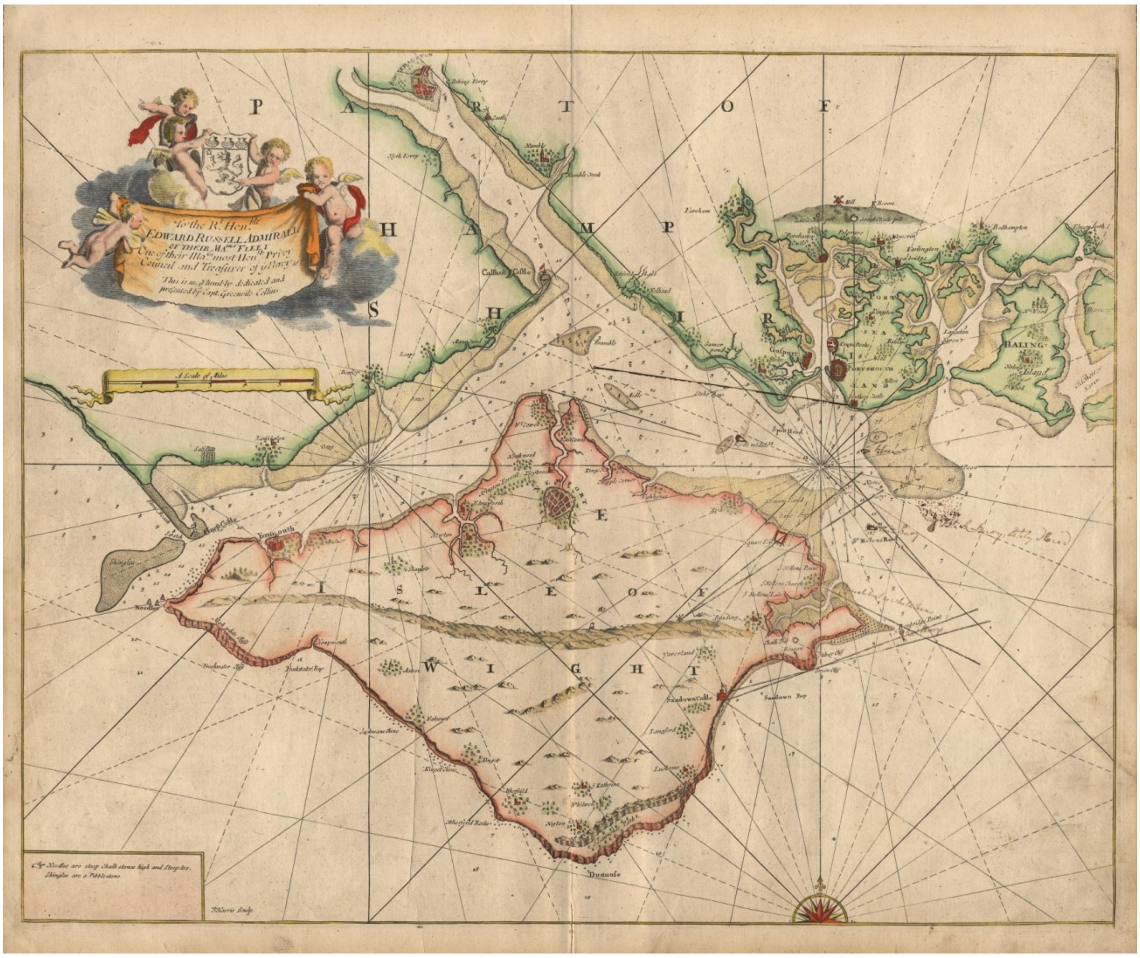

Figure 6.40 Captain Greenville Collins' chart of the Isle of Wight and the Hampshire coast

The next map examined was Isaac Taylor's 1 inch map of Hampshire dating from 1759, which displays more detail than the maps of Speed or Greenville Collins (Fig. 6.41).

Figure 6.41 Detail from Isaac Taylor's 1 inch map of Hampshire showing the north east coast of the Isle of Wight

Unlike many parts of the country, which were mapped at a smaller scale, there is available for the Isle of Wight the unpublished six inch to one mile Ordnance Survey dating from 1793. There are two versions of the map, the field sketches which are stored in the National Archives and the finished drawings which are found in the British Library (Basford 2008). A digital copy of the maps held by the British Library was obtained by the Isle of Wight Council in 2004. The maps are not georeferenced.

In order to make a direct comparison between the various antiquarian maps and the modern Ordnance Survey, it was first necessary to place each map at the same scale within a GIS, and to correct errors of distortion where possible. This was done by rectifying the image using the ArcView Georeferencing Tool. To achieve this, the raster image was loaded into ArcMap and the command ‘fit to display’ was carried out. A number of control points were selected and matched with the same features on an overlain modern Ordnance Survey MasterMap layer. For the Speed map and Greenville Collins chart, these were restricted to major buildings such as churches or fortifications, but it was possible to use a wider range of distinctive features on the unpublished Ordnance Survey. In an attempt to minimise errors, where possible control points were selected to cover the entire area of the raster image, in particular spread around the edges of the image and spaced throughout its interior (Fig. 6.42). ArcView allows three orders of transformation to be carried out. When georeferencing the small scale maps of the whole island it was found that a first order transformation produced the most satisfactory results.

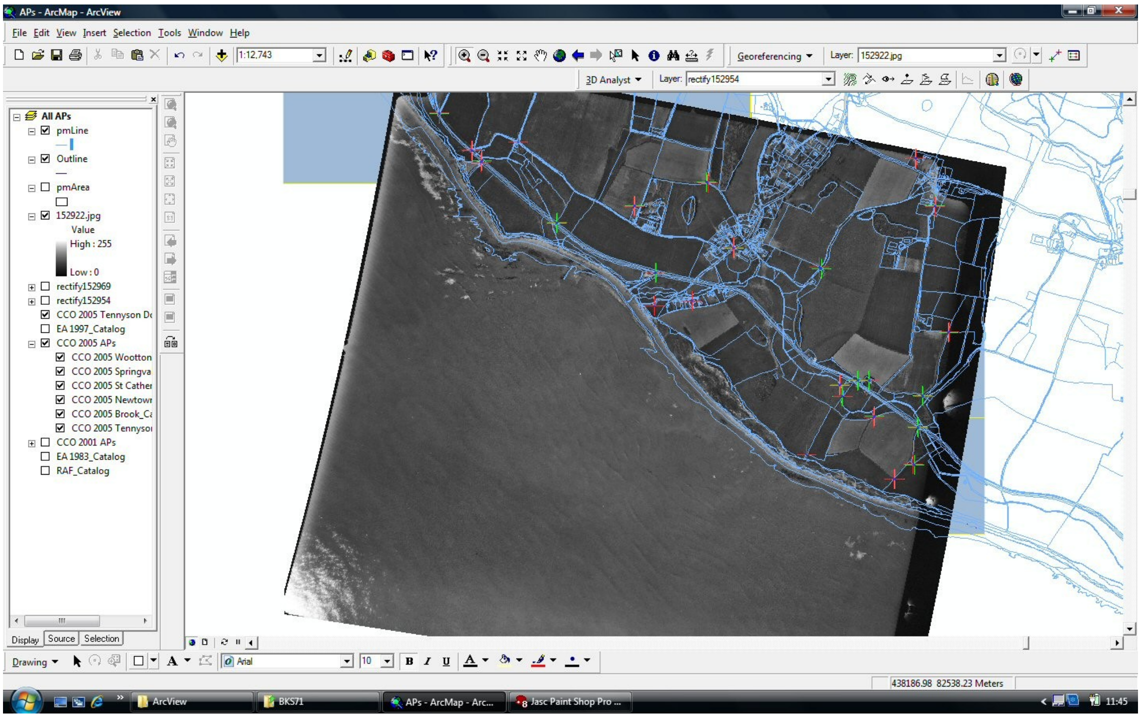

Figure 6.42 Example of georectification tool in use

Ordnance Survey digital historical mapping at 1:2500 is readily available and was downloaded from Digimap as GIS raster images covering five epochs of mapping; the County Series First Edition (1862), first, second and third revisions (1898, 1909 and 1942), and the National Grid 1:2500 1943-1995 map edition (1976). The features being examined in this study (i.e. low water mark, high water mark and coastline) were found to not to have been updated comprehensively for the latest MasterMap digital mapping so the National Grid 1:2500 edition mapping was subsequently not included.

For each map edition, the low water mark, high water mark, and coastline, were digitised as individual ArcView shapefiles (see figs. 7.6 to 7.11). Within the six individual survey areas, measurements were then made at 100m intervals perpendicular to the coast using the low water mark, high water mark or coastline shown on the first edition map as a base line. The results were input into an Excel spreadsheet for analysis (Appendix 1).

6.3.4 Aerial photographs

A number of sets of vertical aerial photographs are held by the Isle of Wight HER, the earliest of which dates from 1946 (Table 6.3). Copyright does not allow the photographs to be reproduced but scans were used for this study. Two further sets of orthorectified photographs were downloaded from the website of the Channel Coastal Observatory.

Table 6.3 Sources of aerial photography

Source	**Date flown**
RAF (IWHER)	12 July 1946
BKS (IWHER)	1971
Environment Agency (Meridian Airmaps)	11 July and 13 August 1983
Environment Agency (Aerofilms)	23 July 1997
Channel Coastal Observatory (Environment Agency)	6 and 7 July 2001
Channel Coastal Observatory (Environment Agency)	23 and 24 July 2005

6.3.5 LiDAR

For the purpose of this study, LiDAR data were examined with the aim of assessing how useful these data are for identifying archaeological sites and features in the intertidal and coastal zone, and to evaluate the use of LiDAR to quantify heritage loss through both lateral and vertical erosion. In this study I chose to look at areas with which I am already familiar and which have been surveyed on the ground previously in order to establish how archaeological features might show up in a variety of coastal settings.

Data covering the study areas on the south west coast of the Isle of Wight (Brook, St. Catherine’s Point and Tennyson Down) were available for download from the website of the Channel Coastal Observatory (www.channelcoast.org/). Raw data in ASCII grid format covering two years, 2004 (flown 11-12 November 2004) and 2005 (flown 4-16 November 2005), were downloaded. LiDAR surveys of the north coast of the island were not available from the website at the time when data were originally being collected for this study, so a request was made to the Environment Agency, and 4 tiles of 2km x 2km covering the coast at Wootton-Quarr and Springvale (flown 4th November 2005) were provided on CD. These have since been made available via the Channel Coastal Observatory. Further surveys flown in 2007, 2008 and 2009 were also subsequently downloaded from this source (Table 6.4 and Fig. 6.43). Data from these later flights were gathered at a higher resolution than the original surveys, which meant that an additional assessment could be made of how much more useful for archaeological purposes the more detailed survey results might be.

Table 6.4 Details of LiDAR data used

Survey area	**Date flown**	**Resolution**	**Source**
Tennyson Down	11-12 November 2004	2m	Channel Coastal Observatory
	14-16 November 2005	2m	Channel Coastal Observatory
	31 October-1 November 2007	1m	Channel Coastal Observatory
	14-16 January 2009	1m	Channel Coastal Observatory
Brook	11-12 November 2004	2m	Channel Coastal Observatory
	14-16 November 2005	2m	Channel Coastal Observatory
	31 October-1 November 2007	1m	Channel Coastal Observatory
	15-16 January 2009	1m	Channel Coastal Observatory
St Catherine's Point	11-12 November 2004	2m	Channel Coastal Observatory
	14-16 November 2005	2m	Channel Coastal Observatory
	10-11 December 2007	1m	Channel Coastal Observatory
Springvale	4 November 2005	2m	Environment Agency
	8-9 February 2008	1m	Channel Coastal Observatory
Wootton-Quarr	4 November 2005	2m	Environment Agency
	8-9 February 2008	1m	Channel Coastal Observatory
Newtown Estuary	9-10 February 2008	1m	Channel Coastal Observatory

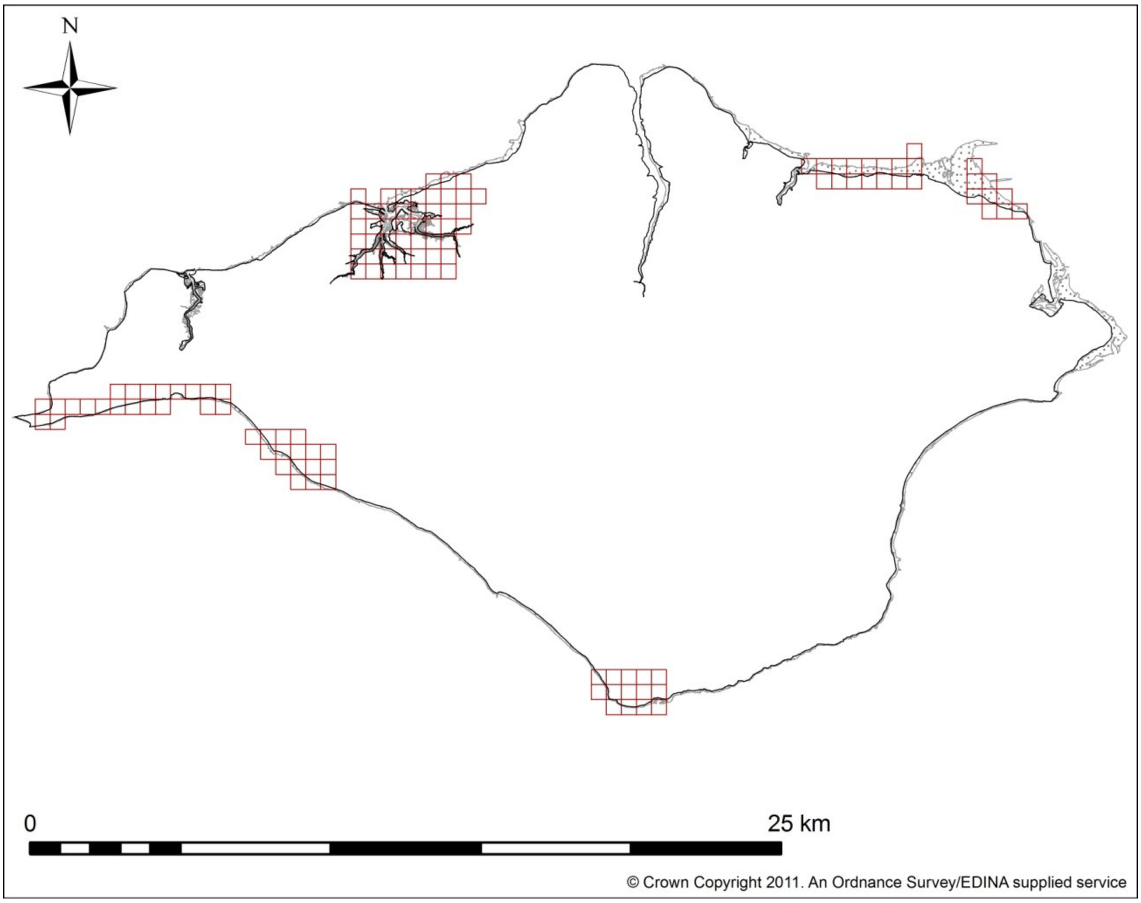

Figure 6.43 Downloaded LiDAR data tiles

The ASCII files were converted to comma delimited text using an ASCII grid to XYZ text file converter (Ascii2xyzV3.exe) which was supplied with the data from the Environment Agency. This produced a text file of three dimensional grid references at 2m intervals (1m intervals for the later flights) from which a shapefile comprising a grid of point data was created in ArcCatalog.

Using the command *Create/Modify TIN* within ArcView's 3D Analyst extension, the shapefile of three dimensional point data was used to create a digital terrain model by means of a Triangular Irregular Network (TIN; Fig. 6.44). This could then be manipulated using additional commands in the ArcView 3D Analyst extension (for example Cut/Fill, and Hillshade). The display could be changed by altering the TIN's Symbology properties such as changing the colour ramp, the number of colours/shades displayed, and the interval between height ranges that were displayed similarly. Within the display, the direction and angle of illumination could also be adjusted. The TIN could then be viewed in conjunction with the other data which had been loaded into the GIS, including shapefiles of archaeological data in the form of HER and survey files, aerial photographs, and cartographic data.

6.4 Summary of choice of study areas and methodology

The range of data collected allowed an assessment of both erosion rates and loss of heritage assets to be made, and enabled multiple datasets to be viewed in combination within a GIS. Areas for detailed study were chosen which, although within a spatially restricted area, were felt to be representative of at the minimum the whole of Southern England, and arguably a much wider area, being faced with a varied but not unusual range of coastal issues and threats, and with a relatively well understood archaeological resource. The study areas were specifically chosen because I have first-hand knowledge of their archaeology and geomorphology. I felt that this would allow a better and more realistic understanding of the limitations and uncertainties both of the methodology employed and of the results.

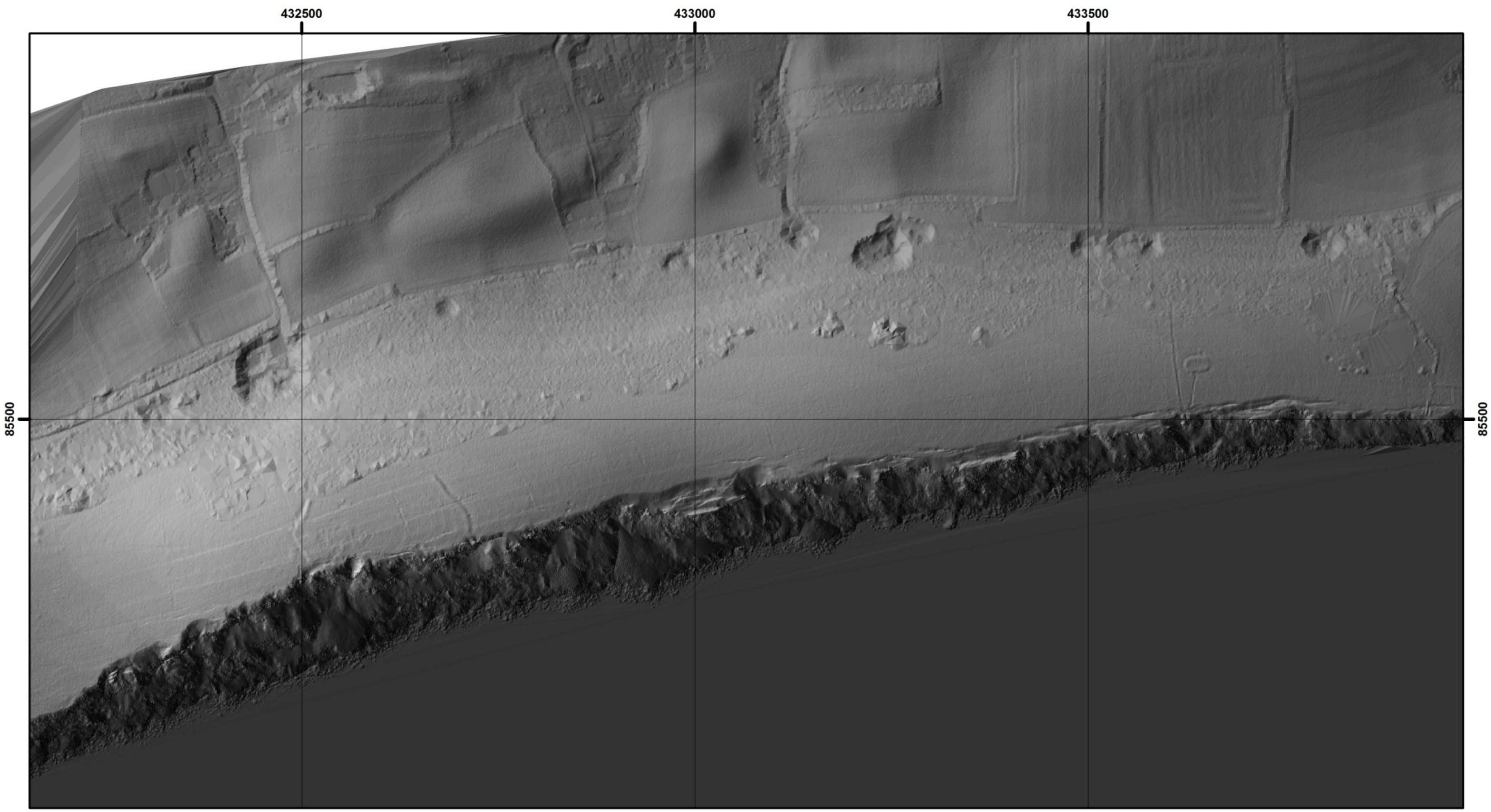

Figure 6.44 LiDAR data from the Tennyson Down – High Down survey area viewed as a TIN (data courtesy of the Channel Coastal Observatory)

7 Results

7.1 Introduction

This chapter will present the results obtained by the use of maps, aerial photographs and LiDAR data within a GIS to calculate past rates of coastal erosion, and will discuss the shortcomings of using such methods. The value of the use of HER data in the quantification of coastal heritage loss will be discussed, and the application of the various methodologies in the six case study areas will be appraised.

7.2 Using cartographic sources to calculate coastal erosion rates

The earliest maps available for this study were the relatively small scale maps and charts dating from the seventeenth century surveyed by cartographers such as Speed and Greenville Collins. These have been found to be of limited value for quantifying coastal loss. A major problem is encountered when attempting georectification of this type of map as the lack of suitably placed control points can result in a very skewed image. Also at this scale, those control points that are available, generally churches and fortifications, are totally out of proportion with the rest of the map so they cannot be used with any degree of accuracy. Yarmouth Castle is a good example of this, being depicted on the Greenville Collins chart at proportionally more than twenty one times its actual size (Fig. 7.1).

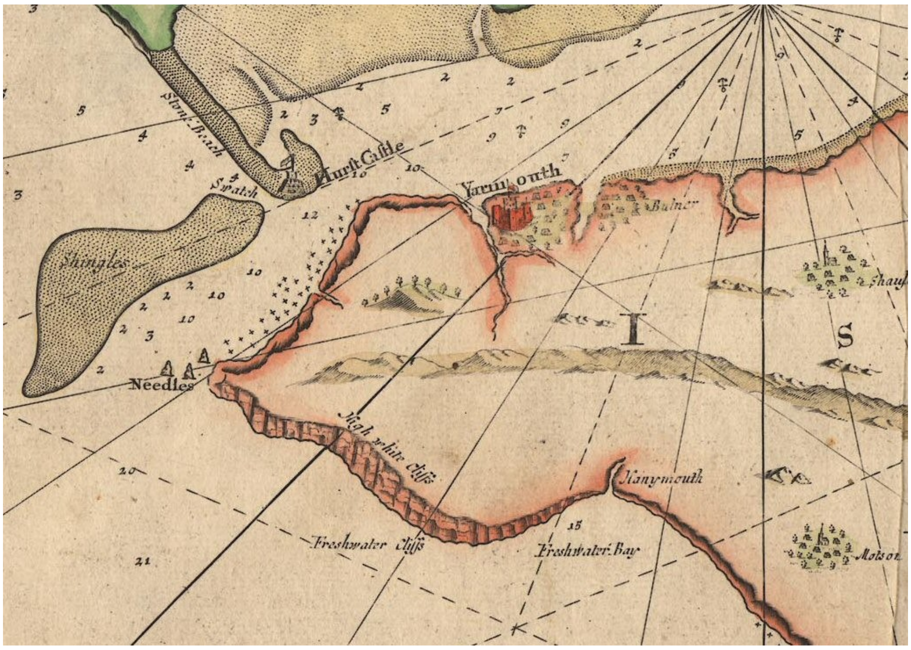

Figure 7.1 Yarmouth Castle as portrayed on the Greenville Collins chart of 1693

Dating from 1759, Isaac Taylor's map of Hampshire, including the Isle of Wight, is drawn at a scale of one inch to one mile. While this map is more detailed than those of Greenville Collins or Speed, it is not of sufficient accuracy to allow a comparison of the position of the coast (Fig. 7.2). One problem is that there are too few reference points near the coast to allow confident rectification.

Figure 7.2 Attempted rectification of the Isaac Taylor map viewed against MasterMap mapping for Brook and St. Catherine's Point

The 1793 Ordnance Survey unpublished six inch to one mile survey of the Isle of Wight is a more accurate representation and can to some extent be georectified and overlain with the modern Ordnance Survey by matching up distinctive buildings and field patterns. However, the degree of accuracy is again not sufficient for the coast to be plotted reliably, and many of the field patterns adjacent to the coast cannot be matched with any certainty. This is especially true for the south west coast of the island which has changed dramatically since the construction of the Military Road in the 1860s (Fig. 7.3), and where there are few other reliable control points on the coast.

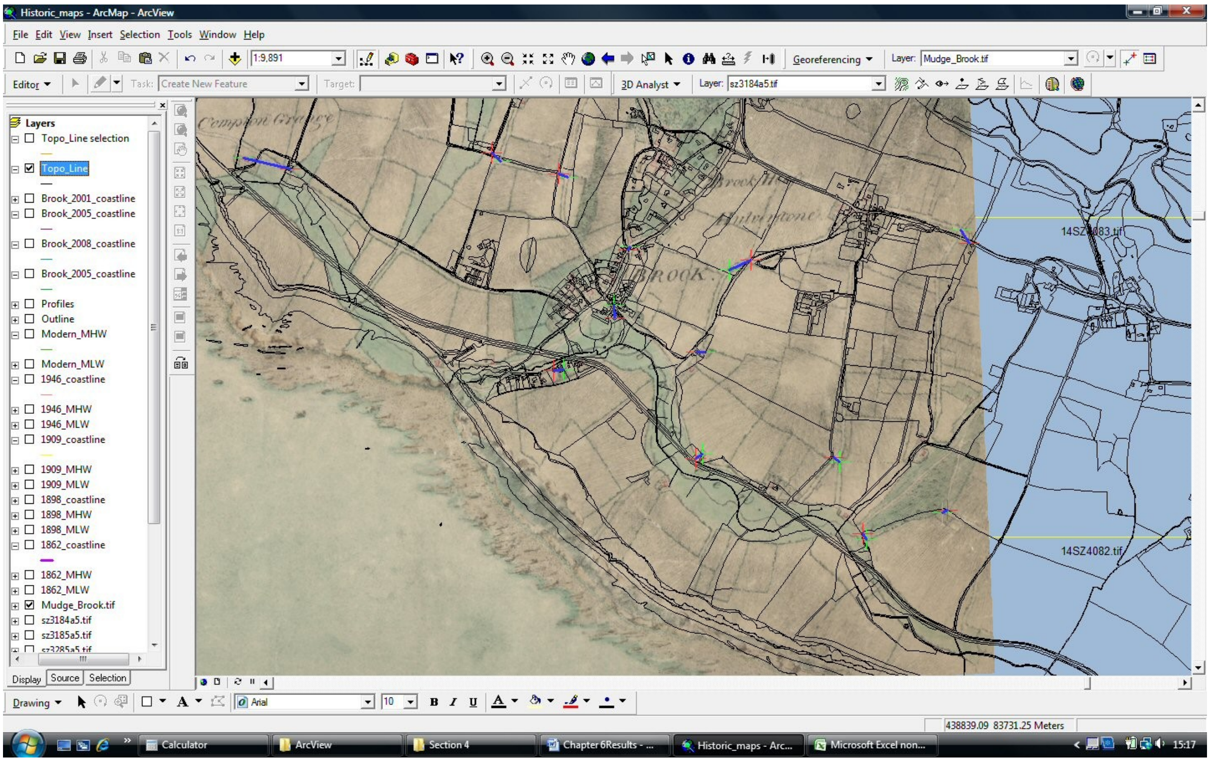

Figure 7.3 The georeferenced 1790s OS unpublished survey for the area around Brook Chine with modern digital mapping superimposed

The Ordnance Survey maps dating from the mid-nineteenth century onwards are more reliably accurate and are available digitally for input directly into a GIS, although it is necessary to allow for a margin of error when comparing different editions of mapping. The Ordnance Survey suggests that an error margin of 5m should be allowed for when using the County Series (pre-1945) maps, and for the National Grid maps (post-1945) an error margin of 3.5m (cited in FutureCoast, 2002). This can be a problem when using the maps to calculate rates of coastal erosion.

For this study, six stretches of coast of different character were examined in detail, and the low water mark, high water mark and coastline were plotted from the First Edition County series (1862), First County Series Revision (1898), Second County Series Revision (1909), Third County Series Revision (1946), National Grid (1970s) and modern (MasterMap) 1:2500 digital OS mapping which was obtained from the Edina Digimap service. The available coverage for the 1946 and 1970s mapping was incomplete, although a better coverage was available for the 1970s edition at a scale of 1:10,000. On much of the coast there was generally little discernable difference between the mapping dating from the 1970s and the modern mapping (Table 7.1). This does raise questions about the validity of attempting to calculate annual rates of coastal recession using cartographic sources that may not have been revised for more than 30 years, almost a quarter of the entire time span of available Ordnance Survey mapping. The most recent mapping available was the MasterMap edition which had last been modified in 2009.

Table 7.1 Differences in the depiction of the low water mark, high water mark and coast edge, between the 1970s Ordnance Survey mapping and MasterMap (2009)

	Mean Low Water	**Mean High Water**	**Coastline**
Tennyson-High Down	Very minor differences	Very minor differences	Minor differences to west, more change to east
Brook	Unchanged	Unchanged	Changes
St Catherine's Point	Unchanged	Significant differences	Significant differences
Springvale	Minor differences	Minor differences due to coastal defence works	Minor differences due to coastal defence works
Wootton-Quarr	Unchanged	Unchanged	Unchanged
Newtown	Unchanged	Unchanged	Unchanged

The low and high water marks can be digitised with certainty from all editions of mapping; any errors are likely to be due either to the original surveyor's interpretation of the low or high water marks, or to warping and stretching of the paper maps. It is also apparent that the changing definition of how the low water mark should be calculated (Oliver 1993; see Chapter 6.2.1) has had an effect on the measurement (Fig. 7.4).

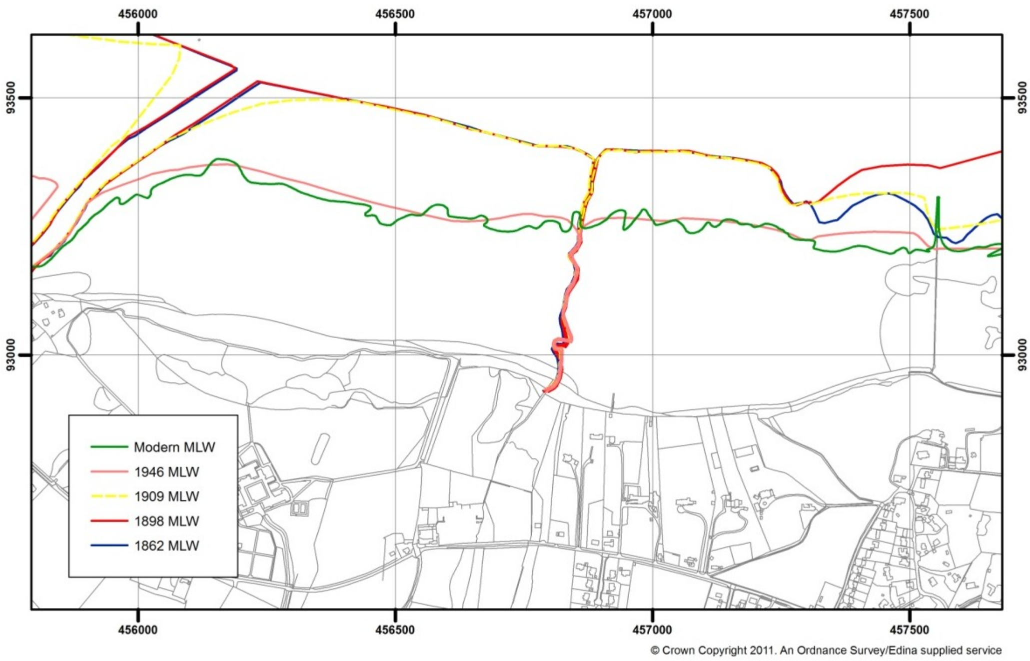

Figure 7.4 The coast between Fishbourne Creek and Binstead showing the changes to the depiction of the low water mark which took place between the 1909 and 1946 Ordnance Survey editions

The position of the coastline, however, is much more open to interpretation, particularly on stretches of coast with an eroding and wooded coastal slope, and when digitising the coastline it is often necessary to refer back to previous map editions in order to determine which line should be followed. Despite the associated descriptive attributes which are tabulated for each feature it can be particularly difficult to determine which line of the modern MasterMap digital mapping represents the coastline, and comparison with orthorectified aerial photographs serves to add to the confusion (see below Fig. 7.18).

For this study, profiles were measured at approximately 100m intervals perpendicular to the coast using the 1862 Ordnance Survey mapping as a base, and the low water mark, high water mark and coast edge or top of cliff were measured on all editions of mapping where available and where there was a difference between editions (figs. 7.5 to 7.10). As has already been stated, there were generally very minor differences between the 1970s and modern mapping. An average of 35 profiles was measured along each frontage, although the Springvale study area was substantially shorter (17 profiles) and the Tennyson Down-High Down frontage was longer (42 profiles).

Since the coastline is unlikely to move seawards except through reclamation or the construction of sea defences, figures which indicate a seaward migration of the coast edge are likely to be erroneous, especially on cliffed frontages. This proved to be a particular problem in the Tennyson Down-High Down study area where almost a quarter of the measurements taken from the modern mapping indicated a seaward movement of the cliff top of up to 8m compared with the First Edition Ordnance Survey mapping. To some extent this can be attributed to differences in the interpretation of the cliff edge, or it is within the acceptable margin of error discussed above, but these figures were removed from the calculations.

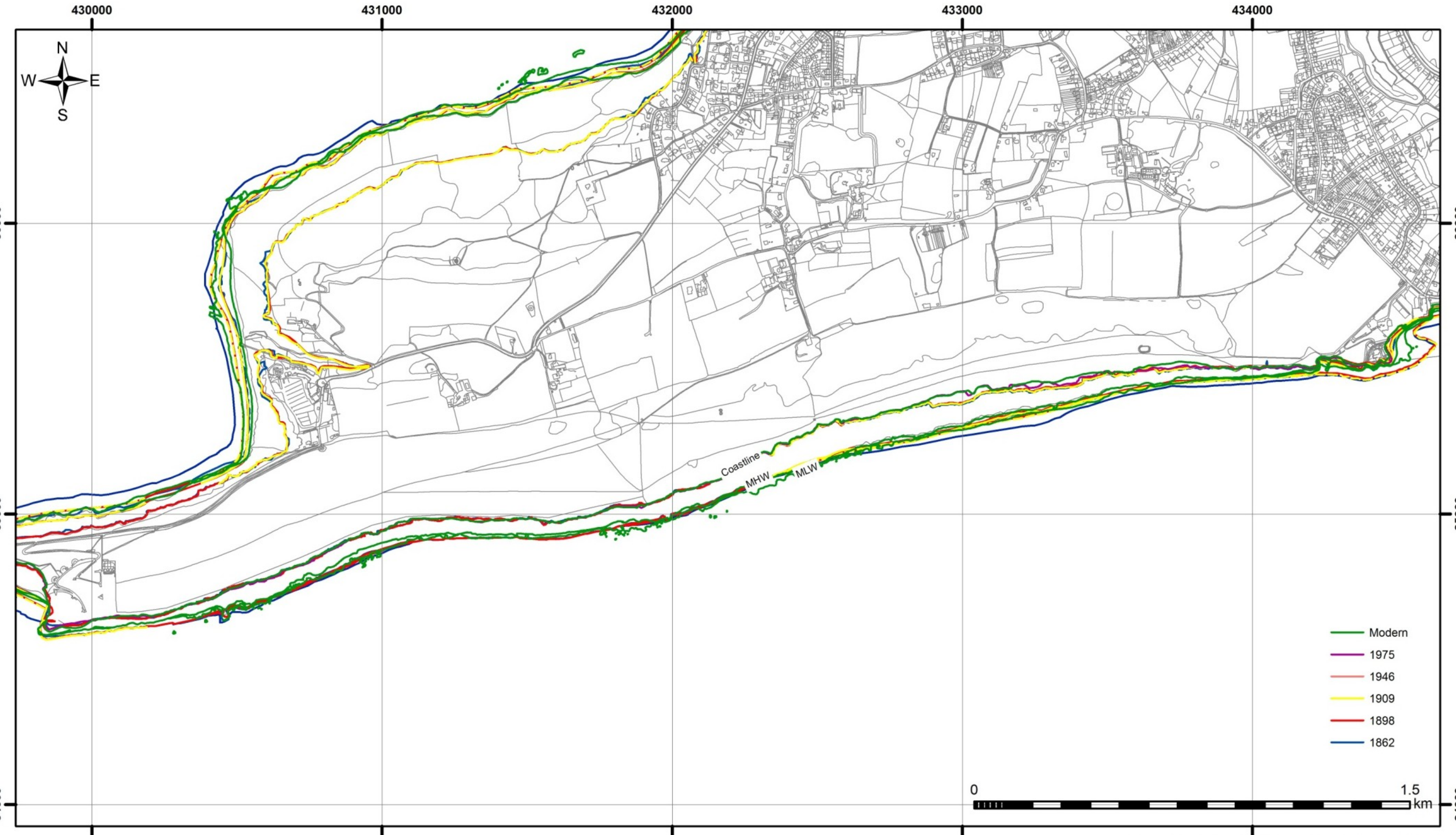

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Figure 7.5 Digitisation of the low water mark, high water mark and coastline, Tennyson Down - High Down study area

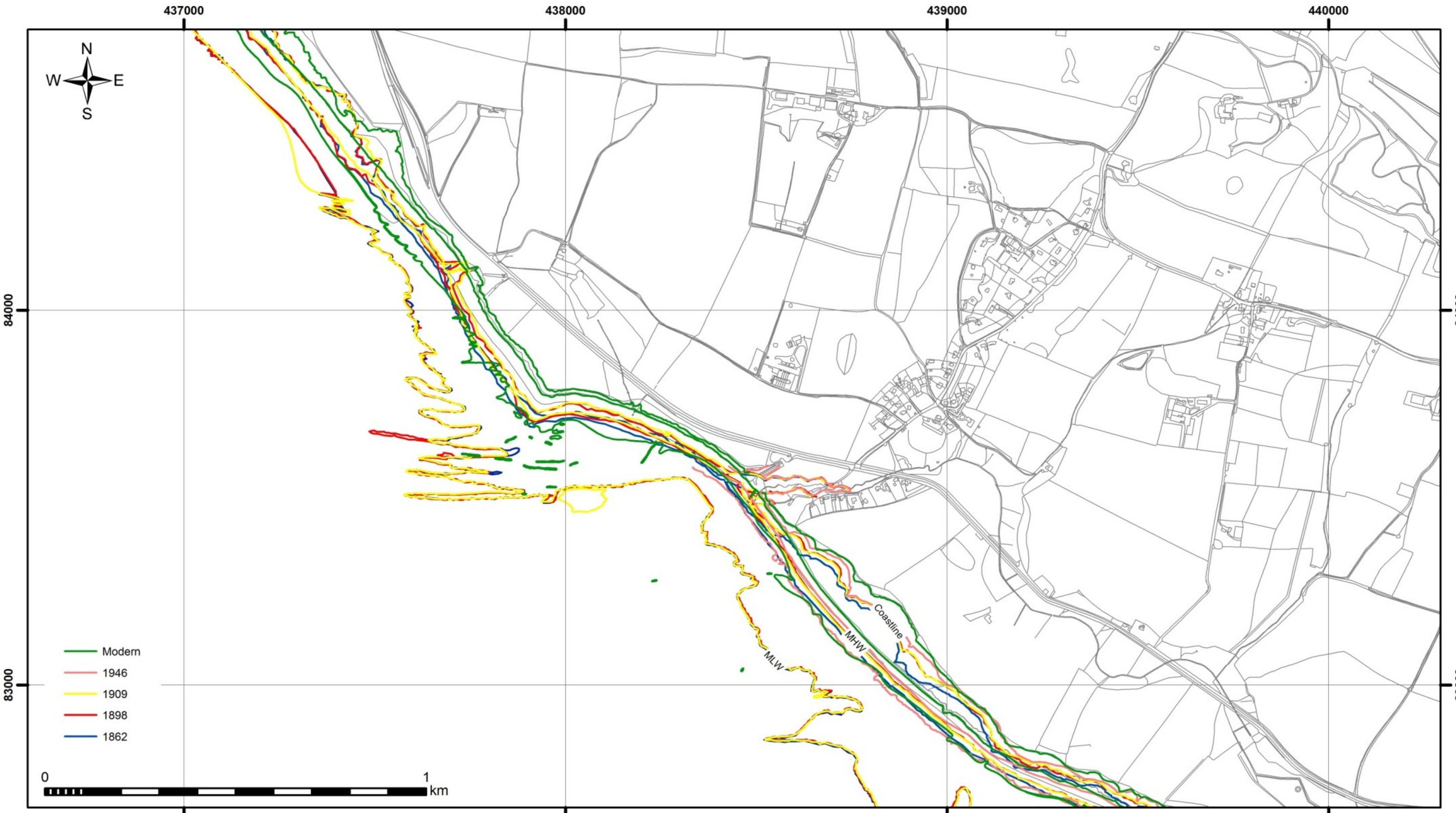

Figure 7.6 Digitisation of the low water mark, high water mark and coastline, Brook study area

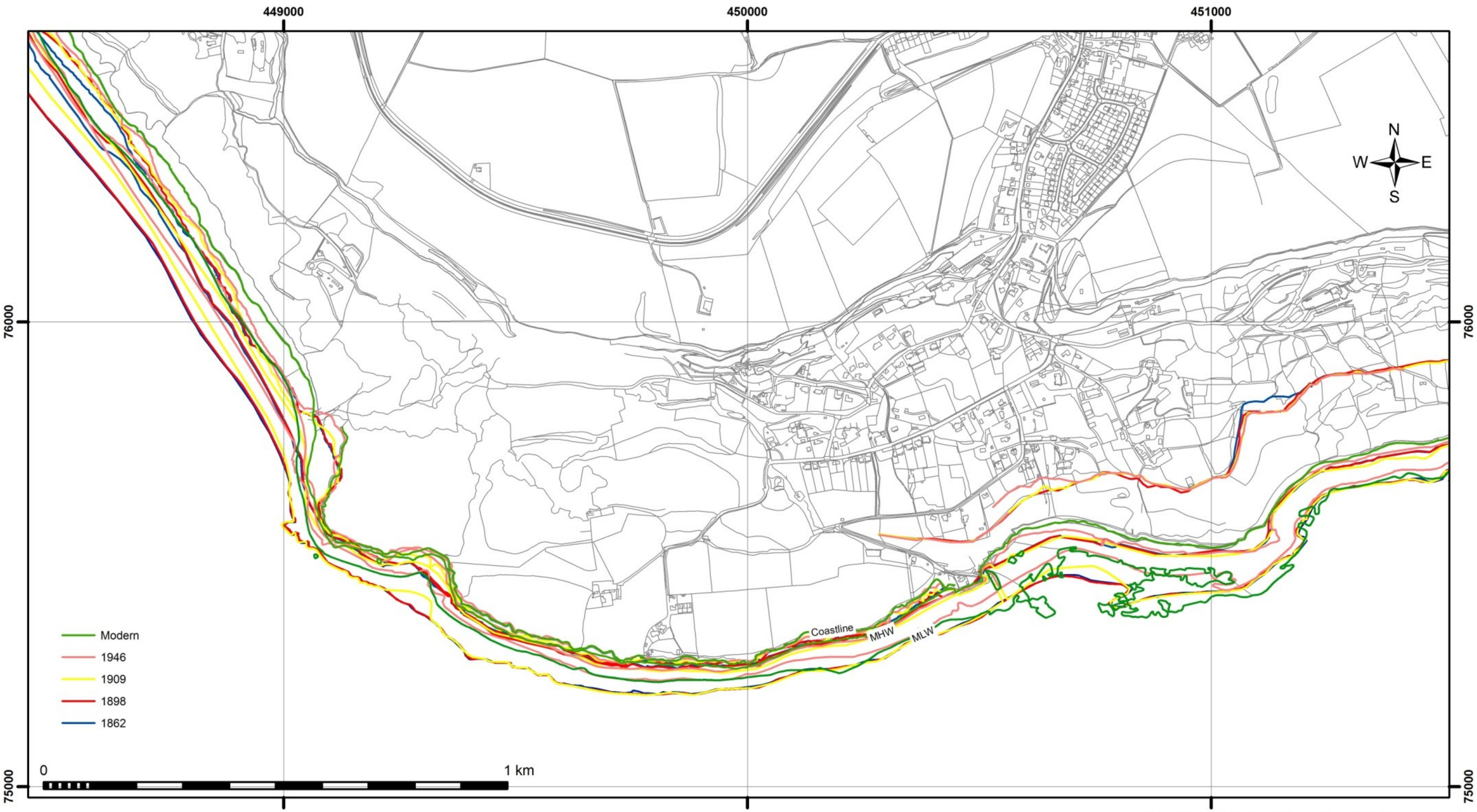

Figure 7.7 Digitisation of the low water mark, high water mark and coastline, St. Catherine's Point study area

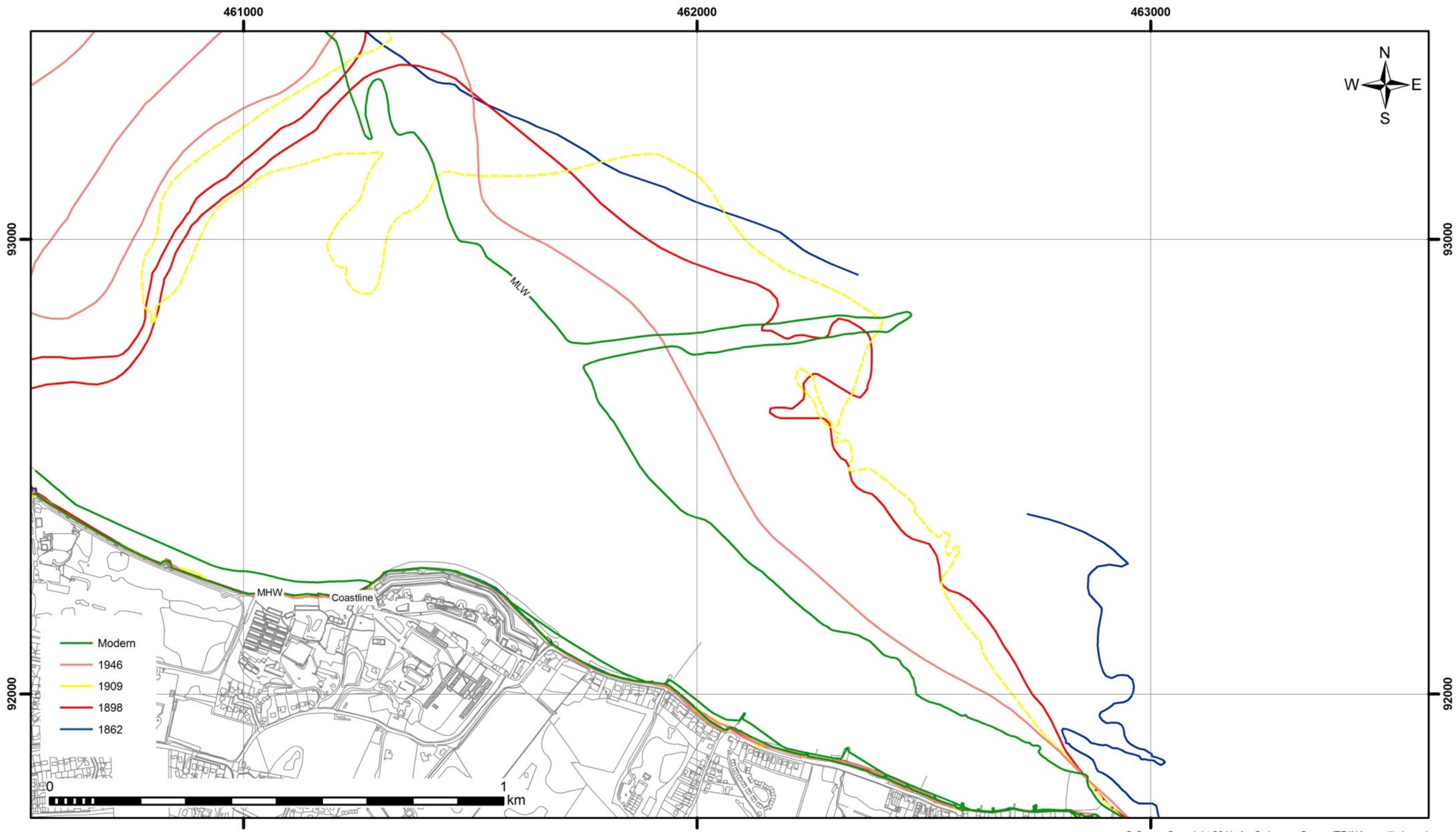

Figure 7.8 Digitisation of the low water mark, high water mark and coastline, Springvale study area

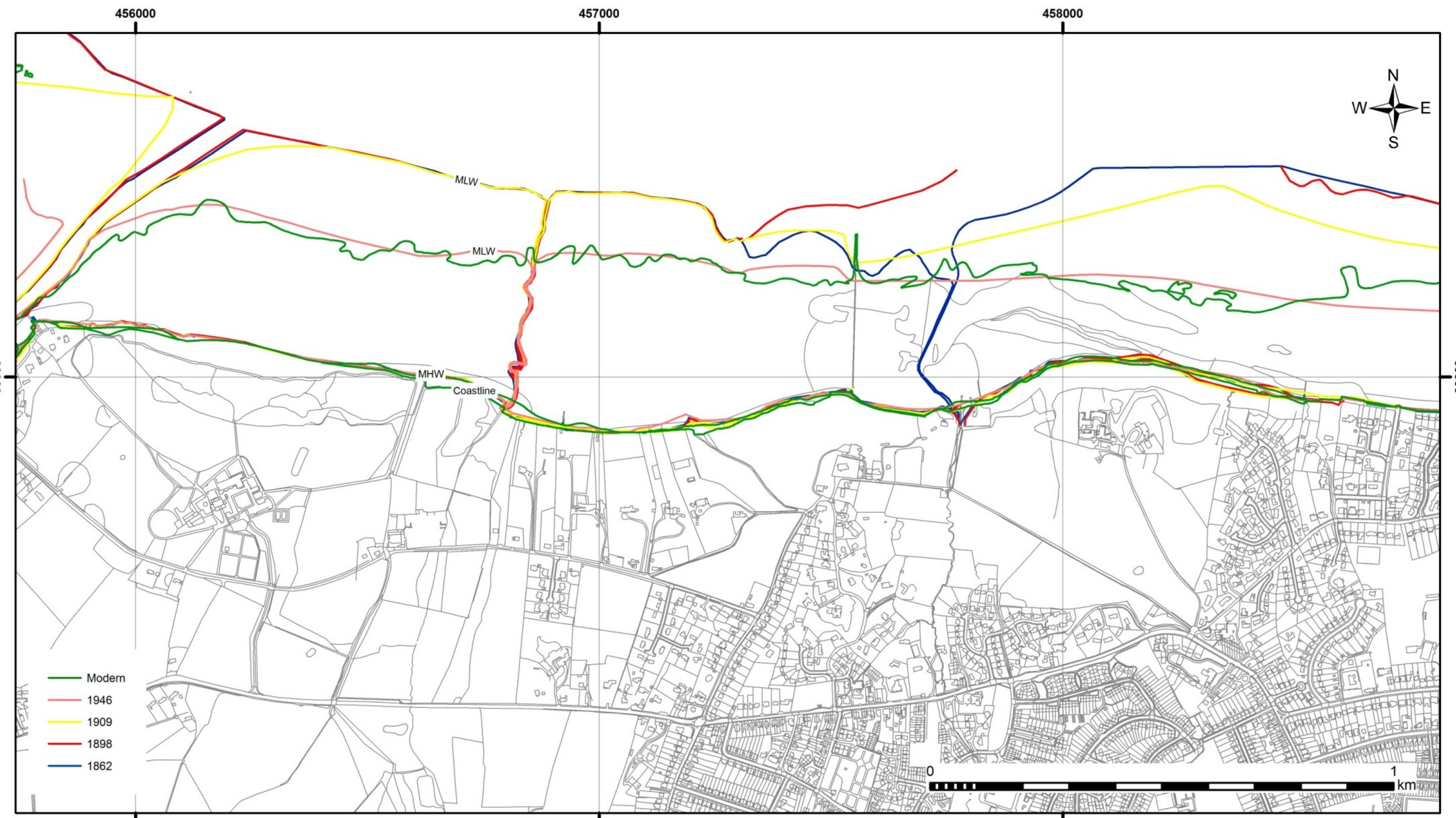

Figure 7.9 Digitisation of the low water mark, high water mark and coastline, Wootton-Quarr study area

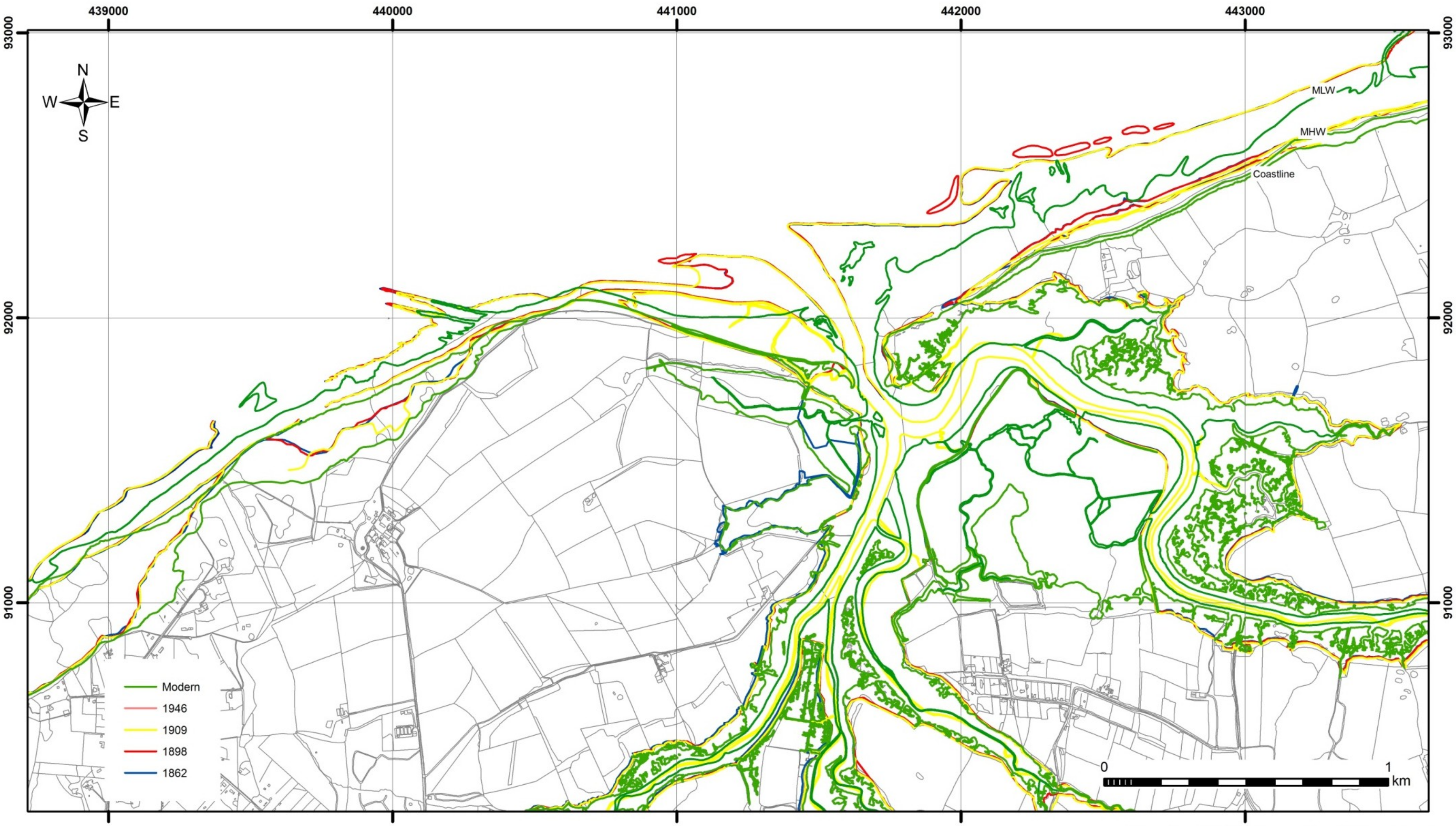

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Figure 7.10 Digitisation of the low water mark, high water mark and coastline, Newtown Estuary study area

It can be difficult to establish whether stretches of the coast have been re-surveyed for subsequent editions of Ordnance Survey mapping. This was again especially apparent in my Tennyson-High Down study area where large parts of the coastline, high water mark and low water mark, appeared the same on both the 1975 and modern mapping, whilst other stretches were markedly different. In order to establish whether this was an accurate representation, I tested the accuracy of the modern mapping by digitising the top of the cliff shown on orthorectified aerial photographs dating from 2008 which had been downloaded from the Channel Coastal Observatory. In some places interpretation was difficult but the top of the cliff generally matched that shown on the 2005 mapping or else it could be appreciated why there might be differences in interpretation, for example where there were tension cracks located near the edge of the cliff (Fig. 7.11 and LiDAR image Fig. 6.44).

Image courtesy of the Channel Coastal Observatory

Figure 7.11 Aerial photograph of Tennyson Down showing tension cracks near the cliff edge

7.2.1 Results

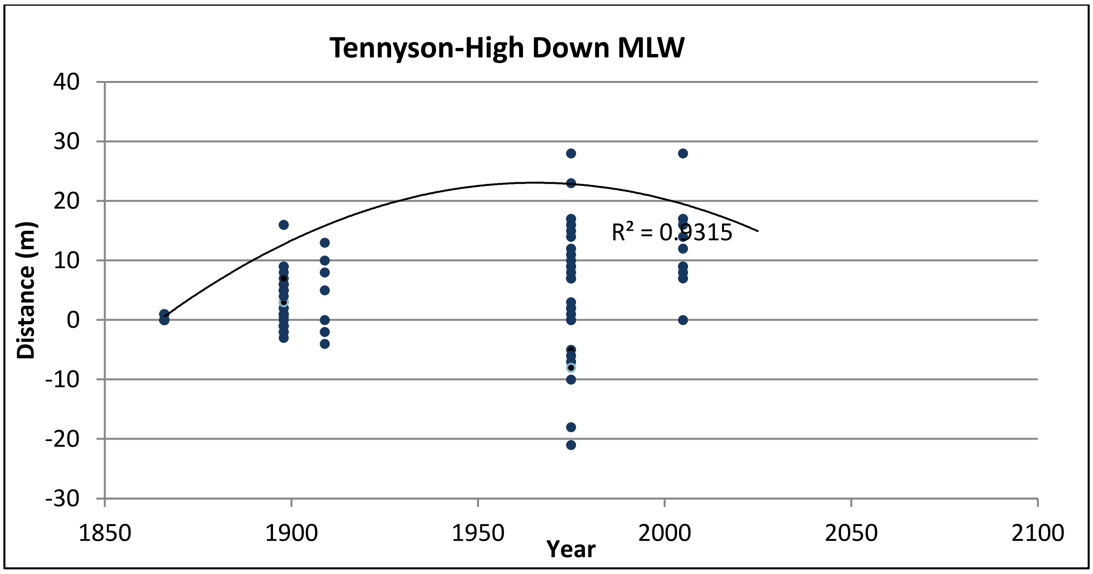
For each profile, the movement of the low water mark, high water mark, and coast edge relative to the position depicted on the 1862 First Edition Ordnance Survey map was entered into an Excel spreadsheet, and the mean movement for each survey area was calculated. A trend line for the mean was added and extended for a 50 year period (figs. 7.12 to 7.17). A polynomial 2nd order trendline was found to be the most appropriate.

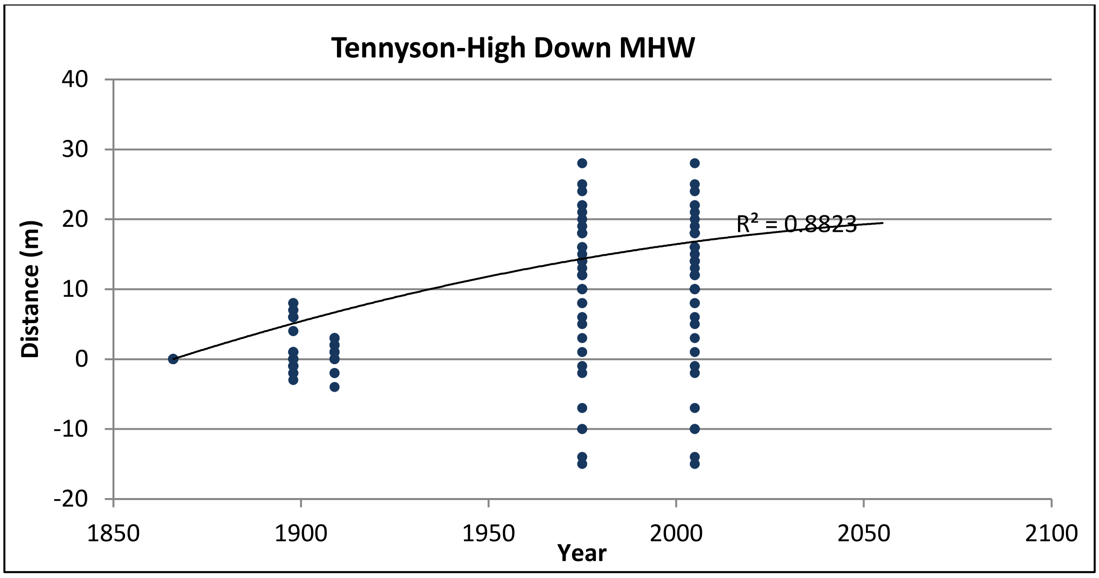
One thing that is immediately obvious from all of the scatter plots of the results is the wide variation in the amount of movement of mean low water, mean high water and the coast edge within each of the frontages examined (Table 7.2). This must raise the question of how meaningful is the calculation of the mean when there is such a wide range of movement? Taking fewer measurements, or measurements in a slightly different place might change the results considerably and the effects of localised erosion events may have significant implications for archaeological sites.

Table 7.2 Movement of mean low water, mean high water and coast edge as shown on historic mapping between 1862 and 2005. ← movement seawards, → movement landwards (metres)

	MLW				**MHW**				**Coast**			
	Min	**Max**	**Mean**	**Range**	**Min**	**Max**	**Mean**	**Range**	**Min**	**Max**	**Mean**	**Range**
Tennyson-High Down	←21	38→	10	59	←15	28→	10	43	←8	43→	6	51
Brook	47→	308→	130	261	30→	168→	52	138	8→	99→	16	91
St. Catherine's Point	←33	89→	20	122	←6	46→	13	52	0	30→	12	30
Springvale	74→	804→	475	730	←26	29→	-2	55	←6	7→	1	13
Wootton-Quarr	0	219→	130	219	←34	15→	-1	49	←12	23→	4	35
Newtown	←13	400→	110	413	←19	100→	27	119	←141	155→	65	296

With the exception of the Tennyson Down-High Down frontage, all study areas demonstrate a narrowing of the intertidal zone between the first and last measurements. This might be due in part to the changing way in which the low water mark has been measured. At Tennyson Down and High Down, the mean retreat of MLW, MHW and the top of the cliff remains the same.





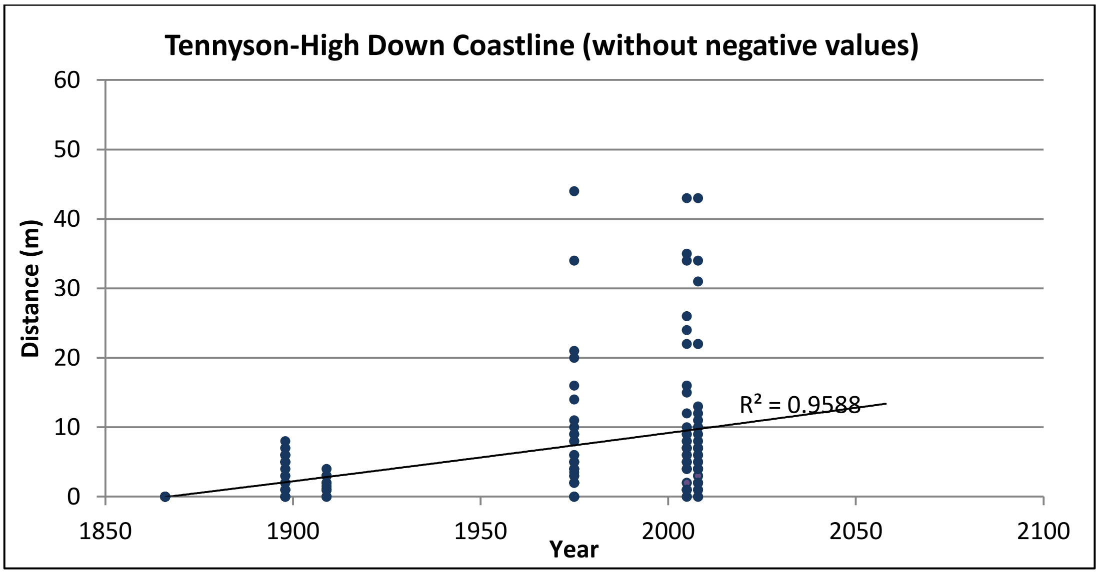
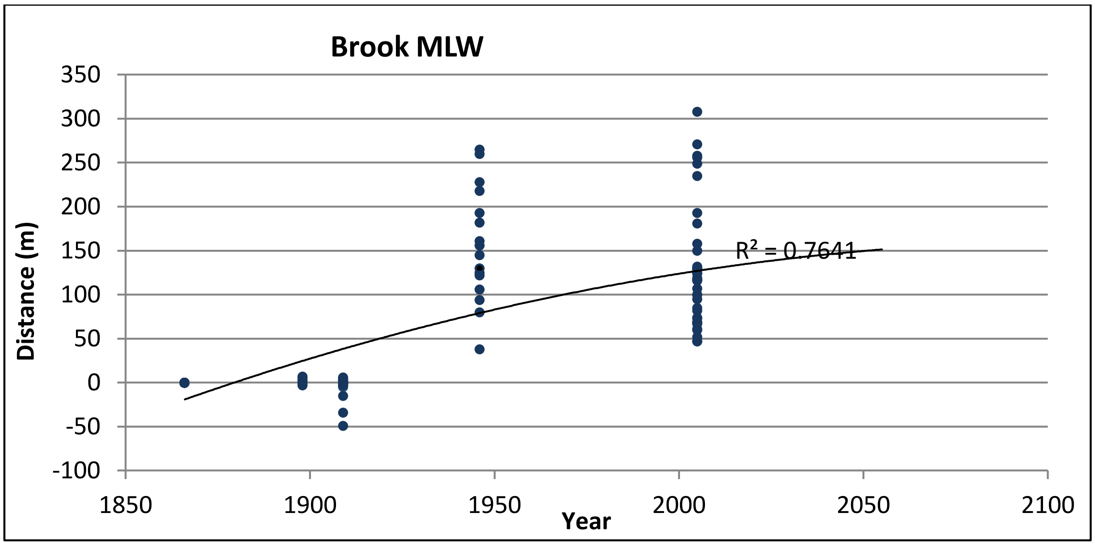
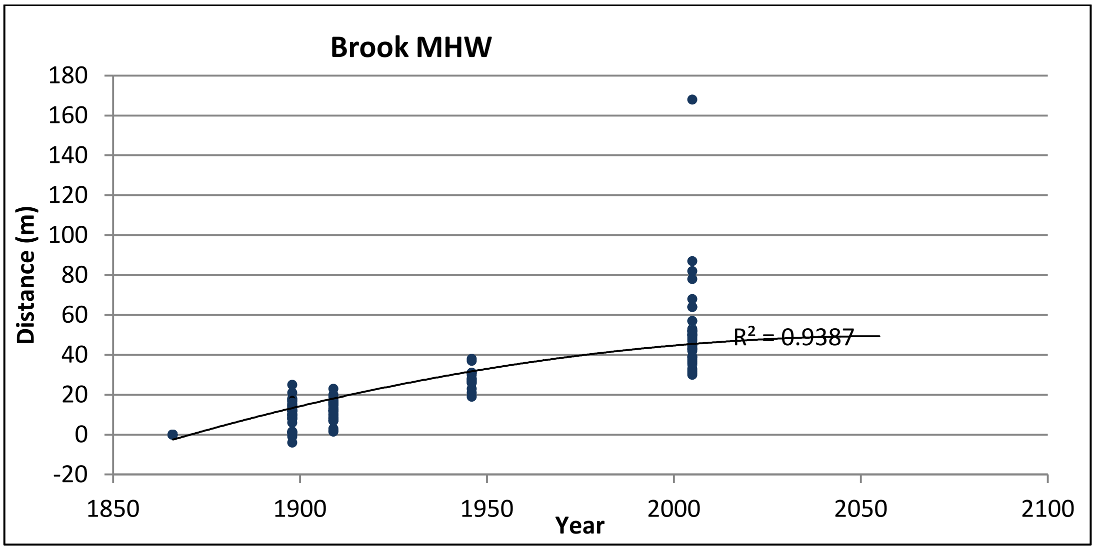


Figure 7.12 Historical movement of MLW, MHW and coastline calculated from Ordnance Survey mapping: Tennyson Down-High Down study area





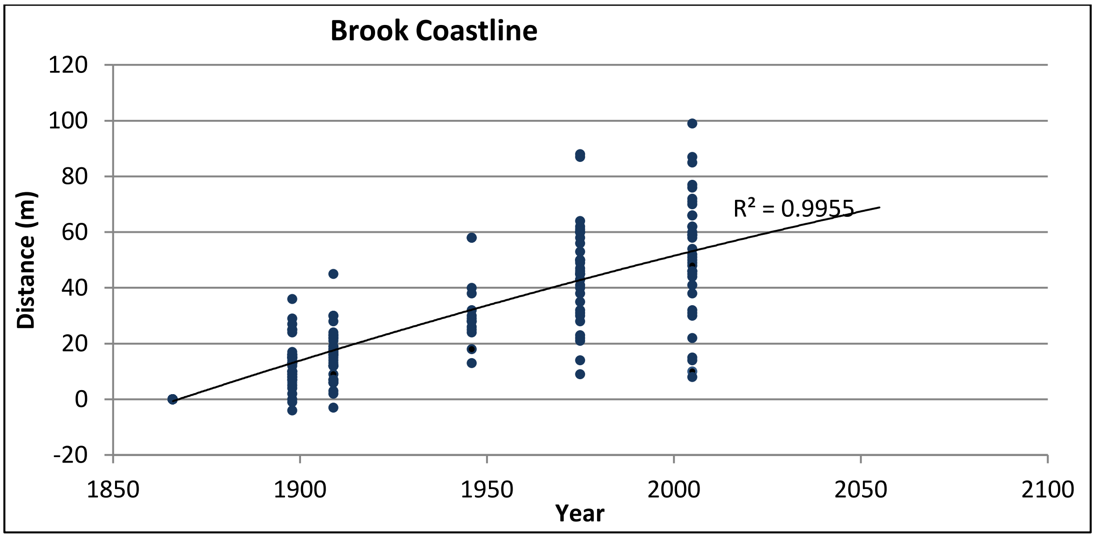


Figure 7.13 Historical movement of MLW, MHW and coastline calculated from Ordnance Survey mapping: Brook study area

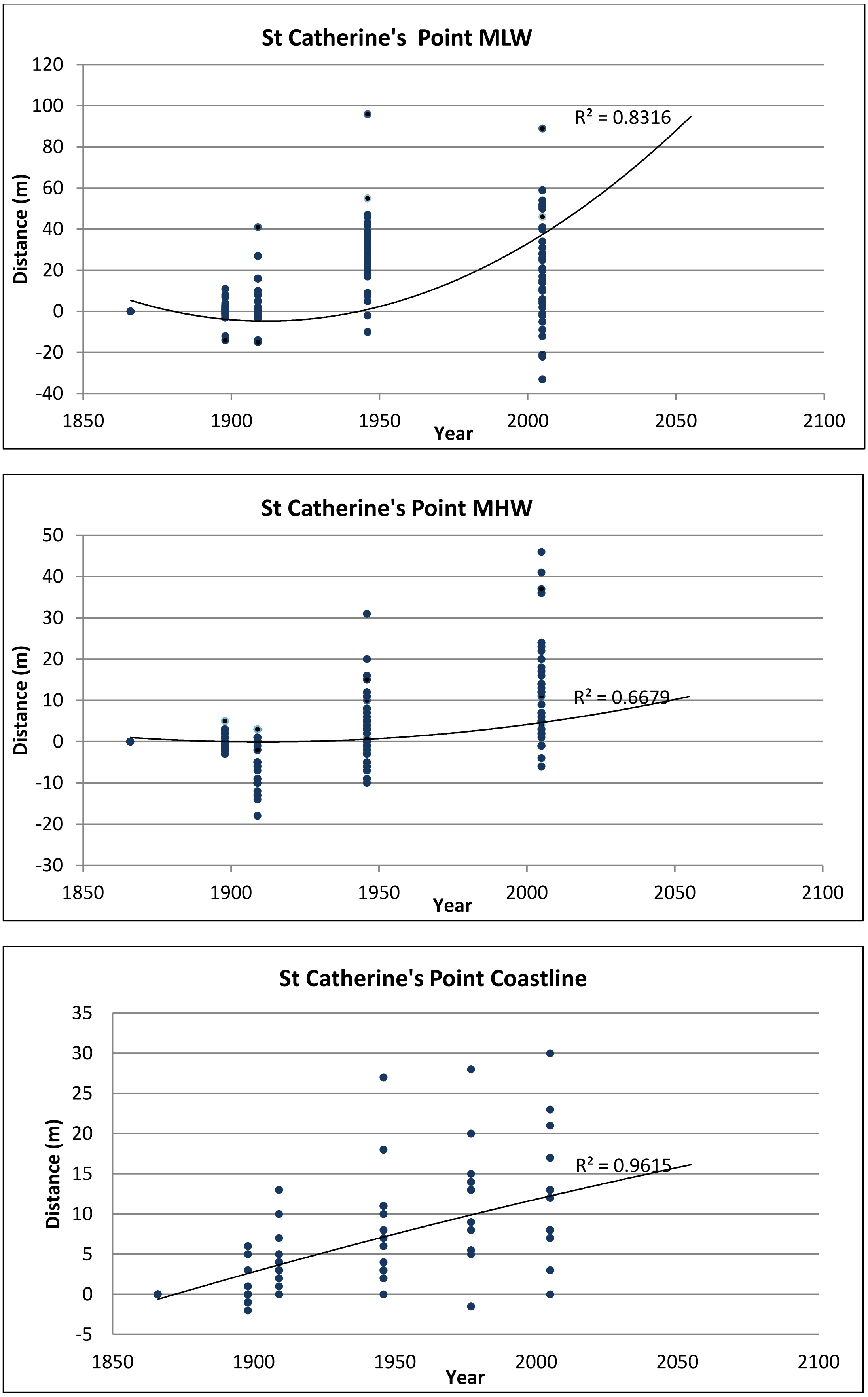


Figure 7.14 Historical movement of MLW, MHW and coastline calculated from Ordnance Survey mapping: St. Catherine's Point study area

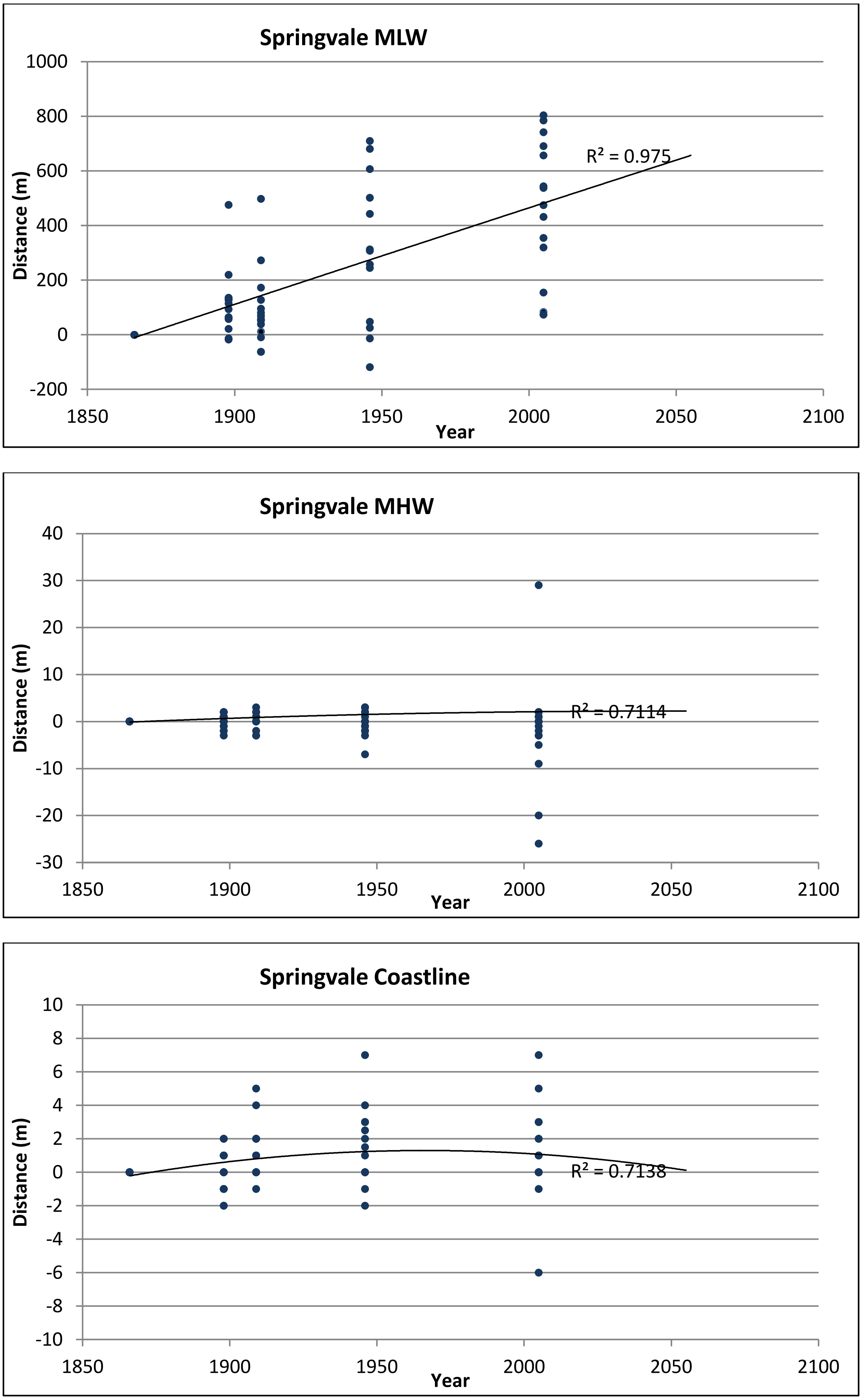


Figure 7.15 Historical movement of MLW, MHW and coastline calculated from Ordnance Survey mapping: Springvale study area

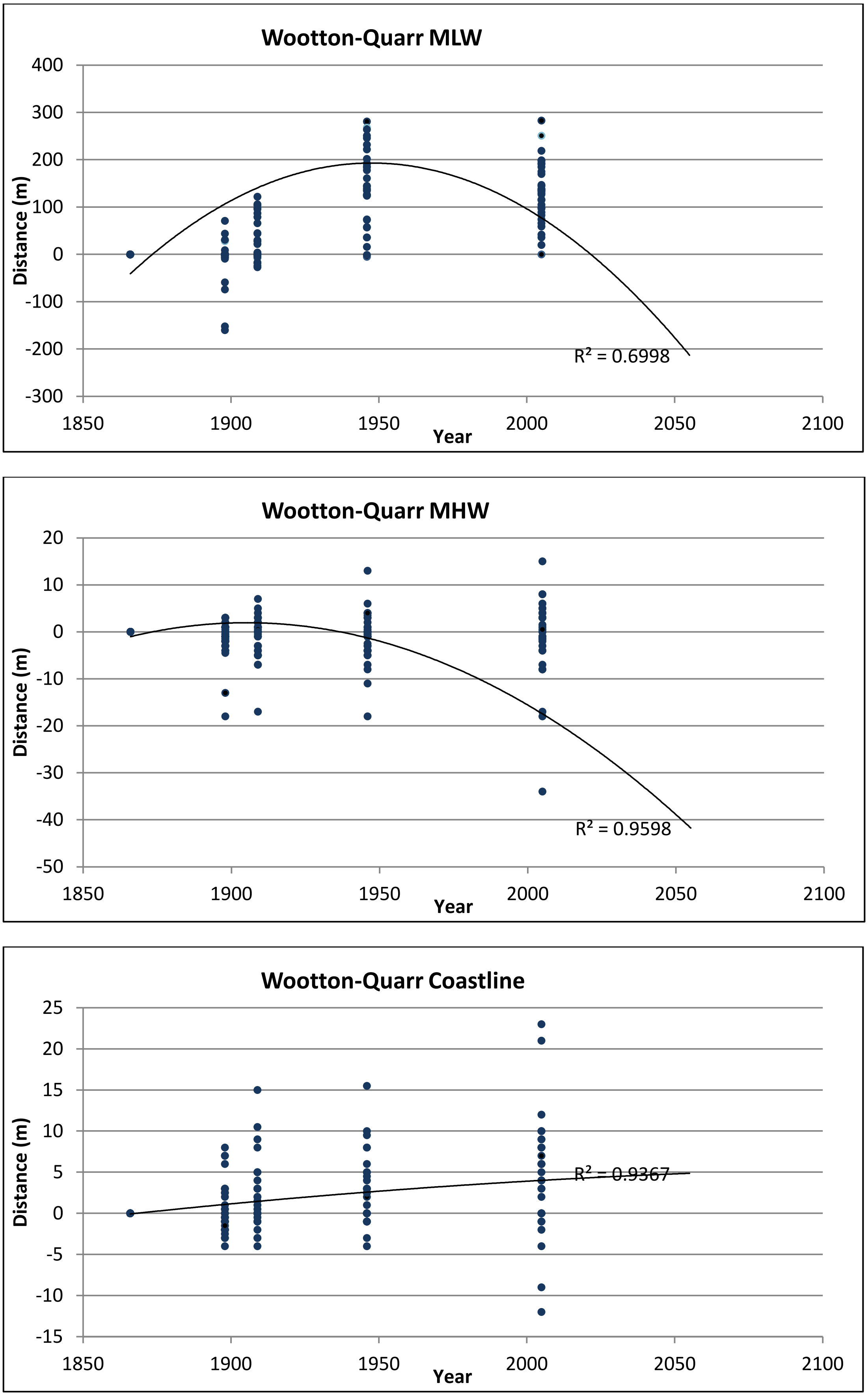


Figure 7.16 Historical movement of MLW, MHW and coastline calculated from Ordnance Survey mapping: Wootton-Quarr study area

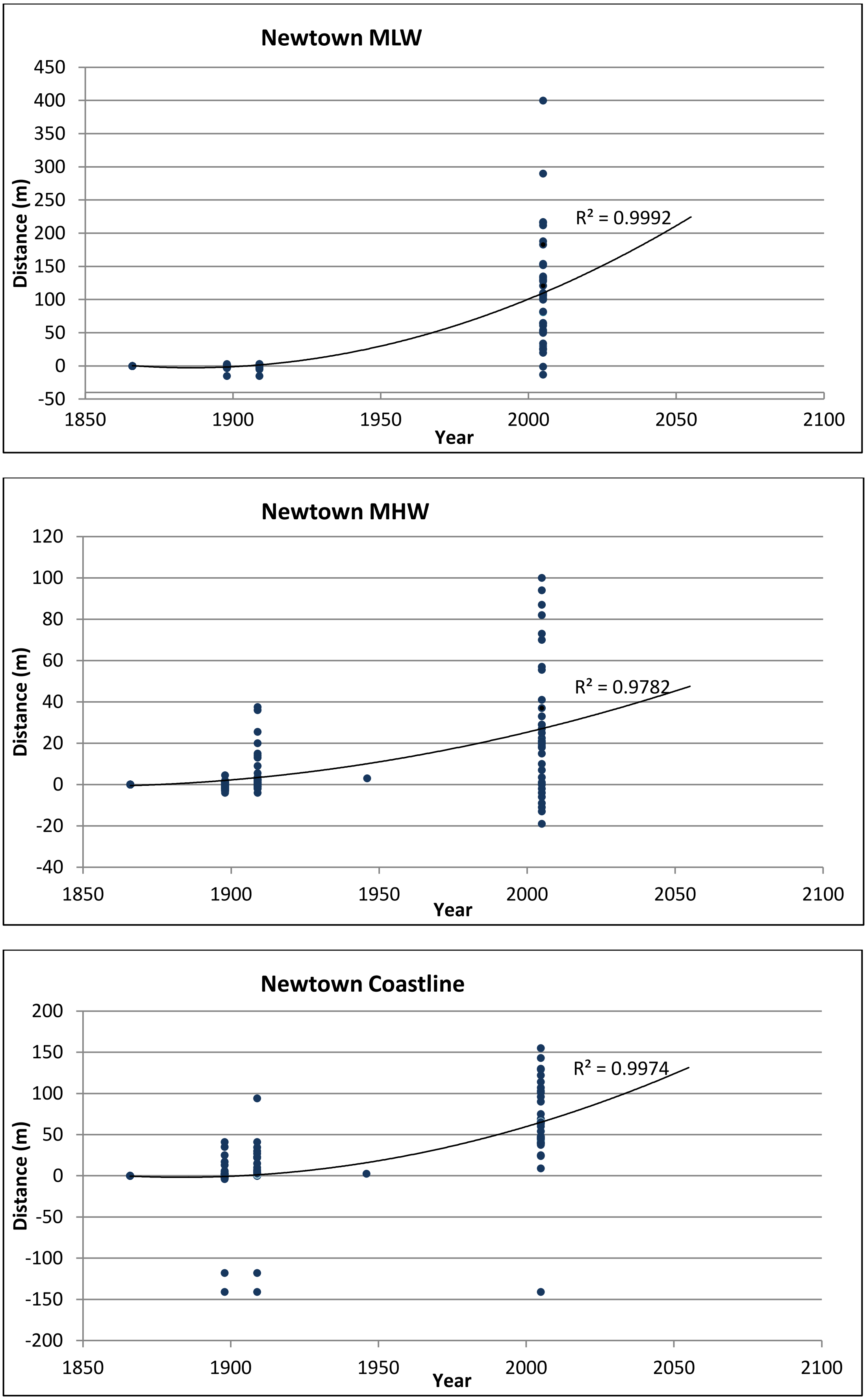


Figure 7.17 Historical movement of MLW, MHW and coastline calculated from Ordnance Survey mapping: Newtown study area

The Isle of Wight SMP and its revision quotes previous studies carried out on the island's chalk cliff frontage which suggested historic rates of recession of the cliff top of 0.08m/yr (May and Heeps 1985) and on the Afton Down section, to the south east of my Tennyson-High Down study area, 0.05m/yr (Barton and McInnes 1988). However, the SMP itself calculates historic recession rates to be between 0.1 and 0.4m/yr; that is 0.1m/yr between 1866 and 1975 but increasing to 0.42m/yr 1975-1995 due to failures in superficial deposits (Halcrow and Partners 1997, volume 1, 2.29). The figure quoted in the SMP revision is 0.25m/yr. My calculated annual recession rate for the Tennyson-High Down study area between 1862 and 2005 was 0.07m.

The annual rates of historic coastal retreat calculated for each of my study areas were in general considerably less than those of the Isle of Wight SMP and its revision (Table 7.3), although they were closer to those given by the two studies cited above. There are several possible reasons for this. The differences are likely to be due in part to the fact that my study areas do not conform to the coastal units which are defined in the SMP or its revision. However, there is little difference between my Tennyson Down – High Down study area and SMP Management Unit FRE 5: Freshwater Bay to the Needles, an area where the discrepancies in the calculated historic recession rates are discussed above.

The location and number of profiles measured may also contribute to the differences in calculated historic coastal recession. For the SMP 517 profiles were measured around the coast of the island at intervals of between 100 and 300m with more profiles concentrated in developed areas (Halcrow and Partners 1997, volume 1, 2.26), whilst the SMP revision relied on these results together with studies carried out for the North-East Wight Coastal Defence Strategy Study (Isle of Wight Council 2005a), which includes my Wootton-Quarr and Springvale study areas. Unfortunately the positions of the measured profiles are not shown in the SMP report. For the FutureCoast project, historic rates of coastal recession were calculated from profiles with a minimum spacing of 1km, with at least one profile every 5km (Defra/Halcrow 2002). Within my study areas, this amounted to just one profile at Tennyson Down, one profile at Brook, 2 profiles at St Catherine's Point/Binnel Bay, none at Springvale, one at

Wootton-Quarr, and at Newtown, profiles to the east and west of the estuary but not within my study area. Profiles were located to be ‘geomorphologically representative’ of stretches of coast, not necessarily at the most active locations.

Table 7.3 Changes to mean low water, mean high water, and the coastline calculated from historic mapping

	1862 – 2005 mean cumulative erosion rate	Mean annual movement	SMP2 Historical Annual Rate
Tennyson Down			
MLW	10m	0.07m	
MHW	10m	0.07m	
Coastline	10m	0.07m	0.25m
Brook			
MLW	130m	0.95m	
MHW	52m	0.37m	
Coastline	52m	0.37m	0.30m/0.50m
St Catherine’s Point			
MLW	20m	0.14m	
MHW	13m	0.09m	
Coastline	12m	0.09m	0.60m
Springvale			
MLW	385m	2.77m	
MHW	-2m	0.01m	
Coastline	1m	0.005m	
Quarr			
MLW	130m	0.95m	
MHW	-1m	0.005m	
Coastline	4m	0.03m	
Newtown			
MLW	110m	0.79	
MHW	27m	0.19m	
Coastline	65m	0.47m	0.60m/0.62m/0.20m

The Isle of Wight SMP revision calculates historic and future recession rates using figures derived from the first SMP and coastal strategy studies. The first edition Ordnance Survey is the earliest mapping used for these calculations but the date of the latest measurement is not always clear, although for the original

SMP, 1909 and 1975 Ordnance Survey mapping at a scale of 1:10,000 was used and 1995 vertical aerial photographs provided a final measurement. It is not stated how these aerial photographs were rectified other than by ‘identifying on the photos reliably mapped (O.S.) features (control points) situated close to the coast and adjusting the photo scale accordingly’ (Halcrow 1997 vol. 1, 2.26). However, it is stated that the differences between the 1975 and 1995 measurements are important because they are likely to represent changes taking place under current management regimes.

In many cases the SMP concludes that trends have accelerated or reversed between the date of the latest (1975) Ordnance Survey mapping and the 1995 aerial photographs, which seems rather coincidental and does suggest that there may be some discrepancy when using a combination of cartographic sources and photographs, although this may simply be due to the way in which the photographs were rectified. Equally, however, the fact that it is not always possible to establish how frequently the coastline has been surveyed for subsequent editions of mapping does mean that even when only maps are used, the calculated rates of erosion may be erroneous.

The interpretation of the coastline as shown on historic mapping is another important factor which might affect measurements of past coastal recession. In areas such as St. Catherine’s Point and the Undercliff which are subject to landslides and instability it can be very difficult to decide which line drawn on the map represents the coastline. A similar difficulty of interpretation can also be encountered when using aerial photographs, for example with the occurrence of tension cracks and unvegetated areas on the cliff edge on the Tennyson Down-High Down frontage as discussed above (section 7.1). At Newtown the changing configuration of the spits protecting the mouth of the estuary complicates the measurement, with the spits pivoting as the coastline is receding.

Apart from the problems interpreting the cartographic evidence discussed above, it is quite likely that the mapping might not reflect accurately the actual ground conditions and coastal recession rates. For example, the rates of erosion in front of Quarr Abbey taken from historic mapping suggest an annual rate of 0.03m, which is less than that of the chalk cliffs of the Tennyson Down-High Down frontage. A comparison between the cartographic evidence and aerial photographs shows significant differences between the mapped coastline and that apparent on photographs (Fig. 7.18). Having observed this stretch of coast during more than 20 years of fieldwork it is very evident that this is an actively eroding coastline (see also Fig. 5.7).

The SMP also noted errors in the Ordnance Survey's depiction of the coastline and MHW, with data from the 1866 mapping being disregarded in several of its process units, including Newtown. I have removed measurements which suggest that the coastline has moved seaward from my calculations but the fact that such errors are present suggests that the validity of the other measurements may also be questionable.

In conclusion, the differences between the rates of coastal retreat calculated in this thesis and those of the SMP can be explained to a large extent by the sources used, differences in the number and location of profiles and the scale at which they were measured, and differences in methodology and availability of digital datasets. It could be suggested that the SMP might overstate the potential coastal loss either to err on the side of caution as protection against future liability or for more cynical reasons, but this seems unlikely given that my study areas are in units where the SMP management option is no active intervention.

However, the simple extrapolation of historical trends into the future can be inaccurate because it assumes that there will be no change in conditions influencing coastal change. Formulae have been developed which consider other factors such as sediment input, the gradient of the shore platform, and predicted rates of future sea-level rise (see Bray and Hooke 1997; Walkden and Dickson 2008).

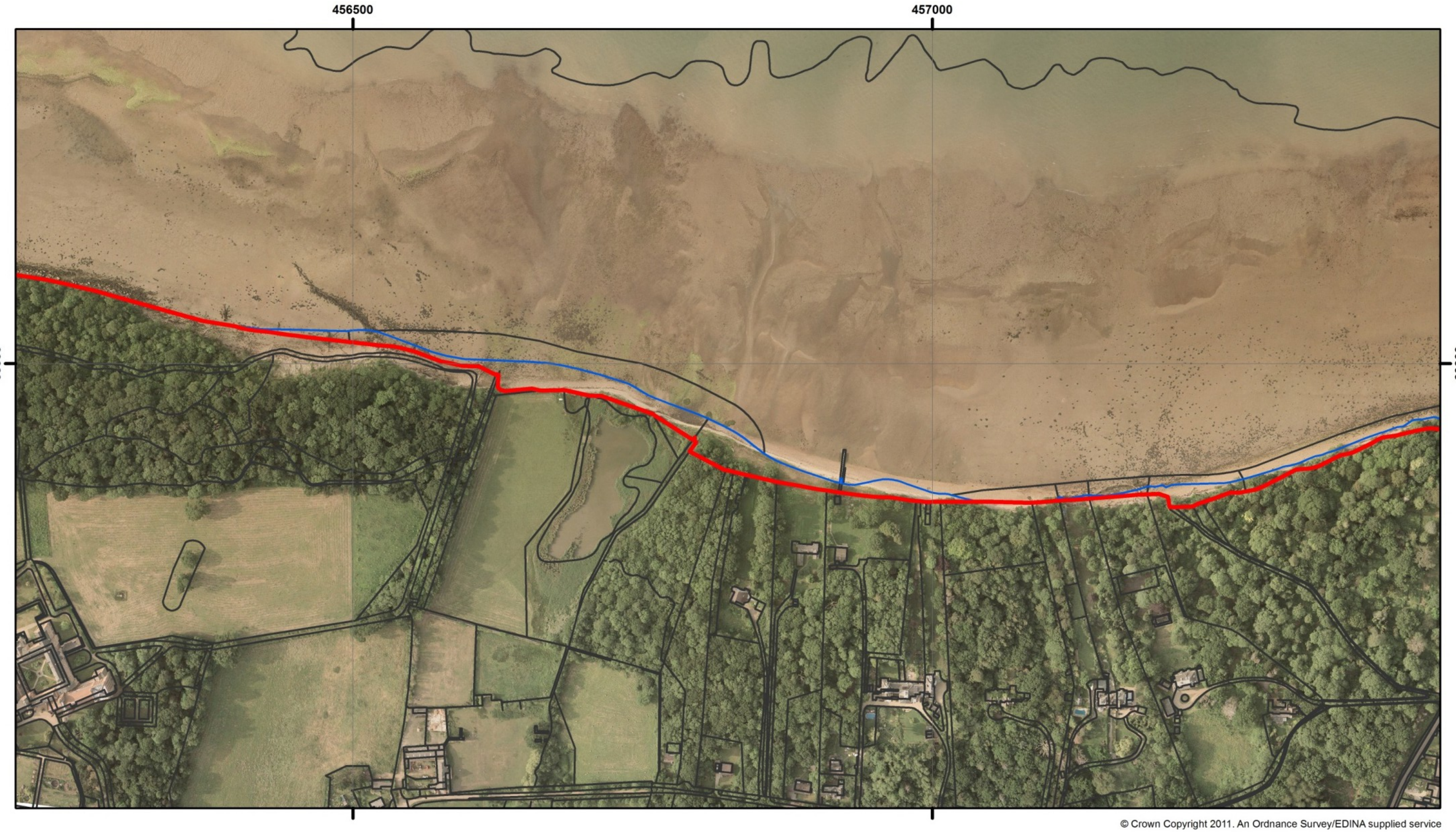


Figure 7.18 Quarr Beach. Differences between the mapped coastline and that shown by aerial photography (coastline shown in red, MHW in blue)

7.3 Aerial photography

The use of aerial photographs in coastal archaeological survey is a well established technique, both to locate sites and to map them more accurately (Tyson *et al* 1997, 100). Indeed, English Heritage's brief for carrying out rapid coastal survey zone assessments requires the transcription of aerial photographs to NMP standard as part of the desk based assessment phase (English Heritage 2007a).

There are examples of spectacular coastal sites that have been revealed by aerial photography, including substantial complexes of fish traps in the Severn Estuary (Crowther and Dickson 2008) and on the Essex coast (Strachan 1998). Military remains, particularly Second World War defences can be readily located on photographs taken during the war and shortly afterwards by the Luftwaffe and RAF, and these formed a major component of the sites recorded during the Suffolk coast NMP (Hegarty and Newsome 2005). Many of these sites are coast specific. Other large scale coastal structures which are frequently visible on aerial photographs include former sea defences and land reclamation banks.

Second World War defences along the Isle of Wight coast are well documented on photographs taken by the RAF in 1946 (Fig. 7.19). These photographs are less successful in revealing earlier archaeological sites, although in the terrestrial zone on the Isle of Wight, several ring ditches and prehistoric/Roman field systems have been identified in areas which have since been planted by the Forestry Commission (IWHER).

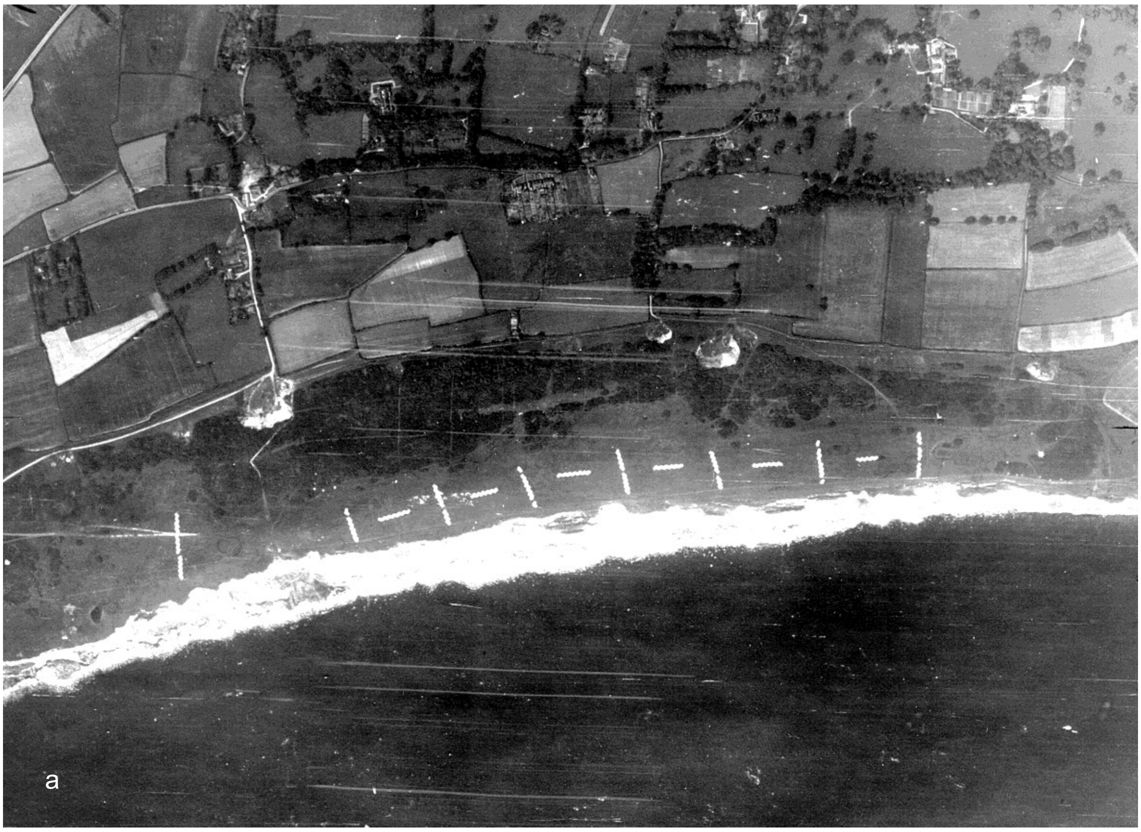


Figure 7.19 a) WWII Anti-landing trenches on Tennyson Down; b) anti-aircraft gun emplacements shown as a row of four white spots on the cliffs at Yaverland on the south east coast of the Isle of Wight, to the east of the mid-nineteenth century Yaverland Battery (RAF 1946)

However, aerial archaeological reconnaissance on the coast is not without its drawbacks. The visibility of sites in the intertidal zone is dependent on the combination of suitable state of tide and light conditions (Tyson *et al* 1997). Since the lowest tides often occur in the early morning or evening on the central south coast of England, it is rare that the two coincide.

The examination of aerial photographs during the Severn RCZAS found that sites pre-dating the medieval period were rarely visible because they were buried by the build up of alluvium caused by flooding events and the late Roman marine transgression. Only the largest, most visible sites were visible from the air (Crowther and Dickson 2008, 131). During targeted coastal aerial photographic survey in Essex it was observed that low tides and optimum conditions for photography seldom coincide (Strachan 1995). It was also found to be difficult to take photographs which showed intertidal features in adequate detail but also included some control points which enabled the features to be located with any degree of accuracy. The North West Rapid Coastal Zone Assessment Survey highlighted the fact that the quality of aerial photographic coverage, both in the number and quality of photographs available was an important factor in determining the effectiveness of the NMP exercise (Bacilieri *et al* 2009).

In Suffolk, more than 65% of new sites recorded during the NMP component of the RCZAS were modern in date (Hegarty and Newsome 2005), whilst during the same exercise for the North East Coast RCZAS 75% of new sites dated from the Second World War (Tolan-Smith 2008, xv). The NMP for the Isles of Scilly produced 108 new sites of which approximately 25% were in the coastal or intertidal zone (Johns *et al* 2004).

For this study, I examined both vertical and oblique aerial photographic prints held by the Isle of Wight HER, but the main part of the aerial photographic aspect of the work was to interrogate aerial photographs within a GIS. For this I used both orthorectified aerial photographs downloaded from the Channel Coastal Observatory, and photographs held by the Isle of Wight Archaeological Service which were scanned and georectified using ArcView's georeferencing tool. It was found that a 2nd order polynomial transformation produced the most satisfactory match with the mapping. The fact that there were few reliable reference points on the coast caused some problems, especially in more remote coastal areas which have few buildings or other distinctive features, such as Tennyson Down and the mouth of the Newtown Estuary. Also, with the exception of the north east coast where Ryde Pier provided a useful control, and where stone fish traps visible on aerial photographs had been surveyed on the ground at Springvale (Fig. 6.24), there were rarely any reference points on the seaward side of the coast so the image often appeared skewed. In conclusion, I did not feel that photographs that I had processed in this way could confidently be used to calculate rates of coastal recession or to plot accurately the location of archaeological features.

It is sometimes possible to measure the high water mark from aerial photographs, but they cannot be used with any confidence for plotting the low water mark. Even the coast edge can be difficult to define. In areas of open grassland, such as Brook Bay and Tennyson Down, the cliff edge is quite clear, although still often open to interpretation, but on stretches of coastline where woodland or scrub is found on the eroding coastal slope, for example to the west of the Newtown Estuary at Hamstead, it is impossible to locate the actual top of the coastal slope (Fig. 7.20).

Figure 7.20 Hamstead, west of the Newtown Estuary, illustrating the difficulties of identifying the top of the coastal slope on a wooden and eroding coast. 1975 Ordnance Survey map overlain on 2001 aerial photograph (image courtesy of Channel Coastal Observatory)

7.3.1 *Use of aerial photography for identifying coastal archaeological sites*

Large scale features, particularly those constructed of stone, can be identified relatively easily on vertical aerial photographs. This is especially true of structures such as fish weirs that tend to conform to a limited number of regular shapes, but despite this there are many features visible in the intertidal zone and in shallow water that cannot conclusively be identified as archaeological features. This is exemplified particularly well on photographs of Springvale. In addition to the curvilinear and linear fish weirs and alignments which have been surveyed on the ground, several curvilinear features can be seen though the shallow water covering the gently shelving sub-tidal zone (Fig. 7.21). Although it is assumed that these are natural, possibly subtidal outcrops of limestone, it is possible that some might be features of archaeological significance.

Figure 7.21 Google Earth image showing archaeological features in the intertidal zone at Springvale and other curvilinear features of possible natural origin to seaward (top right hand corner of the image)

I have been involved in extensive coastal archaeological surveys which included examination of aerial photographs around the coast of the Isle of Wight, both rapid, large scale and more targeted surveys, and very few intertidal sites have been first identified from aerial photographs, with the exception of the stone fish weirs and other features at Springvale mentioned above and a number of wrecks.

Timber structures are less easy to identify from aerial photographs unless they are particularly substantial. During the Wootton-Quarr survey, an aerial photographic survey was carried out at extreme low water for photogrammetric purposes. Black and white photographs were taken at a scale of 1:4000 (CUCAP 1993). Even the most extensive stake alignments, including one longshore alignment at Quarr which extends for *c* 1.25km cannot be made out on these photographs (figure 7.22). However, this is not altogether surprising when one considers that they are constructed of wooden stakes at most 230mm in diameter and spaced about 1m apart. Equally, however, several linear features were visible on the photographs that appeared to be post alignments but when they were checked out on the ground were found to be rocks, often covered in kelp, that had been arranged in a line due to the movement of tides and currents.

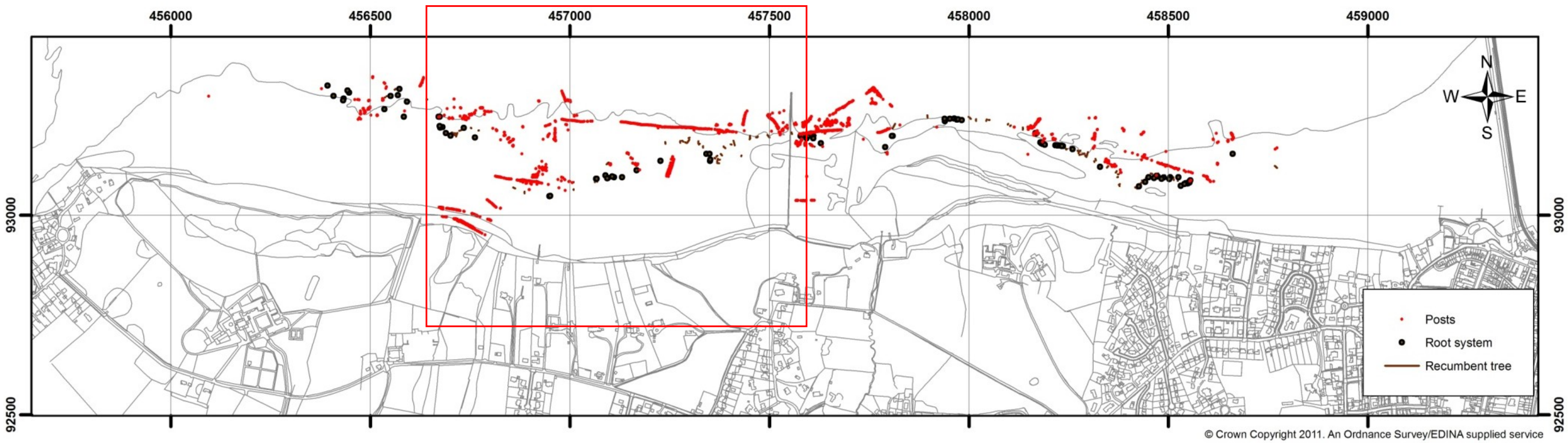


Figure 7.22 Wootton-Quarr plan and photograph

Probably the greatest impediment to the successful use of aerial photography for coastal archaeology, and particularly that of the intertidal zone, is the availability of suitable photographs. Even when specifically taken for archaeological purposes, such as those of the Wootton-Quarr coast previously mentioned, many intertidal features are too slight to be seen from the air.

Oblique photographs are more likely to reveal archaeological sites in more detail (see for example Fig. 6.4). However, the availability of oblique photographs of the intertidal zone is extremely limited. The Isle of Wight HER contains over 10,000 oblique aerial photographs dating from the 1920s onwards, but none have proved useful in the intertidal zone. Flights have tended to be taken in the summer months when cropmarks are at their most visible, and in areas where it is likely that they will be seen, which does not include the intertidal zone at extreme low water.

7.4 LiDAR

LiDAR was used in this study with the aim of assessing its value both for identifying archaeology in the coastal zone and to quantify heritage loss through vertical and horizontal erosion.

7.4.1 Availability of LiDAR data

At the beginning of this research only limited amounts of data could be obtained on request for specific projects from the Environment Agency, but during the last five years coastal data have been made available for download free of charge through portals such as the Channel Coastal Observatory (www.channelcoast.org/). Around the Isle of Wight coast surveys are flown on average every two years, so for the south west coast of the island four datasets are available. This stretch of coast includes two of my study areas; Tennyson Down - High Down and Brook. The raw data can be processed and manipulated with relative ease in ArcView GIS using the 3-D analyst extension.

The use of LiDAR in this study proved to be disappointing, particularly in the intertidal zone. The main limitation was found to be the state of tide; surveys have rarely been undertaken at extreme low water, so even substantial intertidal features such as the stone fish traps at Springvale were not visible. As is the case with aerial photography the resolution of available data is often too coarse to identify archaeological features in the intertidal zone. Most of the data that are freely available through the Channel Coastal Observatory are at a resolution of 2m, with some of the more recent surveys available in a 1m grid. Additional data can be obtained at cost from the Environment Agency at a spatial resolution of 0.50m or 0.25m, although the 0.25m coverage is considerably more restricted; for example on the Isle of Wight just small areas of the Eastern Yar valley are covered; Fig. 7.23). The Environment Agency quotes a vertical resolution for its data of between 5cm and 50cm (Environment Agency 2011) whilst the Channel Coastal Observatory quotes a vertical precision of ±0.15m (Channel Coastal Observatory 2003a).

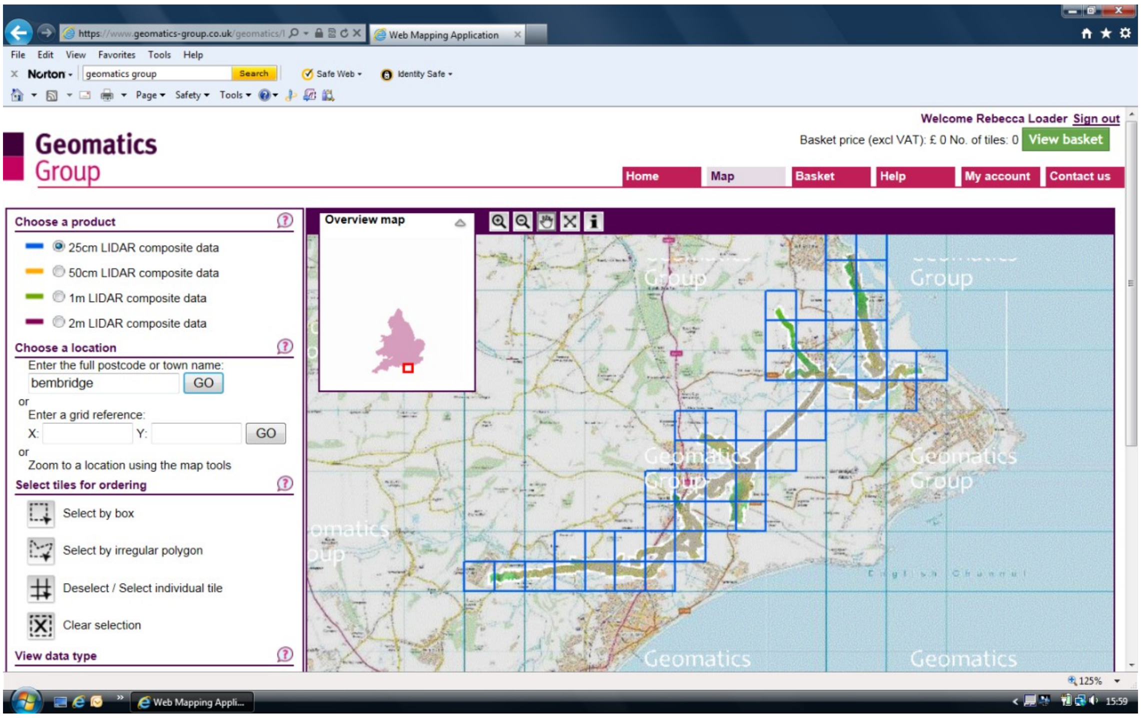


Figure 7.23 LiDAR data at 0.25m resolution for the Isle of Wight available from the Environment Agency

No new archaeological sites were found from an interrogation of the coastal LiDAR data, but the data did prove useful for improving understanding of known sites, in particular for establishing their accurate location and spatial extent. In this respect, LiDAR has been shown to be an invaluable tool from the perspective of HER enhancement (Challis *et al* 2008).

I also hoped that the multiple runs of data LiDAR would prove useful in the calculation of sediment loss/movement in the intertidal zone and erosion of the cliffs. However, this was not successful, possibly because of the vertical resolution of the available data, but also because the coverage of the intertidal zone is limited as a result of the Environment Agency's policy of applying a 'predefined water line mask' to data available through the Channel Coastal Observatory (Matthews 2010).

7.5 HER data

On first appearances, information from an HER seems ideally suited to provide a quantitative assessment of coastal heritage loss, and indeed, taking the data at face value, it is very easy to produce graphs and statistics which show how many sites have been destroyed or damaged (Fig. 7.24).

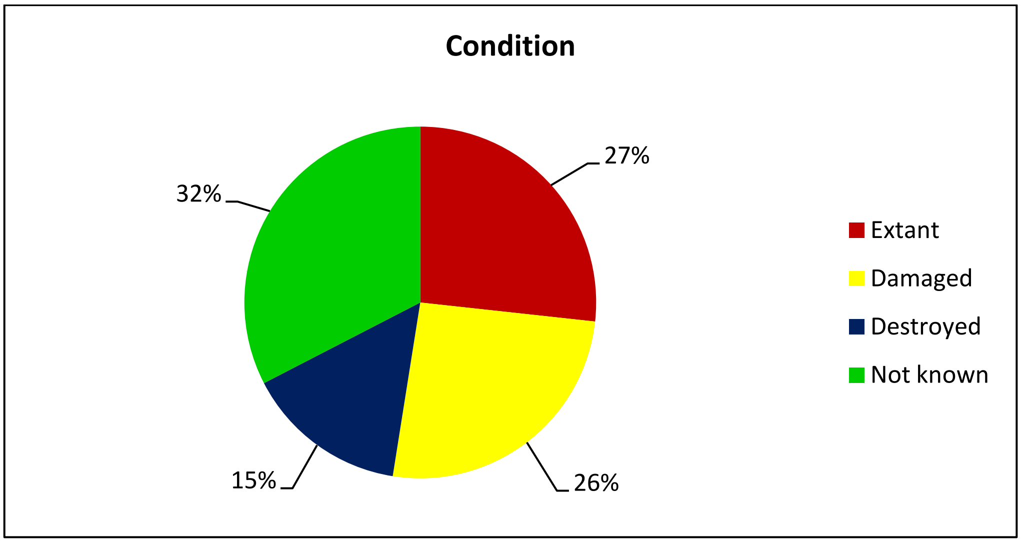


Figure 7.24 The condition of coastal monuments (excluding buildings) recorded in the Isle of Wight HER (2010)

However, it is necessary to consider what these figures actually mean. For the majority of sites it is possible only to say that a site has been destroyed between the date that it was first noted, possibly hundreds of years ago (Fig. 7.25), and a recent observation, for example, a modern survey such as the Isle of Wight Coastal Audit.

Information held by the HER was used to note the date that sites were first recorded. This was not necessarily when the site was first entered on the HER;

it might be the date of a documentary reference, or the date that a map was published, the earliest records relating to references in Domesday Book.

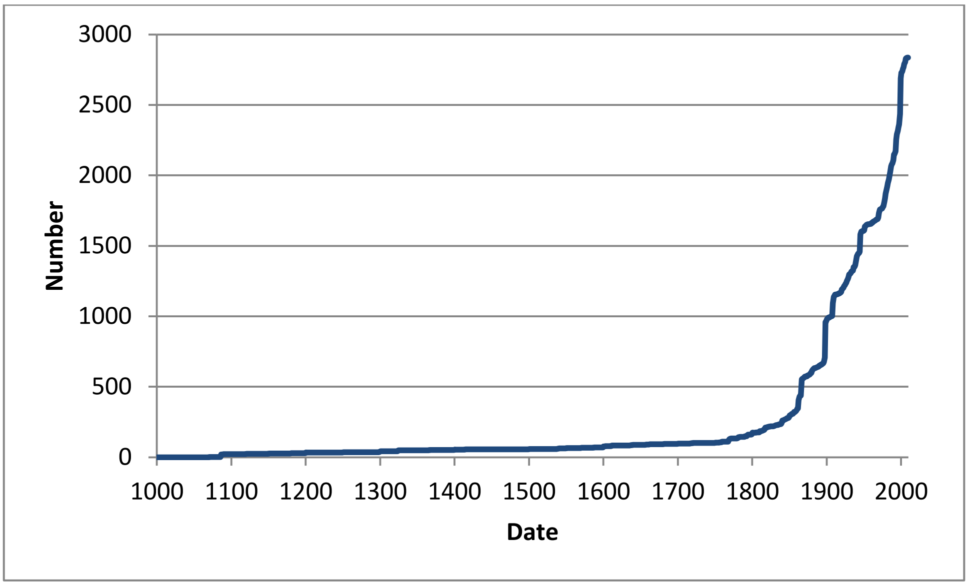


Figure 7.25 Data from the Isle of Wight HER showing the date of the first recorded reference to sites

These first recorded dates can be split into five main date ranges (Fig. 7.26):

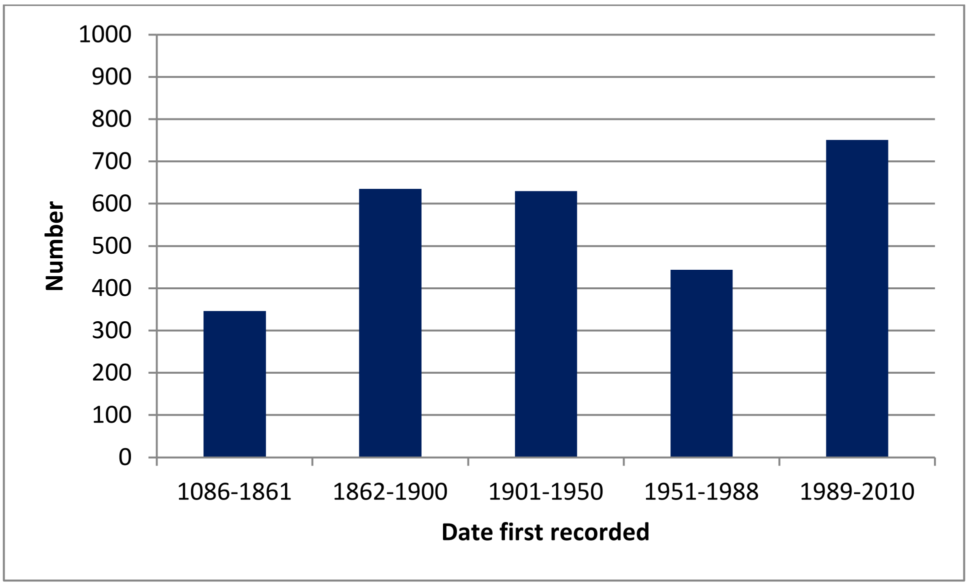


Figure 7.26 Date ranges of the first recording of sites within the Isle of Wight HER

1086-1861 Earliest reference (Domesday Book) to First Edition Ordnance Survey mapping. Mostly imprecise locations, documentary evidence.
1862-1900 Reliable mapping. Mostly post medieval sites – cartographic evidence.

1901-1950 Antiquarian activity and reasonably detailed recording (researchers on the Isle of Wight including Hubert Poole, Gerald Dunning and G.A. Sherwin). More widespread use of photography.
1951-1988 More limited but arguably more professional recording.
1989-2010 Use of accurate survey equipment and funded coastal surveys.

Due to the way that sites were plotted originally, the grid reference recorded in the HER is very likely to be imprecise. The site may have been plotted by someone other than the original fieldworker, often working from descriptive text or sketch plots, and possibly many years after the original find, and often it is not possible now to establish the accuracy of the original location. Sometimes the mapped location may just be at a named place, for example 'found in Brook Bay'. In other cases a site located on an eroding cliff will have been plotted on the cliff edge as shown on available mapping, but it is highly likely that this does not represent the contemporary cliff edge.

It was anticipated that it would be possible to quantify the rate of destruction of archaeological sites recorded in the HER. However, in addition to the problems of the accuracy of locational information, it is often not possible to quantify the rate of loss of archaeological sites. The HER usually records when a site was first noted (see above, Fig. 7.25), and recent survey such as the Isle of Wight Coastal Audit might have found no trace of the site, but all that can be established from this is that the site may have been lost between those two dates. Also, by the very nature of some coastal sites it is seldom possible to say conclusively that sites in the coastal zone have been destroyed. In the intertidal zone, conditions are often not conducive to relocating what are often very slight features. Apart from the problems of tracing sites in large expanses of featureless intertidal mud, artefact scatters or stakes protruding just a few centimetres above the surface can be very easily masked by a thin layer of mobile sediment, algal bloom, or weed.

It can be equally difficult to assess the condition of sites recorded in the cliff face. It is often not possible to gain access safely, either because the cliffs have become too sheer, too dry and crumbly, or too wet. There may be masking vegetation, and very dry, weathered conditions can make it difficult to see features such as pits and ditches in the cliff section.

Bearing in mind these facts, it is hard to see how the rates of destruction of archaeological sites can be quantified without a regular programme of monitoring.

7.5.1 HER data in the coastal zone

The Isle of Wight HER includes 4703 entries within 500m of the coast, of which 2836 are monuments (archaeological sites and find spots), 1871 are buildings, and 234 are maritime (wrecks). Designated sites on the coast comprise 22 Scheduled Monuments out of a total of 119 on the island, and 1009 Listed Buildings, which is a significant proportion of the island's total of 1933. More than 80% of the total monuments in the coastal zone are above high water, less than 12% in the intertidal zone and just over 5% are marine (Fig. 7.27a). If buildings are removed from this, the percentage above high water falls to 72%, with almost 19% in the intertidal zone and 9% below low water (Fig. 7.27b).

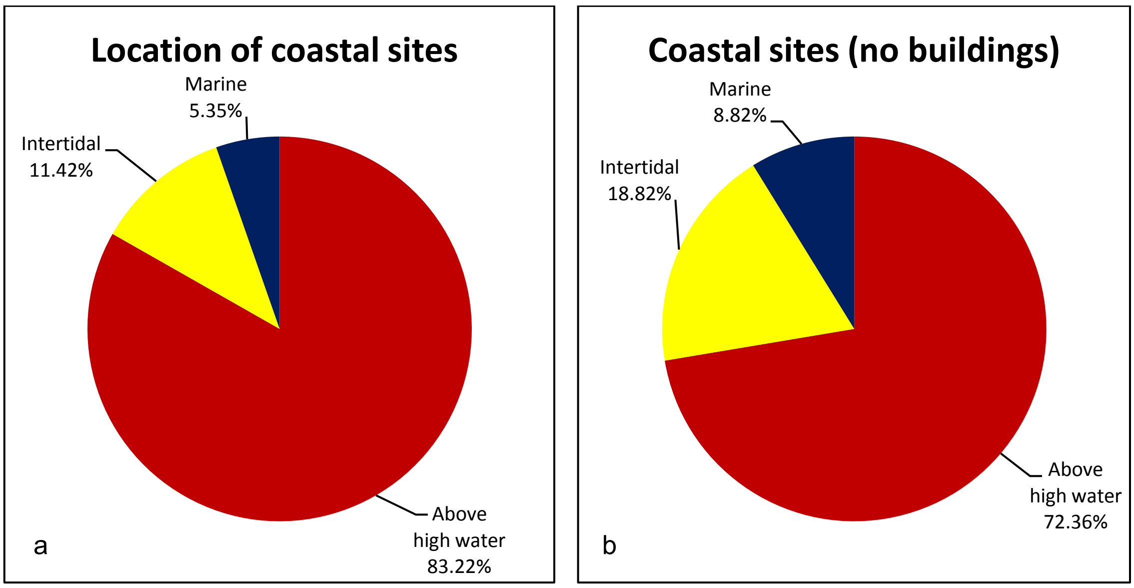


Figure 7.27 The location of sites in the coastal zone recorded in the Isle of Wight HER

Fifty seven per cent of archaeological sites recorded in the HER in the coastal zone are dated to the post medieval or modern periods, with a further 13% of unknown date (Fig. 7.28). This is largely due to the fact that rapid surveys such as the Isle of Wight Coastal Audit generally identify robust, more easily visible sites which tend to be of post medieval or modern date (Tyson *et al* 1997). Prior to the Coastal Audit, less than 20% of records were of this date (Loader and Basford 2000).

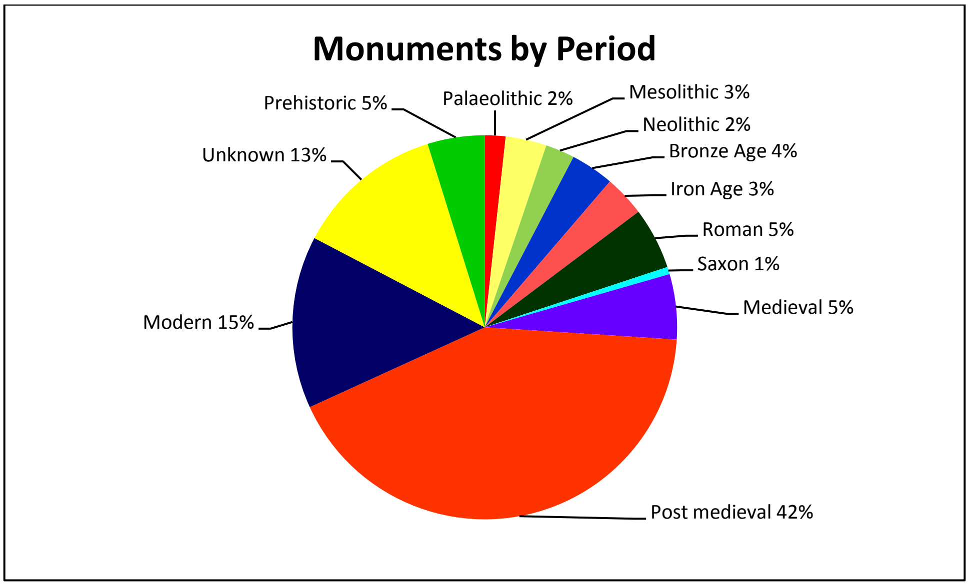


Figure 7.28 Sites recorded in the Isle of Wight HER in the coastal zone, by period

This is in marked contrast to areas of coast which have been subjected to more intensive intertidal survey, such as the Wootton-Quarr coast. During the Wootton-Quarr survey, of a total of 178 sites, were recorded in the intertidal zone, and only five have a post medieval or modern date. Although 114 remain undated, many are closely related to other dated features so they are quite likely to be of similar age.

Sites recorded in the Isle of Wight HER within 500m of the coast include 315 monument types, of which 50 can be classified as specifically coastal or maritime (Table 7.4). These coast specific types comprise 621 monuments.

More than 75% of the coast-specific sites are of post medieval or modern date (Fig. 7.29). This is partially a reflection of the fact that these more recent sites are more visible, but also earlier sites that find themselves on the coast now were not necessarily on the coast when they were in use. In addition, it is less easy to assign a function to prehistoric or Roman sites which might just be identifiable as surface scatter of worked flints or pottery.

Table 7.4 Coast specific sites recorded in the Isle of Wight HER

Anti boat landing obstacle	Landing point
Beach scaffolding	Leading light
Boat house	Lifeboat station
Boat yard	Light ship
Boom defence	Lighthouse
Breakwater	Oyster beds
Coast artillery battery	Pier
Coast light	Post alignment
Coastal fish weir	Post built structure
Coastal observation post	Promenade
Coastguard station	Quay
Coastguard tower	Sailing club
Coastwatcher's pole	Saltern
Craft	Sea defences
Dock	Sea mark
Dry dock	Seaplane factory
Ferry	Shipyard
Floating harbour	Slipway
Groyne	Submarine forest
Harbour	Submarine mining depot
Hard	Tide mill
House boat	Timber pond
Hovercraft factory	Torpedo station
Hovercraft terminal	Wharf
Jetty	Wreck

Equally, there are other sites on the coast which are rare and significant but their coastal location is not necessarily a prerequisite. For example, the Neolithic mortuary enclosure located on Tennyson Down is one of only 126 recorded nationally (English Heritage, Pastscape). Also on this stretch of coast is the High Down rocket testing site, dating from the mid 1950s to early 1970s and sited to be sufficiently remote in case of accidents and to avoid noise nuisance. There are few other examples of purpose built rocket testing facilities of this date in the world (Cocroft 2007).

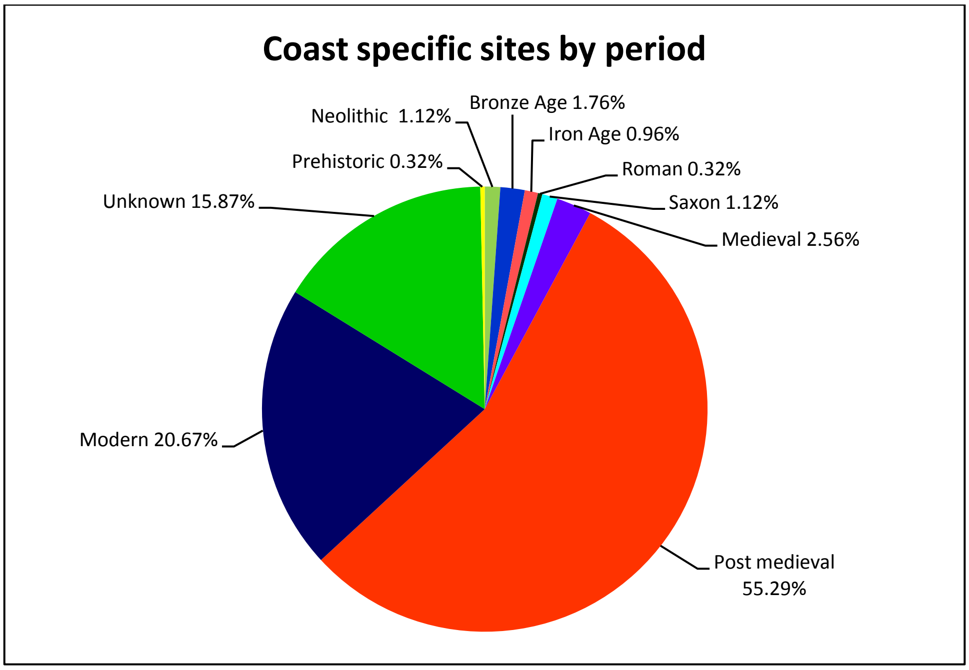


Figure 7.29 Coast specific sites recorded in the Isle of Wight HER, by period

7.5.2 Survey data held in the HER

The Isle of Wight HER includes survey data obtained between 1989 and 2005 during the Wootton-Quarr project (Tomalin *et al* forthcoming). The main survey phase was followed by a five year monitoring project. During this monitoring phase the difficulty of establishing conclusively whether sites had been destroyed or were simply not visible because of prevailing conditions was a problem encountered again and again. One of the project tasks was to re-survey previously recorded structures using total station theodolite in order to assess their survival (Loader 2008). The position of posts, the height OD, and length of stake surviving above the sediment was recorded.

A total of 137 stakes from seventeen structures were re-surveyed throughout the survey area, both at extreme low water and at various positions further up the beach. Of these, only 75 (less than 55%) could be matched positively with stakes surveyed originally, and many of the others could confidently be said to be additional posts which had not been visible previously (Fig. 7.30). Both the original and the later survey were carried out by the same field team, but it was possible that by the time of the second survey they had become more experienced working in the inhospitable conditions of the intertidal zone. Alternatively, it may be that the posts had been masked by mobile sediments, by trampling, or had not yet become exposed at the time of the original survey.

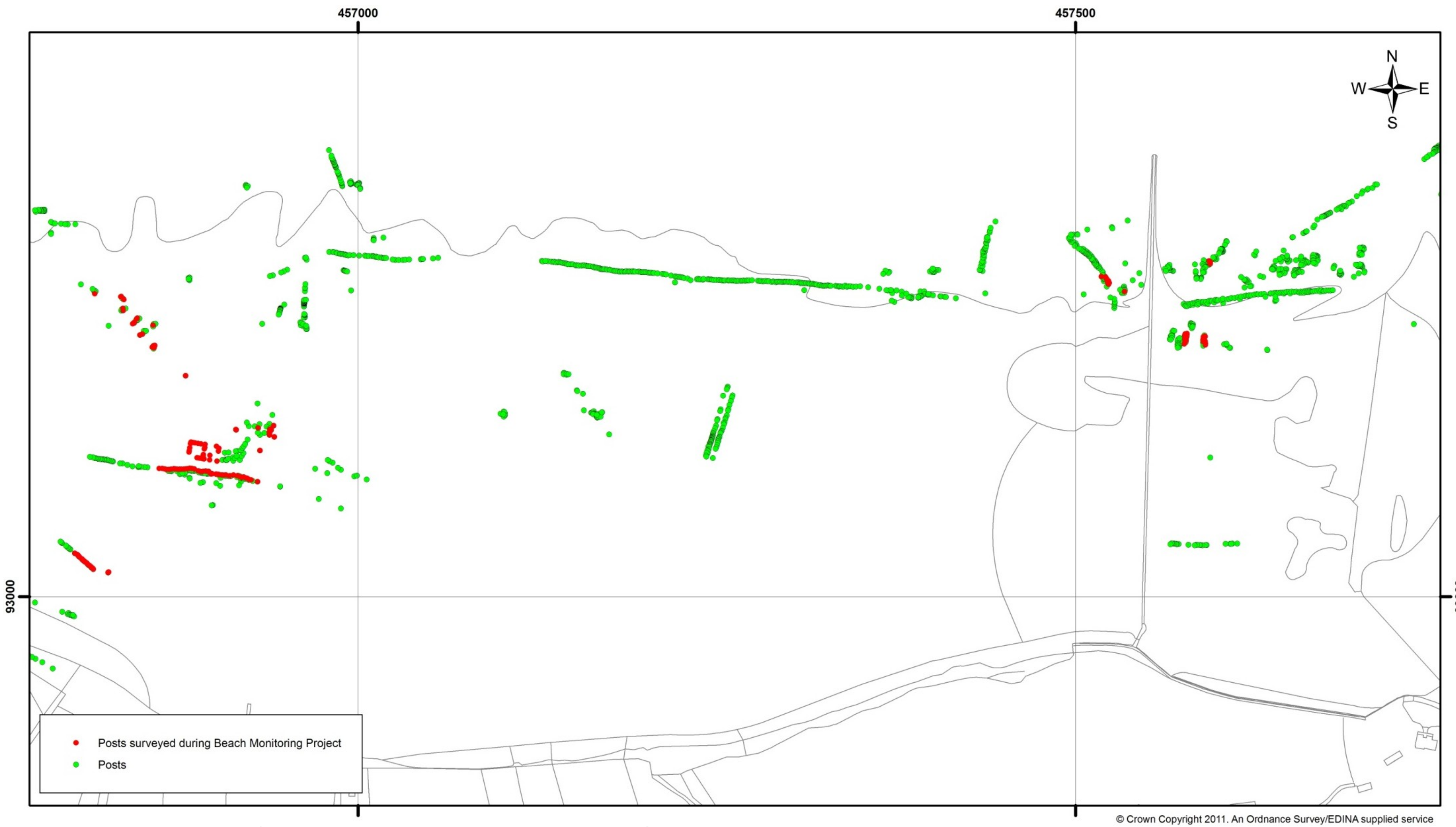


Figure 7.30 Location of posts resurveyed during the Wootton-Quarr Beach Monitoring Project

This exercise, carried out in September 2004, suggested that towards low water at both Quarr and Binstead sediment levels had fallen generally, in places by as much as 300mm, since posts were first surveyed in 1992-3 (figs. 7.31 to 7.33). Some posts surveyed previously were no longer detectable, but additional timbers which were part of the same structures were now visible.

In contrast, sites in the upper half of the foreshore at Quarr appeared to be more affected by the movement of mobile deposits such as sand and gravel banks. Whilst beach levels had gone down generally, some posts appeared to have become buried beneath mobile sediments. Alignment Q11 had been the subject of repeated surveys during the Wootton-Quarr main project (Simpson forthcoming, b) which, together with the results of the 2004 survey, showed the mobile sediments to be moving westwards. However, it should be noted that these observations were based on very limited data and, whilst they may reveal trends they do not take into account changes due to episodic events such as storms.

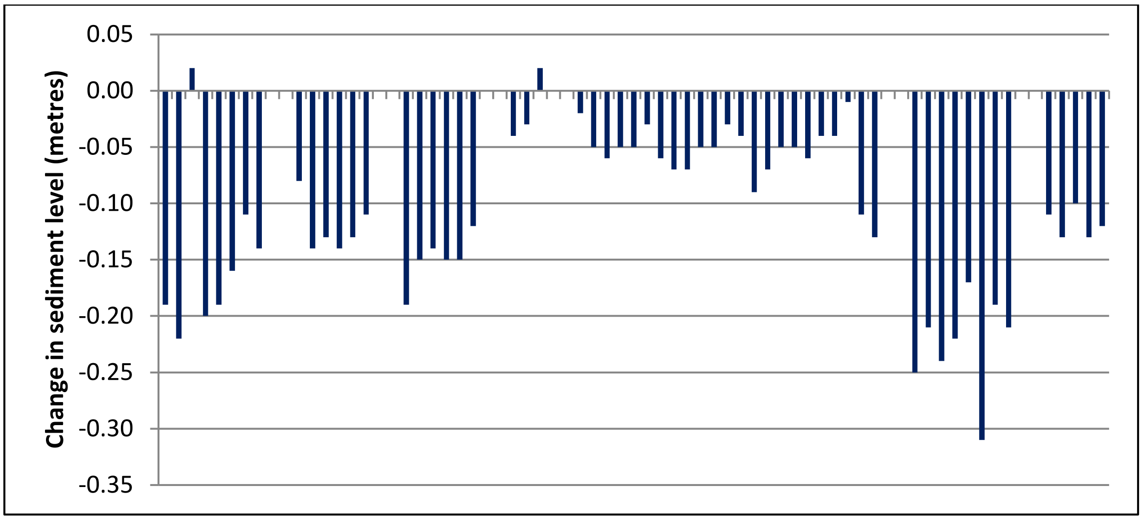


Figure 7.31 Change in sediment height around posts surveyed at Quarr and Binstead

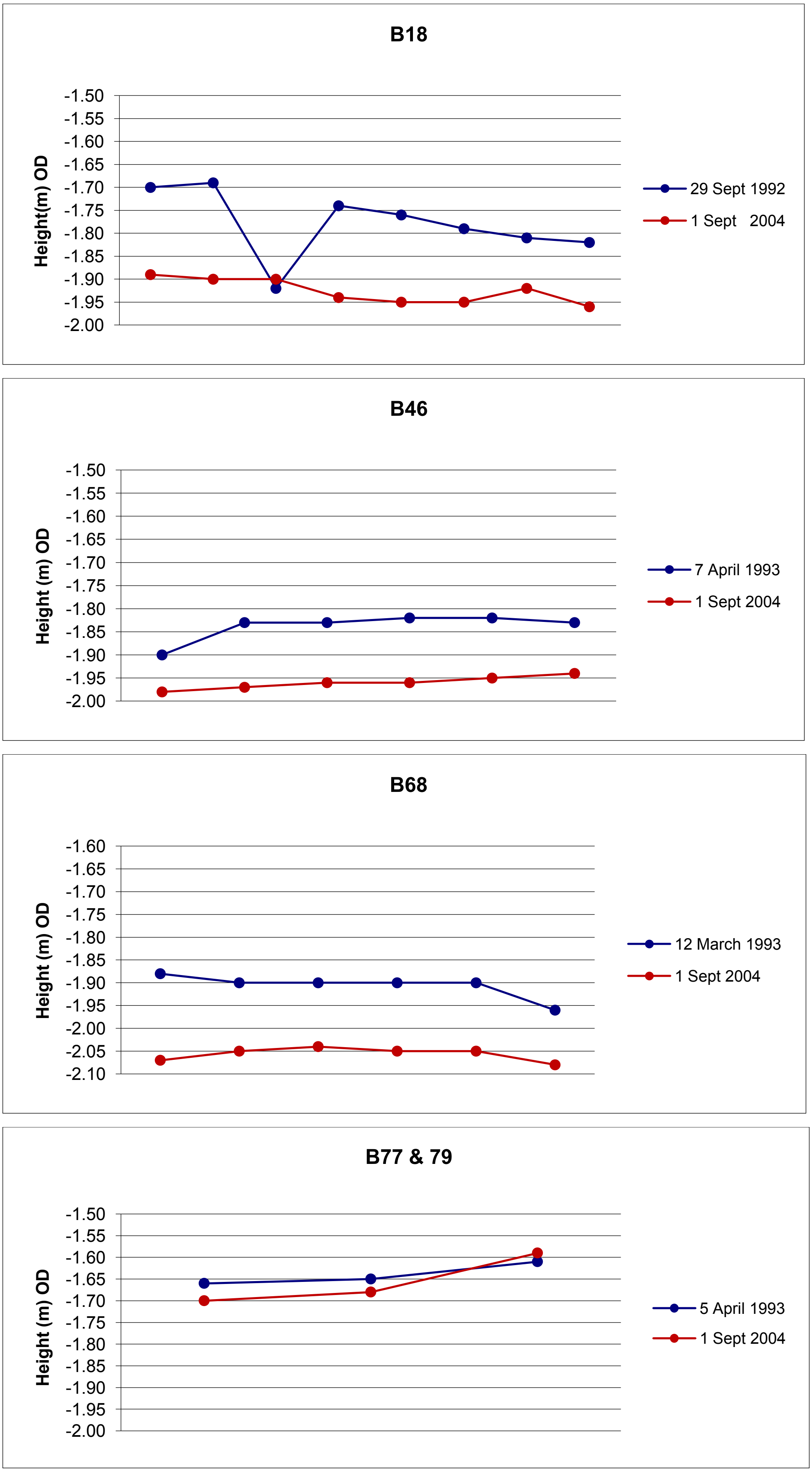


Figure 7.32 Fall in sediment levels around posts from structures at Binstead. Symbols represent individual posts but are not an accurate portrayal of the distance between posts

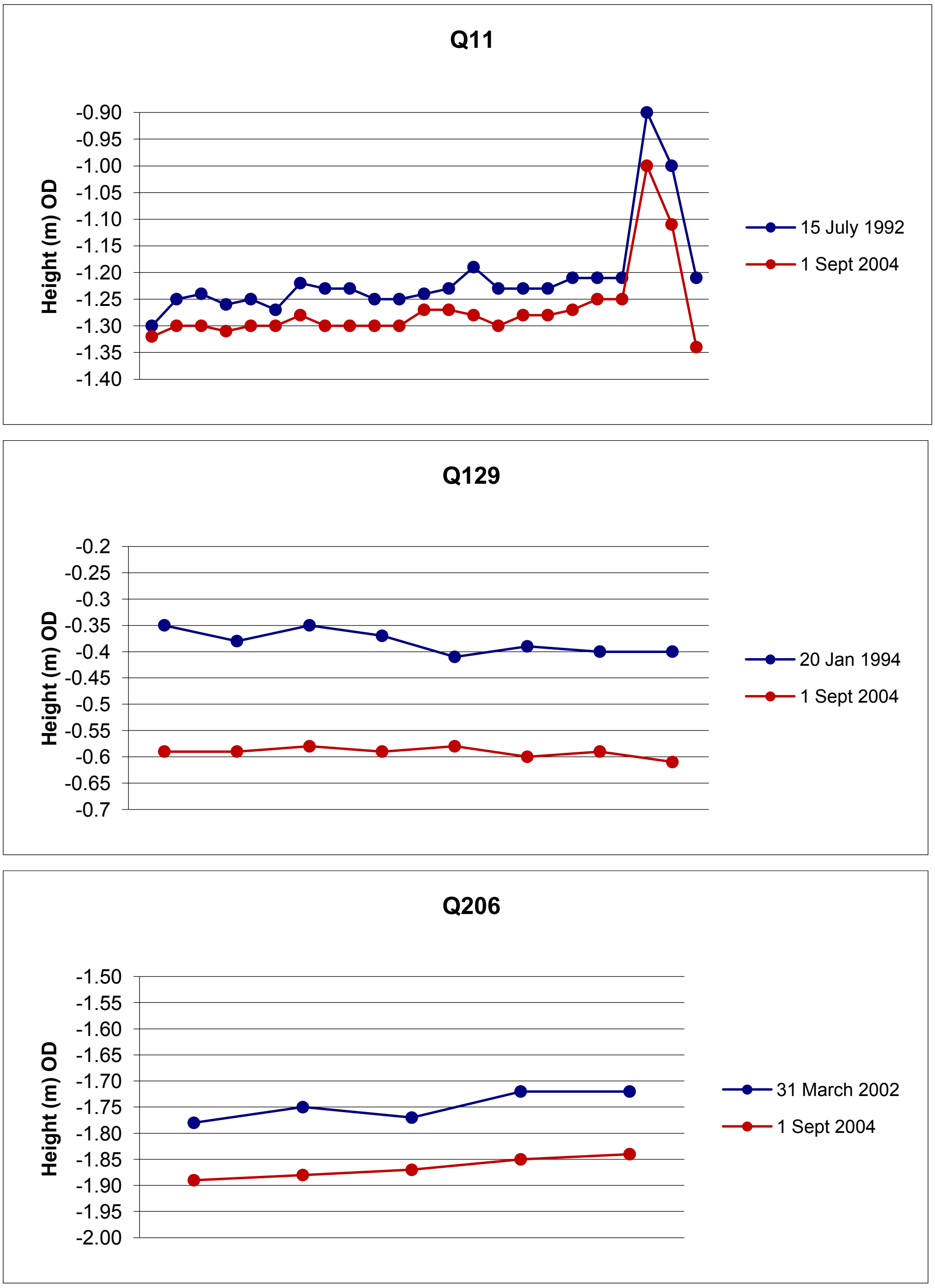


Figure 7.33 Fall in sediment levels around posts from structures at Quarr. Symbols represent individual posts but are not an accurate portrayal of the distance between posts

A second monitoring exercise carried out at Quarr was the repeated survey of the cliff line adjacent to the medieval monastic tile kiln enclosure (Fig. 7.34 and see Fig. 6.26). This was surveyed using total station theodolite five times over a period of twelve years between 1992 and 2004. This monitoring showed the cliff to have receded almost 10m over this period, and although the rate of erosion at this spot might have increased due to the excavation of the tile kiln in 1993, it does indicate that rates of erosion on this stretch of coast are considerably greater than is suggested by the historical mapping (see above, Section 7.2.1).

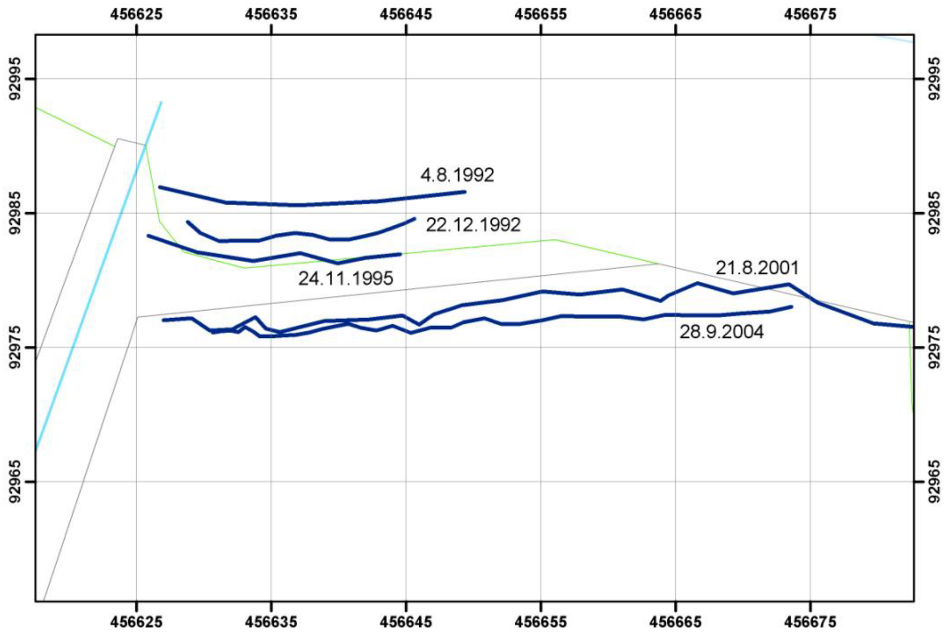


Figure 7.34 Cliff recession at the monastic tilery at Quarr (© IWCAHES)

7.6 The study areas and the techniques most applicable to them

The six study areas were specifically chosen because they represent a contrasting range of archaeological sites in a variety of settings and with diverse issues (see Chapter 6). In most of the case studies, remote techniques, whilst providing a useful context for coastal archaeological sites, have proved to be no substitute for intensive field survey, and familiarity with the area's coastal archaeology. Most importantly they should not be used in isolation without ground truthing.

7.6.1 Tennyson Down and High Down

The Tennyson Down-High Down frontage comprises steep chalk cliffs which are retreating relatively slowly. Due to the nature of the coast, beaches are insignificant.

Aerial photographs taken by the RAF in 1946 proved particularly useful for locating military earthworks and other structures dating from the Second World War. Oblique aerial photographs taken in optimum conditions revealed earthworks such as the Neolithic mortuary enclosure but vertical photographs were not helpful for this purpose.

LiDAR proved useful for confirming the location and extent of earthwork features but no new sites were revealed. Although filtered LiDAR data were used, in some cases vegetation could be mistaken for archaeological features, highlighting the necessity for this type of remote sensing to be combined with ground truthing, or at the very least a familiarity with the area being investigated.

Threats

Although natural erosion is not regarded as a particular problem on the on the chalk cliffs of the Tennyson Down-High Down frontage, if coastal recession proceeds as predicted the cliff edge will be approaching the Neolithic mortuary enclosure in 100 years (figs. 8.1 and 8.6). The Tennyson monument will be lost or will require repositioning before 2085, and approximately two thirds of the large, undated, circular enclosure visible on LiDAR plots will have disappeared.

The coastline between Freshwater Bay and the Needles is one of the most popular with walkers and tourists, so visitor impact is potentially a problem. However, most walkers keep to a wide path which is robust enough to cope with current visitor numbers. Unless they are particularly interested in the archaeological features they often pass them by unnoticed.

7.6.2 Brook Bay

Archaeology in Brook Bay comprises sites including hearths and Bronze Age cremations revealed in the eroding cliff faces. Palaeoenvironmental deposits associated with the former Western Yar tributary have been dated to the early Mesolithic although they require further investigation and additional scientific dating and analysis**.** Little survives in the intertidal zone due to the coast's exposure to the prevailing south westerly wind.

Whilst aerial photography and LiDAR may help to put sites in context and can to some extent provide quantitative evidence of coastal recession, there is no substitute here for regular inspection on the ground by experienced fieldworkers, coupled with adequate scientific dating and environmental analyses.

Threats

Erosion of the soft cliffs is the main problem affecting the archaeology of Brook Bay. The predicted effects of climate change - increased storminess, extremes of wet and drought, and sea-level rise - are likely to make the problem worse.

The foreshore is a popular tourist beach and 'fossil walks' are held regularly during the summer months. While these are primarily focussed on collecting dinosaur remains, worked flints have been found and reported to the Portable Antiquities Scheme (Frank Basford, Isle of Wight Finds Liaison Officer, pers. comm.). Of more concern, there are also collectors who remove material from the cliff face. Whilst some finds are reported and some collectors record accurately where material came from, the scale of collection is unknown.

7.6.3 St. Catherine's Point

St. Catherine's Point comprises the south-western end of the apron debris of a large and ancient landslide complex forming the Undercliff. Sites recorded in the HER include palaeoenvironmental deposits, historic buildings, middens, and ridge and furrow. Little survives in the rocky and exposed intertidal zone.

Aerial photographs reveal ridge and furrow that is only visible on the ground in optimum conditions of very low sunlight and short grass. Although it might be expected that LiDAR would also be useful in this respect, it appears that the terrain is too extreme and undulating for this technique to reveal slight earthworks.

Threats

The main threat to the archaeology of the St. Catherine's Point area is natural erosion. The apron debris on which much of the archaeology is placed is sliding seaward whilst at the same time the marine cliffs are eroding through wave action. The activities of private collectors are also cause for concern. It is known that a Roman coin hoard, human remains, and substantial amounts of prehistoric and Roman pottery have been recovered from the cliff face without being reported to the landowners, the National Trust, or the local HER.

7.6.4 Springvale

At Springvale, most of the archaeological sites that have been recorded are intertidal, mostly substantial structures of limestone. Intertidal features are visible on vertical aerial photographs because of their scale and robustness. Palaeoenvironmental deposits and artefact scatters are also present.

Although most of the archaeological features at Springvale are robust enough to be visible, LiDAR has proved to be of limited use because surveys have not been undertaken on very low spring tides. This is now compounded by the fact that changes to the presentation of LiDAR data by the Environment Agency Geomatics Group through the Channel Coastal Observatory website mean that data are now filtered using a 'predefined water line mask' (Matthews 2010).

The coast at Springvale has been defended since the First Edition Ordnance Survey mapping so the measurement of coastal recession using historic mapping is not applicable.

Threats

The archaeology on the Springvale/Puckpool frontage comprises intertidal sites on a developed coast. Coastal protection works in 2004 were subject to archaeological conditions but damage to intertidal timbers occurred when there was no archaeological presence on site (R. Martin pers.comm.). Since the completion of the works there have been changes to the beach topography to the north west of the defences, although it is unclear whether the two are related. Field observations and aerial photographic evidence available from the

Channel Coastal Observatory suggested that sites in the lower part of the intertidal zone had been progressively uncovering, but during field visits in 2010-2011 some features seemed to be less prominent. Without further monitoring it is not possible to say whether this is a long-term trend.

7.6.5 Wootton-Quarr

The Wootton-Quarr coastline was the subject of an intensive intertidal archaeological survey in the late 1980s and 1990s (Tomalin *et al* forthcoming). The medieval Cistercian monastery, a Scheduled Monument, and modern Benedictine abbey of Quarr (Grade 1 Listed Building) lie just inshore of the eroding coast. In the intertidal zone, numerous find scatters and timber structures dating from the Mesolithic to the post medieval period have been recorded. Many of these are insubstantial and easily masked by mobile sediment.

Extensive palaeoenvironmental deposits survive, and a dendrochronological sequence of 770 years between 3463 and 2694BC has been established from fallen trees lying within the organic sediment (Hillam forthcoming). LiDAR has proved to be of insufficient resolution to show any of the intertidal features. Apart from some of the larger recumbent trees they are also not visible on aerial photographs which are more often than not misleading; linear alignments of weed and rocks, or stone outcrops can often look like post alignments. Accurate measurement of falling beach levels has proved a problem.

Threats

The main threat to the archaeology of the Wootton-Quarr coast was believed to be that of natural erosion exacerbated by the effects of ship wash created not only by the car ferries operating between Portsmouth and Fishbourne, but also by the increasingly larger vessels moving through the Solent to Southampton and Portsmouth. Following years of intertidal archaeological survey on this stretch of coast, it is clear that the effects of ship wash are undoubtedly adding to the erosion, but the fact that there is no base-line data available before ship wash was perceived to be a problem means that the connection cannot be proved conclusively.

Tomalin (1997, 2000b and forthcoming) states that bait digging on a commercial scale at Wootton-Quarr is a major threat to the intertidal archaeology. As has already been stated (Section 4.4.5), this author has seen little evidence of this activity in the parts of the beach which are rich in archaeology. This may be due in part to the site's designation as a SSSI in 1993 and SAC, SPA and Ramsar site in 1998, and possibly because the beach is privately owned and relatively inaccessible. Apart from a small number of shellfish collectors, few people venture seaward of the storm beach.

Other than erosion the most damaging activity noted at Wootton-Quarr has been the operation of trawlers at high water. Prior to viewing the evidence for this activity (Fig. 4.4) it was not appreciated that this was a problem for the intertidal zone. The scale of damage caused by trawling is not so apparent when it occurs below low water.

7.6.6 Newtown Estuary

The Newtown Estuary is important archaeologically because of the survival of the layout of the deserted medieval settlement within the estuary. At the mouth of the creek intertidal timber structures, lithic scatters and palaeoenvironmental deposits have been recorded both by antiquarians and recently. Aerial photographs reveal changes to the configuration of the spits protecting the mouth of the estuary, including breaching of the eastern spit. This has implications for the survival of sites both on the open coast and within the estuary (Fig.7.35). LiDAR would undoubtedly also be useful in this respect but unfortunately only one survey is currently available.

Threats

Aggregate dredging during the period 1950 to 1990 is thought to have contributed to erosion at the mouth of the estuary, particularly of the East Spit (Bray and Cottle 2003). As a consequence of the reduction in sediment supply, the spit was overtopped and breached, and has not recovered due to ongoing limited sediment supply, possibly caused by the divergence of littoral drift at the mouth of the estuary (SCOPAC 2003c).

Unlike many of the Solent's estuaries, S*partina* die-back is not occurring in the Newtown Estuary, and in some places within the estuary *Spartina anglica* is still colonising (Bray and Cottle 2003). On the mainland, *Spartina* die-back has occurred 30 to 50 years after its peak colonisation, thus the problem is likely to be delayed in the Newtown Estuary, or it might be that as yet unknown local factors are preventing die back at this location (ibid, 10).

Most of the archaeological sites in the Newtown Estuary are in areas that are not accessible to the general public. The East Spit can only be accessed by boat or following a long walk across private land, and access is restricted at certain times of the year due to nesting birds. Whilst this serves to reduce the impact of visitors, it also makes archaeological monitoring more challenging. Tomalin (2000b) has cited the activities of 'all terrain vehicles' as being damaging to archaeological sites in the intertidal zone at Newtown, possibly the result of 'night operations' by the South East Reserve Forces' and Cadets' Association at Jersey Camp. Unfortunately no photographs of this damage are available, and the problem has not been witnessed by this writer.

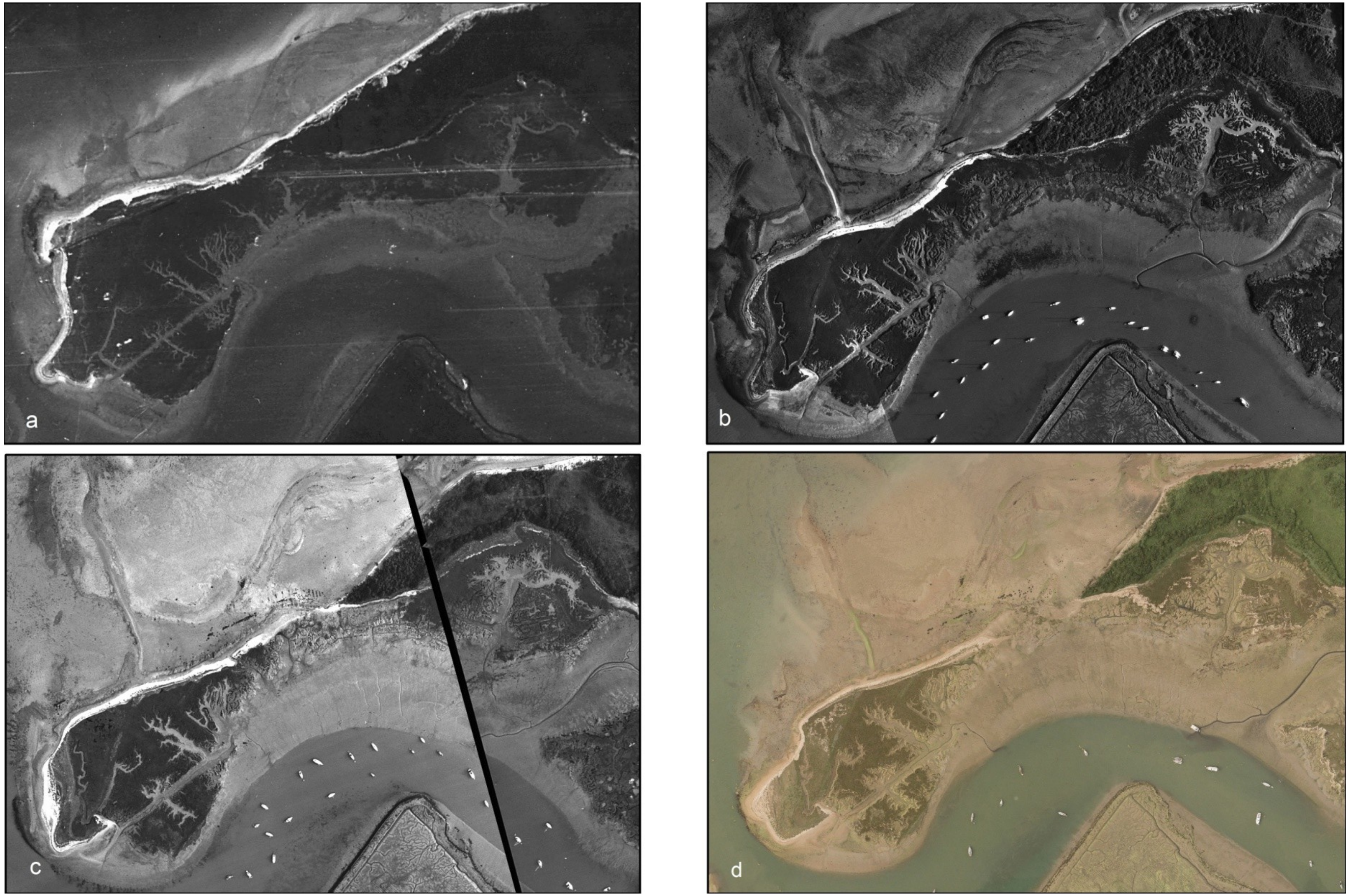


Figure 7.35 The changing configuration of Newtown East Spit: a) 1946, b) 1983, c) 1997 and d) 2005

8 Predicting future coastal heritage loss

In this chapter the results discussed in Chapter 7 will be used to assess potential future heritage loss on the coast.

8.1 The prediction of coastal change

The prediction of future coastal change is an important element of coastal management planning, and there is a range of data available for the Isle of Wight, for example in the SMP and its revision (Halcrow 1997; Isle of Wight Council *et al* 2010), Coastal Strategy Studies (Isle of Wight Council 2004, forthcoming a and b), FutureCoast (Defra/Halcrow 2002), and the BRANCH project, an INTERREG IIIB spatial planning project looking at the south west coast of the island and the Newtown Estuary, with partners in England, France and the Netherlands, which aimed to identify ways in which spatial planning might assist wildlife to adapt to climate change (BRANCH Partnership 2007).

There are several formulae for predicting future coastal recession which take into account different influencing factors, such as future sea-level rise or sediment input (for examples see Bray and Hooke 1997; Walkden and Dickson 2008). Crucial to the calculation of future coastal recession rates are an indication of historic recession rates and historic sea-level rise, and predicted rates of future sea-level rise. However, it has been said that without an understanding of cliff-beach system behaviour, and sediment and energy inputs, the extrapolation of past rates of erosion can be very misleading, and variations in beach levels can have a more significant effect on recession rates than climate change or relative sea-level rise (Lee 2008).

8.1.1 SMP2 and projected coastal recession

The Isle of Wight SMP revision (Isle of Wight Council *et al* 2010) uses projections of coastal recession rates based on Defra (2006e) guidance for calculating future sea-level rise. This guidance advises replacing the previously predicted constant sea-level rise in the south of England of 6mm/yr with exponentially rising rates over four epochs; 1990-2025, 2025-2055, 2055-2085 and 2085-2010 (Table 8.1).

Table 8.1 Projected sea-level rise for the south of England (Defra 2006e)

Date range	Net sea-level rise (Defra guidance)	Cumulative total sea-level rise (from 2009)	Previous predicted future annual rate
1990-2025	4mm/yr	7cm	6mm/yr
2025-2055	8.5mm/yr	32.5cm	6mm/yr
2055-2085	12mm/yr	68.5cm	6mm/yr
2085-2105	15mm/yr	98.5cm	6mm/yr

Using these predictions of annual sea-level rise, and having calculated historic rates of recession using maps and aerial photographs, the SMP revision calculates future coastal recession rates for each epoch under a scenario of 'No Active Intervention' using the Walkden and Dickson equation 6 which is applicable to 'soft rock shores overlain by a low volume (or absent) beach in which the profile is subjected to an increase in the rate of sea level rise' (Walkden and Dickson 2008, 83):

$$\varepsilon_2 = \varepsilon_1 \sqrt{\frac{S_2}{S_1}}$$

where ε_1= historic recession rate, ε_2 =future recession rate, S_1 = past sea-level rise and S_2 = future sea-level rise.

This was felt to be the formula most appropriate to the geomorphology of the Isle of Wight coast. Other SMP revisions, for example that for the North East Coast, have used the Leatherman formula for calculating future coastal recession rates (Royal Haskoning 2007, C-110). The Leatherman formula:

$$\text{Future recession rate} = \text{Future sea-level rise}\left(\frac{\text{Historical recession rate}}{\text{Historical sea-level rise}}\right)$$

is used when sea-level rise is taken to be the dominant influence and other factors remain constant. The Isle of Wight SMP revision describes this model as producing an upper limit of future coastal recession while the Walkden and Dickson formula results in a mid range or 'best guess' estimate, and the projection of historical trends alone provides the lowest estimate (Isle of Wight Council *et al* 2010, Appendix C3).

As an example, if future sea-level rise is four times that of the past, then using the Walkden and Dickson formula the future recession rate is double that of the past; under the Leatherman formula the future recession rate is four times that of the past.

Walkden and Dickson state that the rates of coastal retreat take *c* 1000 years to reach equilibrium following a change in the rate of sea-level rise, but that half of the change will occur after the first 50 years. The Isle of Wight SMP2 takes this into account by the use of ‘epoch factors’ which moderate the rates of erosion. These ‘epoch factors’ are not defined, however, nor is the historic rate of sea-level rise.

The SMP revision tables the predicted recession rates for 58 individual units around the island’s coast. Those relevant to the areas under examination here are listed below (Table 8.2).

Table 8.2 Historical and future annual coastal recession rates as calculated by the Isle of Wight SMP revision (Isle of Wight Council et al *2010)*

Study Area	SMP 2 Unit	Historical rate (m/yr)	2010-2025 (m/yr)	2025-2055 (m/yr)	2055-2085 (m/yr)	2085-2105 (m/yr)	Potential 100 year erosion (m)
Tennyson Down-High Down	**Tennyson Down and the Needles (IW42)**	0.25	0.29	0.38	0.44	0.48	40
Brook Bay	**Atherfield Clay to Compton Chine (IW40)**	0.50	0.58	0.76	0.88	0.96	80
St Catherines	**St Lawrence Undercliff (IW37)**	0.30	0.35	0.46	0.53	0.58	27
	Castlehaven and St Catherines (IW38)	0.60	0.69	0.91	1.06	1.15	93
	Blackgang (IW39)	1.00	1.15	1.52	1.77	1.92	91
Newtown Estuary	**Newtown -West Spit (IW53)**	0.60	0.69	0.91	1.06	1.15	93
	Newtown - East Spit (IW53)	0.62	0.72	0.94	1.10	1.19	96
	Newtown - inner (IW53)	0.20	0.23	0.30	0.35	0.38	31

The figures quoted in SMP2 for the north east coast of the Isle of Wight were taken from the North-East Wight Coastal Defence Strategy Study (Isle of Wight Council 2005a). Three epochs rather than four were considered (Table 8.3). Epochs 1 and 2 allowed for a 6mm/yr rise in sea-level. For the third Epoch, the rates were input into the Walkden and Dickson model with a recalculated sea-level rise allowance. The historical recession rate is not recorded.

Table 8.3 Annual future coastal recession rates as calculated by the Isle of Wight SMP revision for the Wootton-Quarr and Springvale frontages (Isle of Wight Council et al *2010)*

SMP Unit	Current to 2055 (m/yr)	2055 to 2085 (m/yr)	2085 to 2105 (m/yr)	Potential 100 year erosion
Wootton-Quarr	1	1.18	1.29	111
	0.4	0.47	0.52	44
	0.4	0.47	0.52	44
Springvale	1	1.18	1.29	111
Seaview Duver	1	1.18	1.29	111

There were differences between the historical recession rates quoted in the SMP revision and those that I had calculated for my specific study areas (see Tables 8.2 and 8.5). I have based my examination of future erosion trends on the figures presented in the SMP, because these are the published figures, but I have also used my calculated historical recession rates with the Leatherman formula to provide an alternative and comparative projection.

Table 8.4 SMP2 Total coastal recession rates for the years 2010-2105 (Isle of Wight Council et al *2010)*

Total predicted coastal recession (m):	2010-2025	2025-2055	2055-2085	2085-2105
Tennyson Down-High Down	4.35	15.75	28.95	38.55
Brook	8.7	31.5	57.9	77.1
St Catherine's Point	10.35	37.65	69.45	92.45
Quarr		45	80.4	106.2
Springvale		45	80.4	106.2
Newtown West Spit	10.35	37.65	69.45	92.45
Newtown East Spit	10.8	39	72	95.8
Newtown inside estuary	3.45	12.45	22.95	30.55

Taking the coastline or top of cliff as portrayed on the latest Ordnance Survey MasterMap mapping as a baseline, these predicted recession rates were applied in the GIS to each of my study areas by creating a buffer landwards of the coastline representing the cumulative total recession for each epoch (figs.8.1 to 8.5). It has to be noted that this measurement is rather artificial because it assumes that erosion rates will be even along the entire length of coast, whereas in reality erosion is episodic and localised. The exercise was not carried out at Springvale because this is a defended coast.

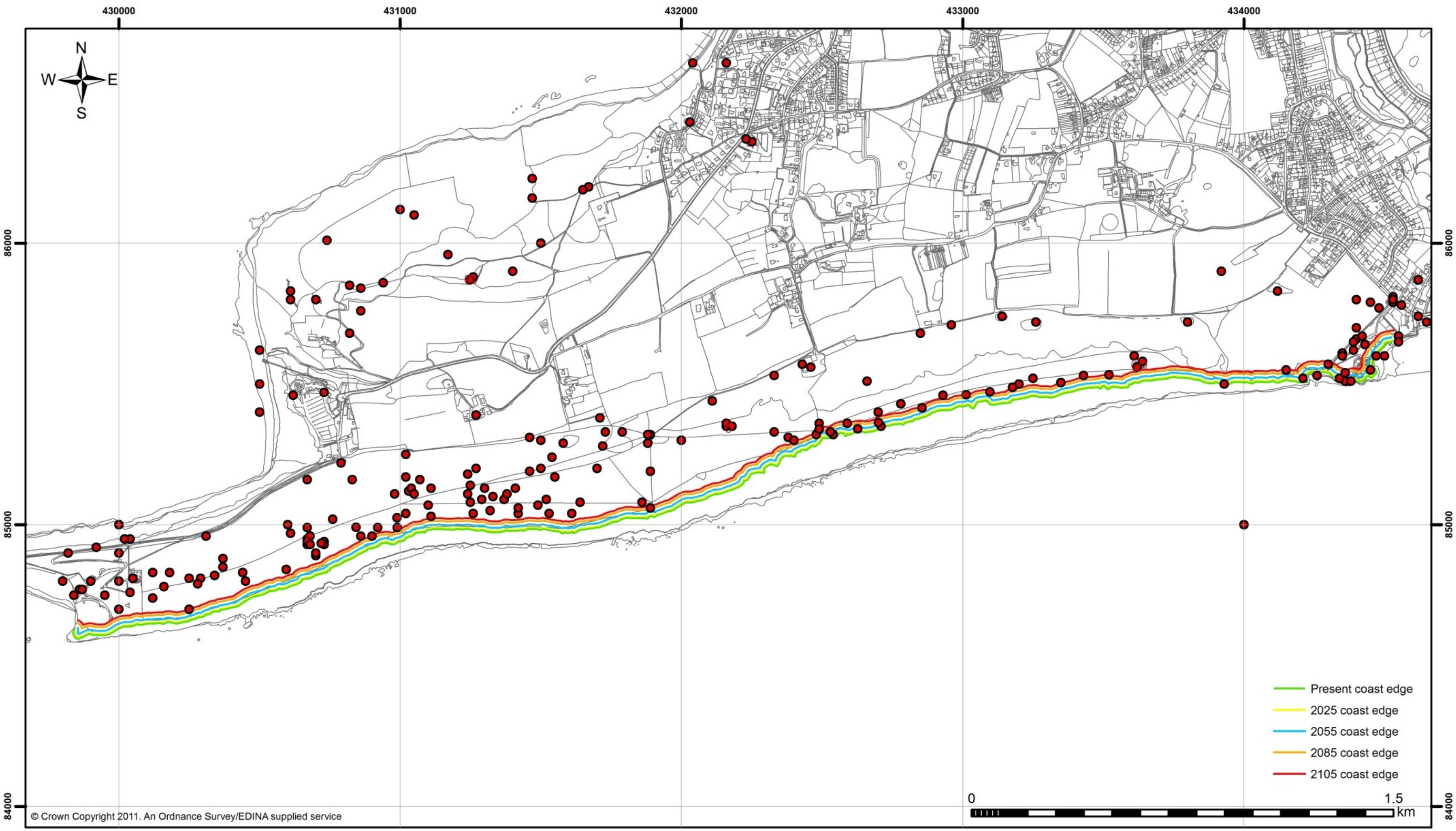


Figure 8.1 Tennyson Down – High Down predicted future coastal recession using figures from the Isle of Wight SMP revision

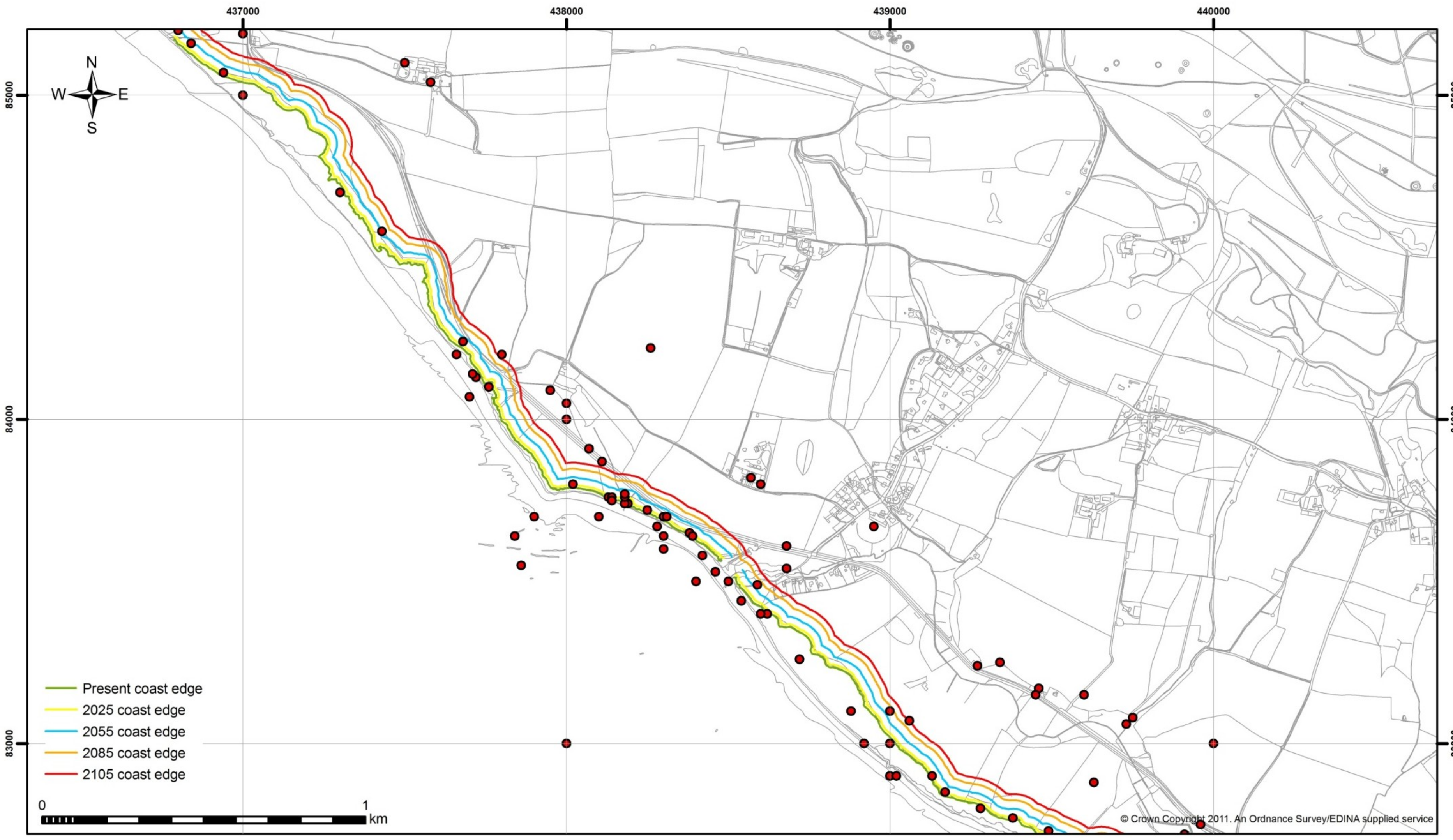


Figure 8.2 Brook predicted future coastal recession using figures from the Isle of Wight SMP revision

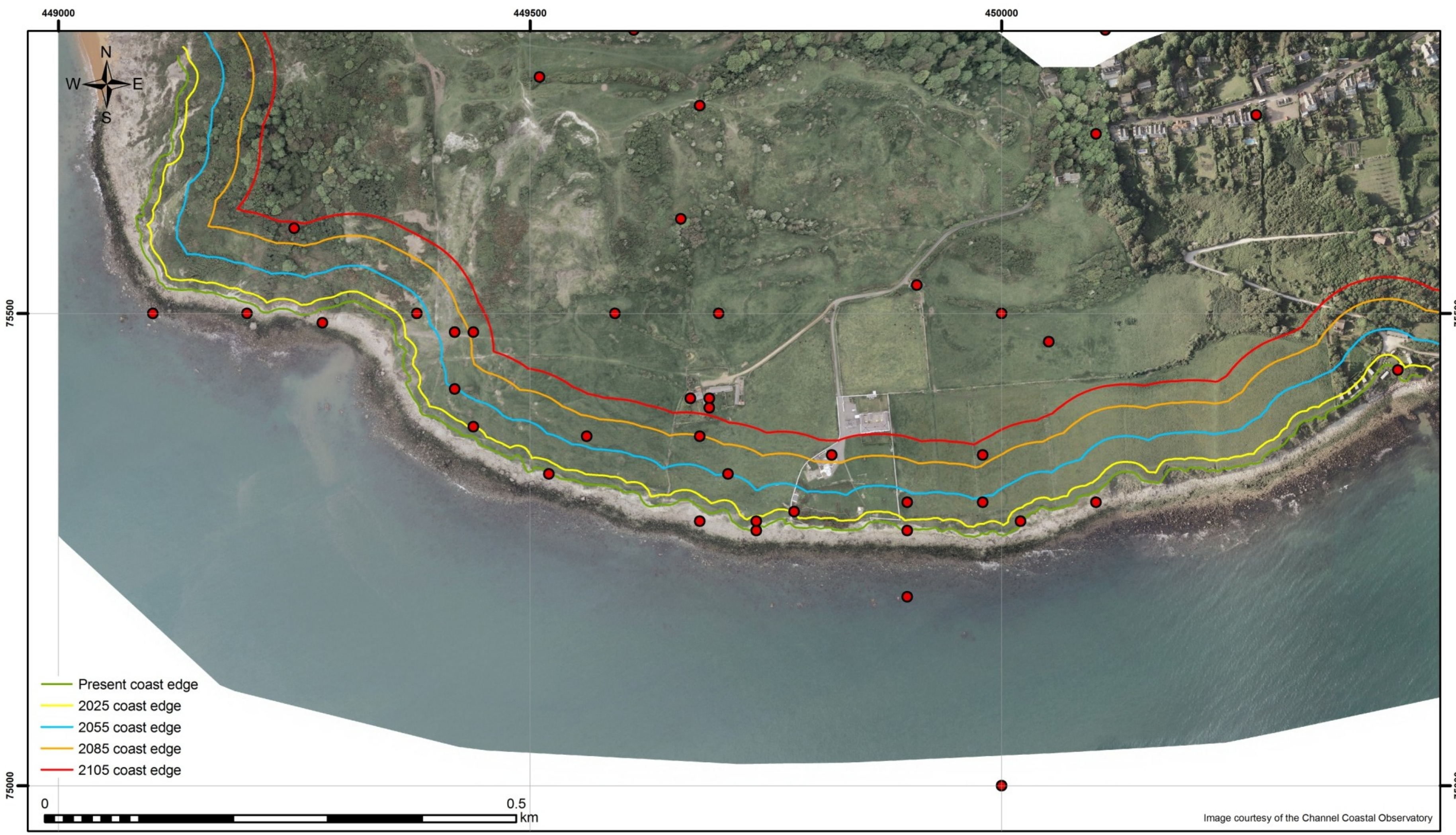


Figure 8.3 St Catherine's Point predicted future coastal recession using figures from the Isle of Wight SMP revision

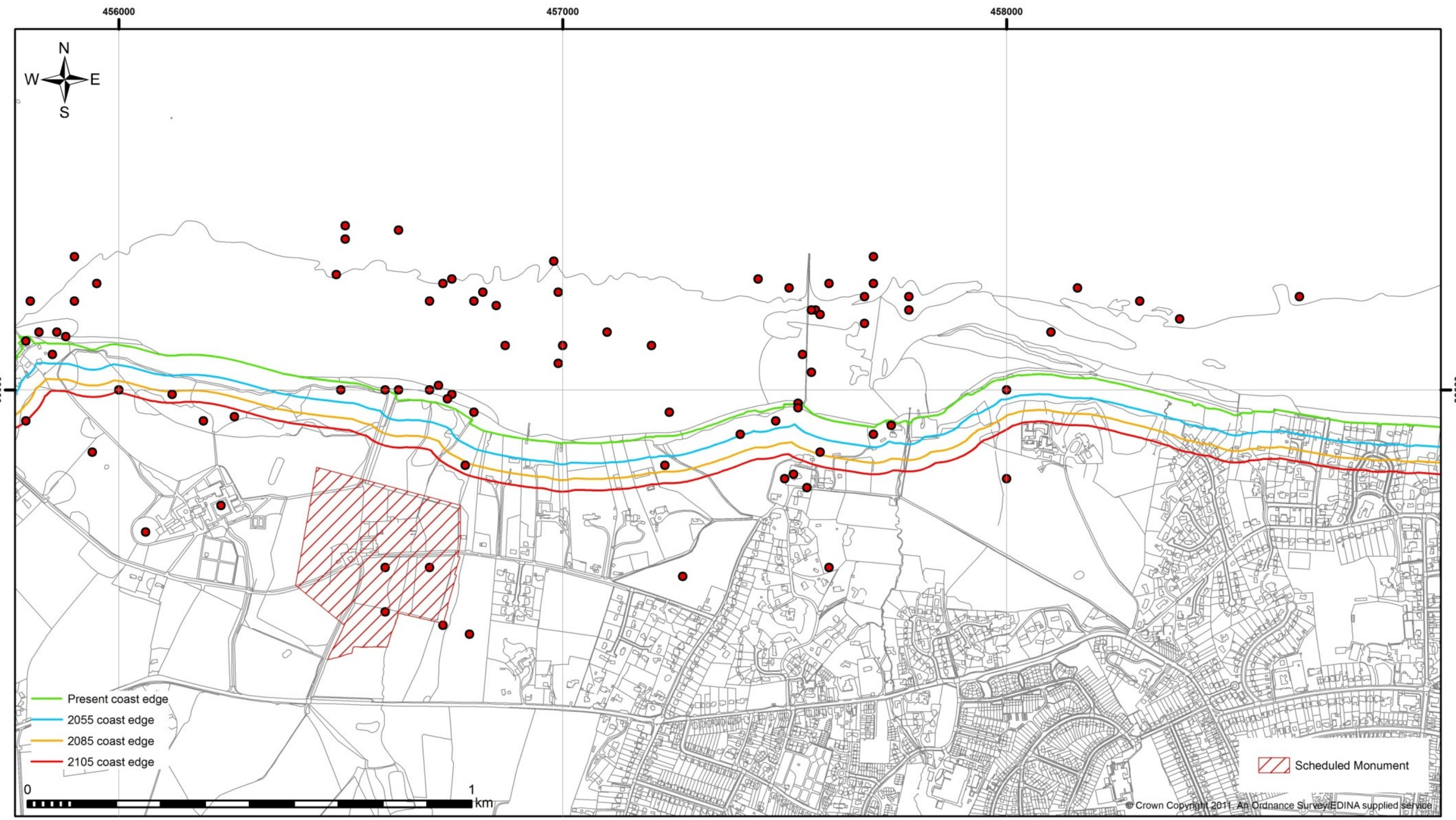


Figure 8.4 Wootton-Quarr predicted future coastal recession using figures from the Isle of Wight SMP revision

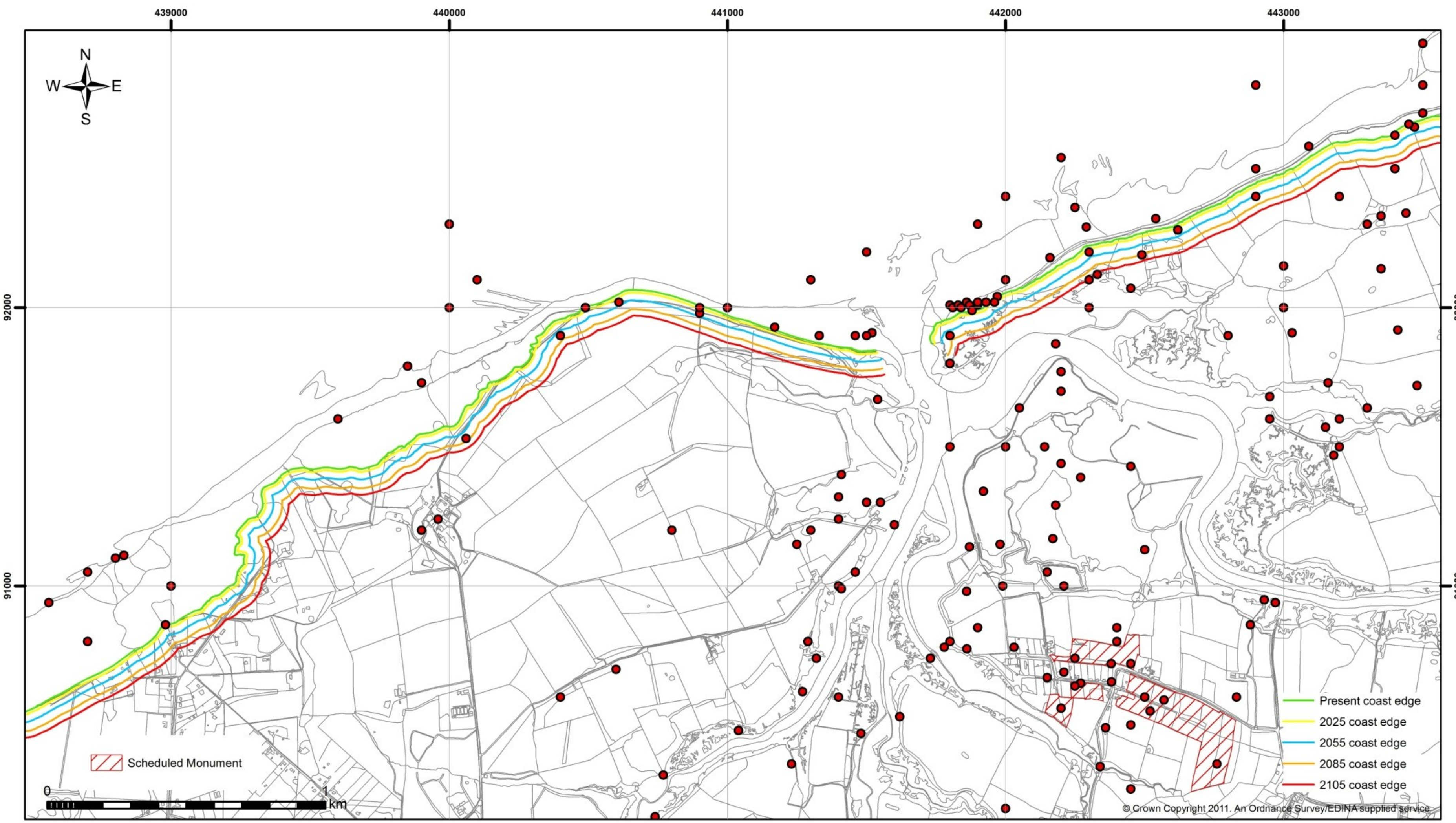


Figure 8.5 Newtown open coast predicted future coastal recession using figures from the Isle of Wight SMP revision

The exercise was repeated using the figures that I obtained from historic mapping and applying the Leatherman formula (Table 8.5 and Figs. 8.6 to 8.10). I allowed for an annual historic sea-level rise of 2mm as this is the rate that is generally applied for the south of England (Walkden and Dickson 2008, 82), although there is a wide variation in the figures used for different studies and the methods by which they are obtained (see Halcrow 1997, and Haigh 2006 for examples). Haigh (2006) cites previous studies which have calculated past sea-level rise at Portsmouth ranging between 1.11mm/yr and 8.35±0.80 mm/yr.

Table 8.5 Future recession rates calculated using the Leatherman formula and historic retreat rates measured from historic mapping

	Historical rate (m/yr)	**2010-2025**		**2025-2055**		**2055-2085**		**2085-2105**	
Tennyson Down-High Down	0.07	0.14	2.1	0.2975	8.925	0.42	12.6	0.525	10.5
Brook	0.37	0.74	11.1	1.5725	47.175	2.22	66.6	2.775	55.5
St Catherine's Point	0.09	0.18	2.7	0.3825	11.475	0.54	16.2	0.675	13.5
Springvale	0.005	0.01	0.15	0.0213	0.639	0.03	0.9	0.0375	0.75
Wootton-Quarr	0.03	0.06	0.9	0.1275	3.825	0.18	5.4	0.225	4.5
Newtown	0.47	0.94	14.1	1.9975	59.925	2.82	84.6	3.525	70.5

Cumulative totals

	2010-2025	**2025-2055**	**2055-2085**	**2085-2105**
Tennyson Down-High Down	2.1	11.025	23.625	34.125
Brook	11.1	58.275	124.875	180.375
St Catherine's Point	2.7	14.175	30.375	43.875
Springvale	0.15	0.789	1.689	2.439
Wootton-Quarr	0.9	4.725	10.125	14.625
Newtown	14.1	74.025	158.625	229.125

There are notable differences between the results obtained using the SMP2 predicted recession rates and those which I produced using historic mapping and the Leatherman formula. In the Tennyson-High Down, St. Catherine's Point, and Wootton-Quarr study areas, the recession rates calculated using my historic recession rates and the Leatherman formula are significantly less than those predicted by the SMP revision, whilst in the Brook and Newtown study areas, my calculated recession rates are considerably greater than those of the SMP revision. Having visited and worked in the study areas for many years, I feel that neither set of results is entirely accurate. Recession rates on the Wootton-Quarr coast are unquestionably greater than those that I have calculated from historic mapping, whilst the future recession rates at Brook that I produced using cartographic evidence and the Leatherman formula appear more realistic than those quoted in the SMP revision.

In conclusion, although it is important and necessary to attempt to predict future recession rates, in reality there is a high degree of uncertainty inherent in such calculations. To use the highest estimates might introduce a degree of panic about the scale of likely heritage loss, but equally, if the lower rates are used the scale of the problem might be underestimated. Perhaps more significant is the fact that the results are so inconsistent; it is not simply as might be predicted that the Walkden and Dickson formula produces a mid range estimate whilst the Leatherman formula gives an upper limit calculation.

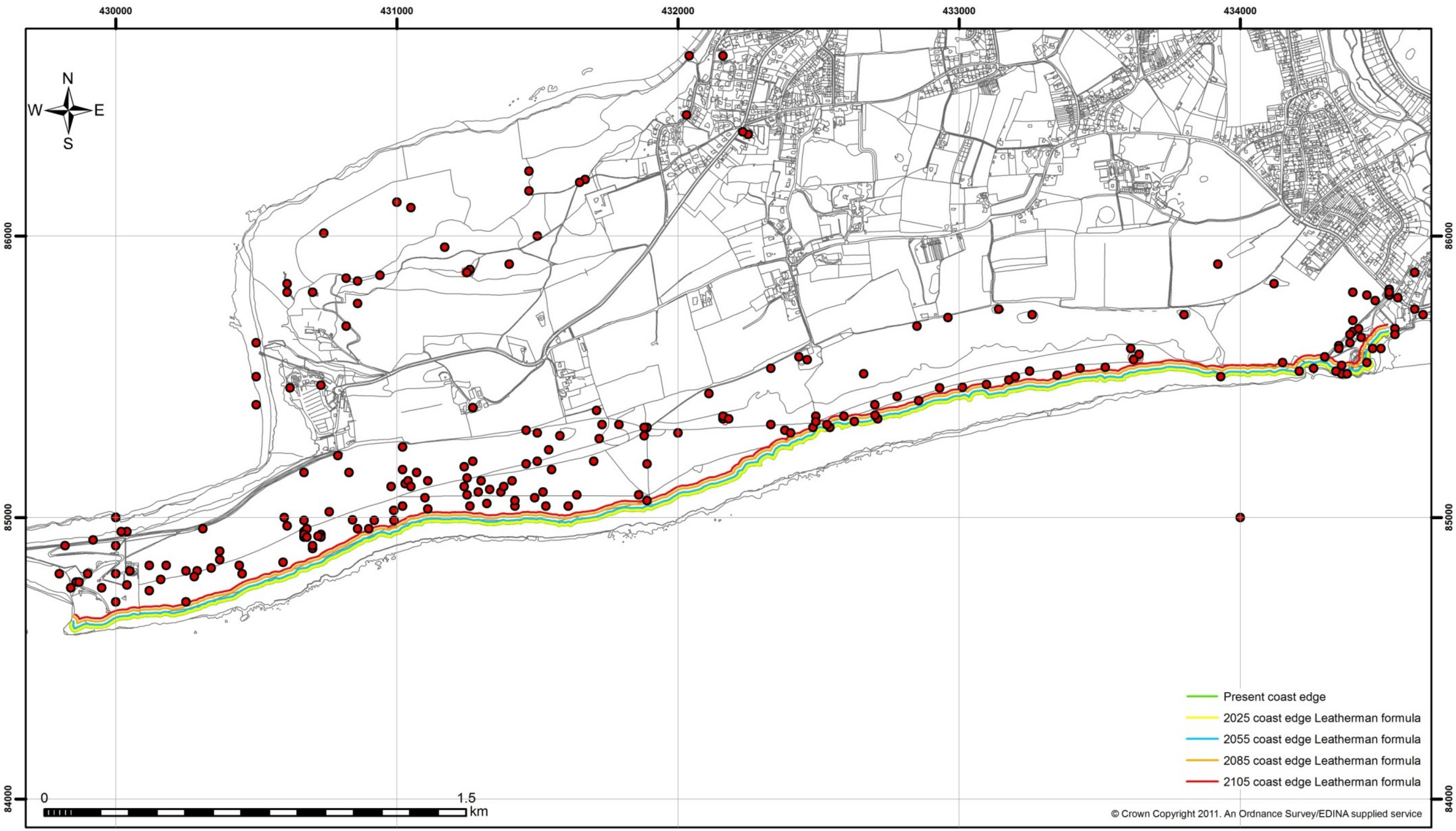


Figure 8.6 Tennyson Down – High Down predicted future coastal recession using the Leatherman formula

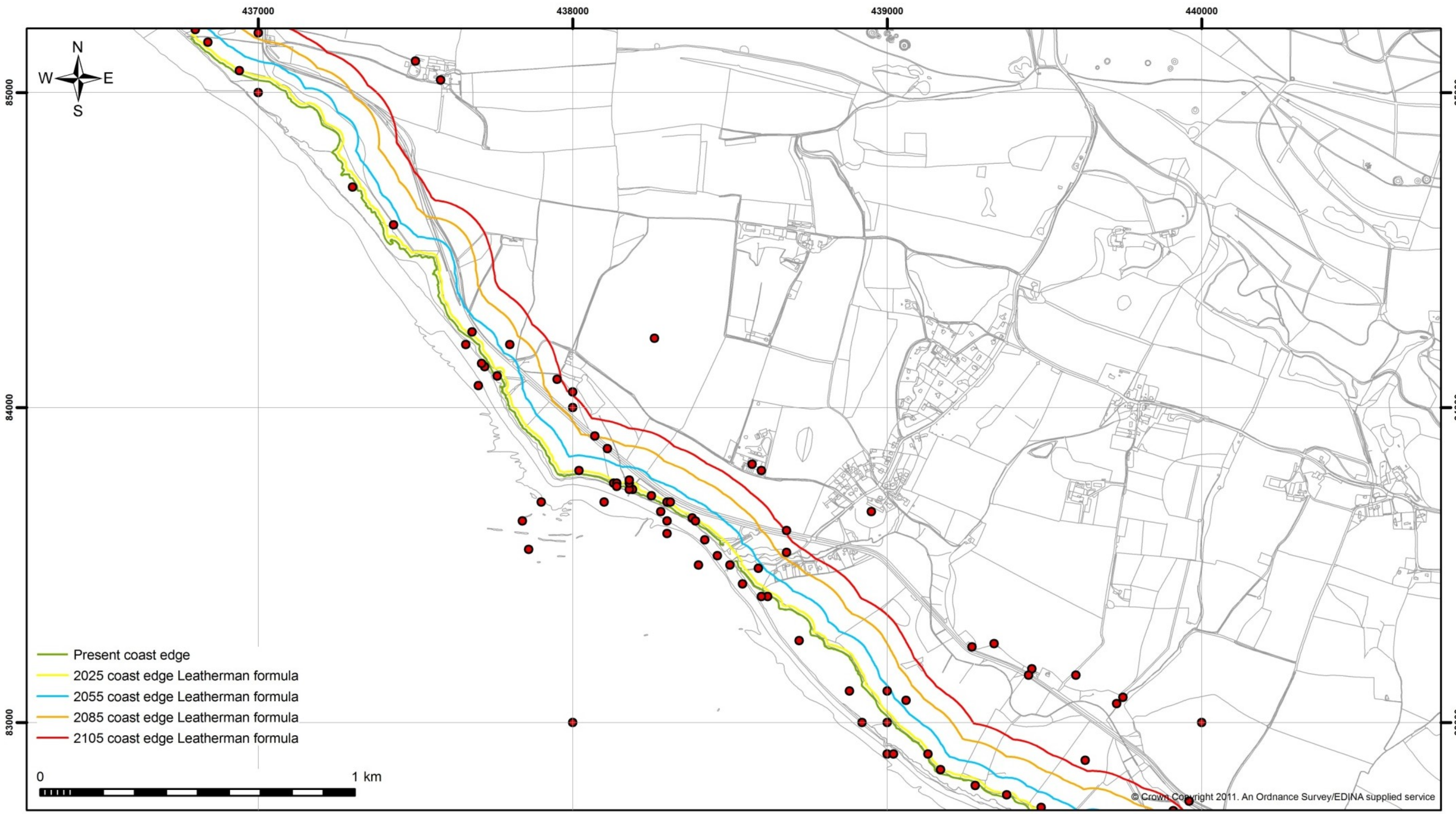


Figure 8.7 Brook predicted future coastal recession using the Leatherman formula

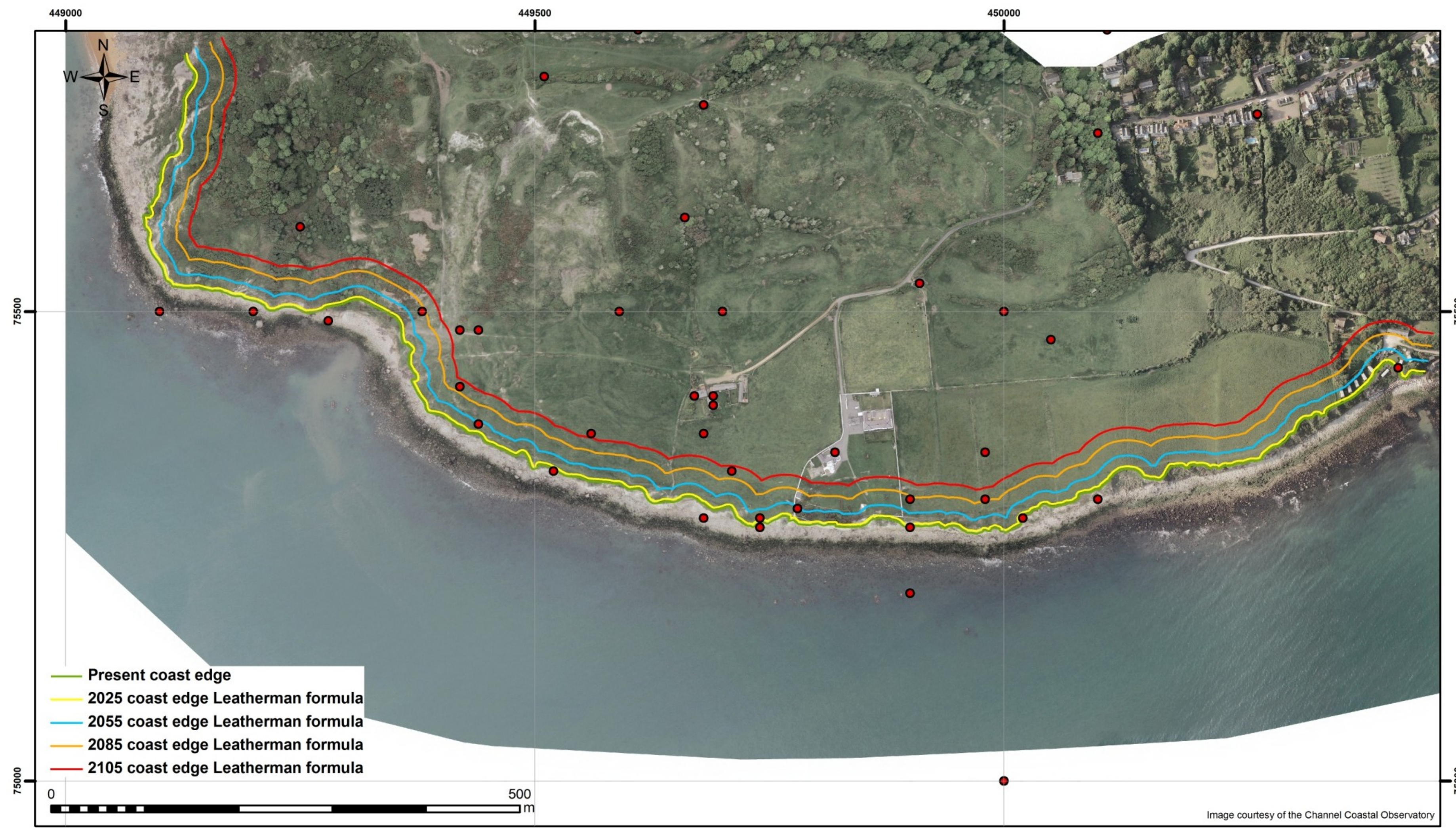


Figure 8.8 St. Catherine's Point predicted future coastal recession using the Leatherman formula

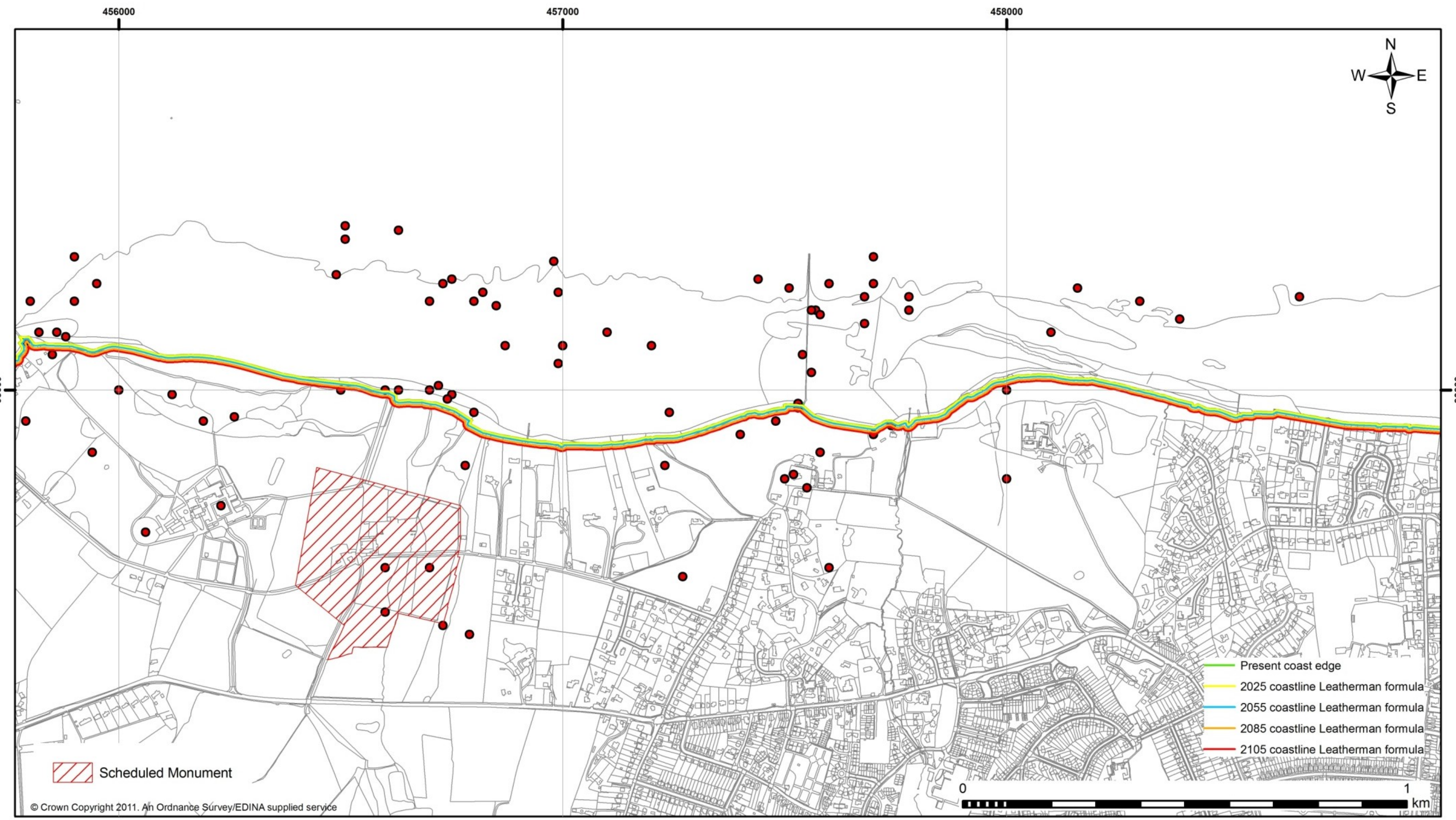


Figure 8.9 Wootton-Quarr predicted future coastal recession using the Leatherman formula

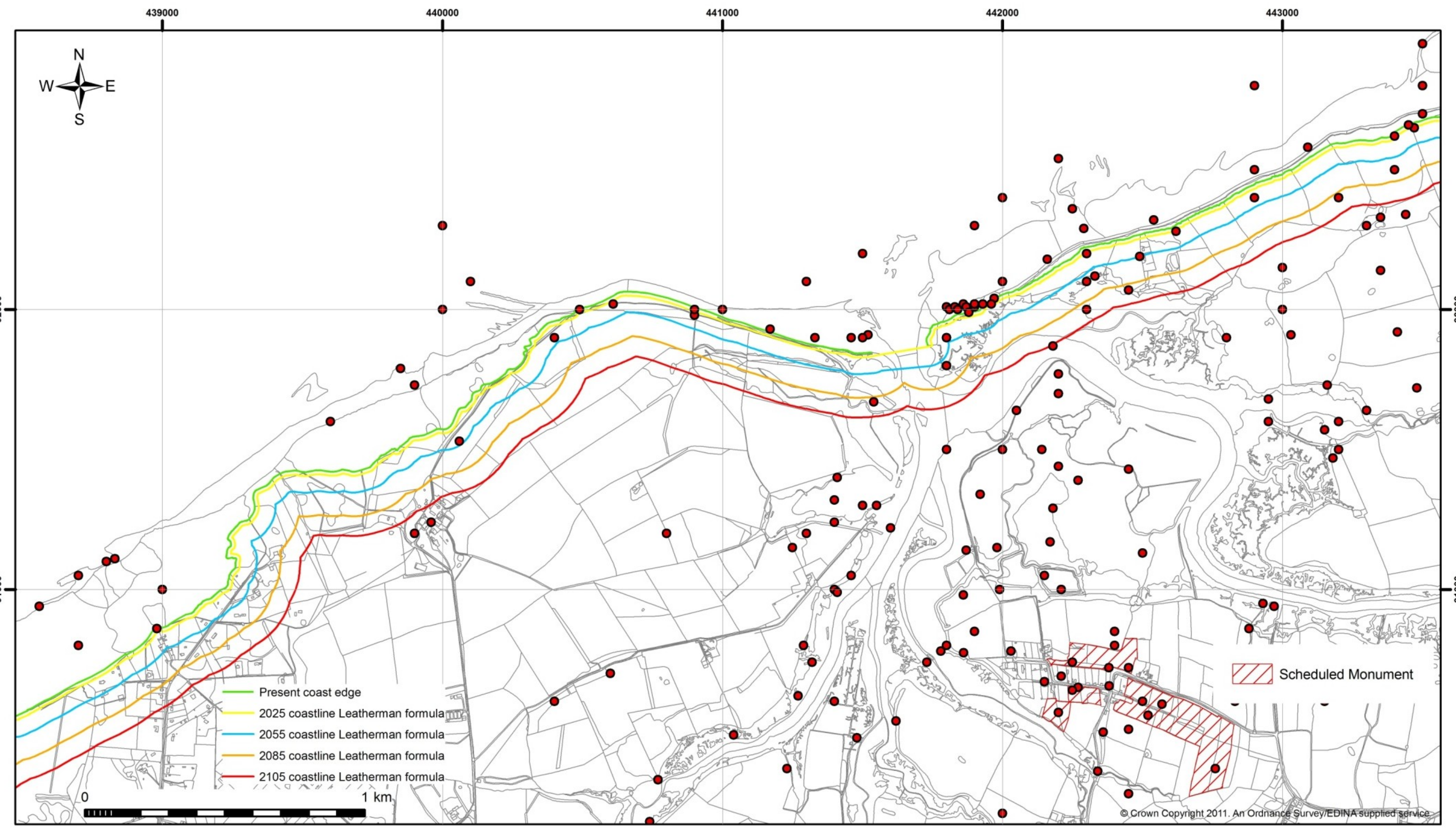


Figure 8.10 Newtown predicted future coastal recession using the Leatherman formula

8.1.2 Predicting coastal heritage loss

Using the recession rates from the SMP revision, the predicted loss of known archaeological sites on the coast of each of my study areas is as follows (Table 8.6).

Table 8.6 Number of HER sites landward of the coastline potentially lost to coastal erosion by 2105 using recession rates calculated by the Isle of Wight SMP revision

	Present - 2025	**Present - 2055**	**Present - 2085**	**Present - 2105**
Tennyson Down-High Down	2	7	12	21
Brook	10	19	23	23
St Catherine's Point	3	8	12	16
Springvale	n/a (defended coast throughout the life of the SMP)			
Wootton-Quarr	0	10	13	19
Newtown (open coast only)	7	12	17	20

The predicted loss of archaeological sites on the coast in my study areas using recession rates calculated using cartographic recession rates and the Leatherman formula, with a 2mm/yr historic sea-level rise is as follows (Table 8.7).

Table 8.7 Number of HER sites landward of the coastline potentially lost to coastal erosion by 2105 using recession rates calculated using historic recession rates and the Leatherman formula

	Present - 2025	**Present - 2055**	**Present - 2085**	**Present - 2105**
Tennyson Down-High Down	1	5	8	13
Brook	12	23	26	32
St Catherine's Point	1	4	6	9
Springvale	n/a (defended coast throughout the life of the SMP)			
Wootton-Quarr	0	0	3	4
Newtown (open coast only)	7	17	23	27

However, quantification of potential heritage loss using HER data will be an underestimation because a large percentage of buried archaeology is only revealed and enters the record as it is damaged by coastal recession. This is especially true in the Brook Bay study area where the majority of archaeological sites have been identified in the eroding cliff face.

Much of the island's coast falls under the SMP management option 'do nothing' due to its environmental significance and because it is economically unjustifiable to protect large stretches of coastline since development is concentrated in the coastal towns and resorts. This means that archaeological sites will not be protected by coastal defences, but also they will not be considered when mitigating against the effects of planned defences.

8.1.3 *The projected loss of archaeological sites in the study areas*

Tennyson Down – High Down

In my Tennyson Down-High Down study area, many of the recorded sites that will be impacted by the projected cliff recession rates are features associated with a late nineteenth-century golf course and Second World War anti-landing obstacles. Of more significance, however, is the High Down rocket testing site which partially reuses the late nineteenth-century New Needles Battery. If it is to survive, the Tennyson monument will need to be relocated. The cliff line will be approaching the Neolithic mortuary enclosure, the only one of its kind on the island and a class of monument that is uncommon nationally. At the highest point of the downs, more than half of the large undated banked and ditched enclosure will have been lost (Fig. 8.11).

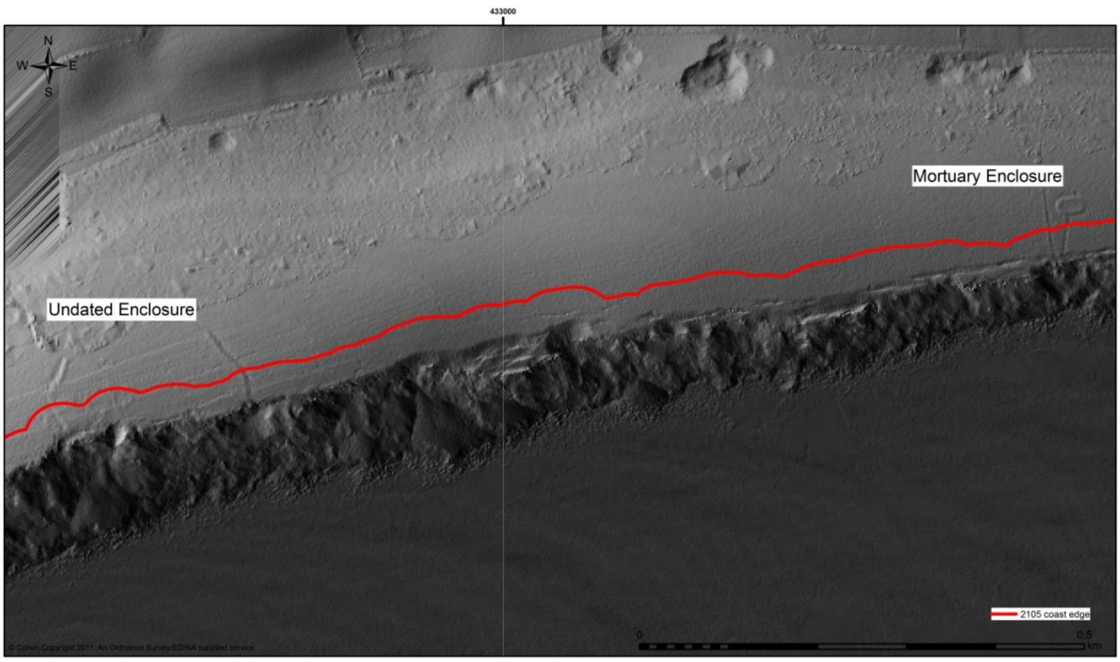


Figure 8.11 The SMP 100 year predicted erosion rate on Tennyson Down in relation to the undated enclosure and the Neolithic mortuary enclosure

Brook Bay

In Brook Bay, as on most of the island's south west coast, many of the sites recorded in the HER have already been lost due to the fact that they only became evident when they had already been partially destroyed by cliff recession. Of most significance are the palaeoenvironmental sediments and archaeological features relating to the Western Yar tributary (Fig. 8.12). Prehistoric activity is focussed around this former wetland and sites recorded include hearths, a Bronze Age cremation cemetery and a hurdle fragment. Although the deposits were first identified over one hundred years ago they are remarkably under studied considering their significance. Only one hearth has been radiocarbon dated, one radiocarbon date has been obtained from the palaeoenvironmental deposits and no environmental analysis has been published since the 1930s (Clifford 1936).

Figure 8.12 Intercalated gravels and organic sediments; part of the former Western Yar tributary at Brook

St. Catherine's Point

At St. Catherine's Point, archaeological and palaeoenvironmental sites that will be impacted by coastal erosion over the next hundred years relate to the formation and early occupation of the Undercliff. Evidence of Bronze Age, Iron Age, Roman and medieval occupation has been recorded in the form of midden deposits both in the cliff face and on the landslide ridges between the coast and the inner cliff. In 2001 human remains were recovered from the eroding cliff face, and the skeleton of an infant is also said to have been retrieved, which suggests that further burials may be at risk from destruction.

Springvale

At Springvale most of the significant archaeological sites are in the intertidal zone. These include large coastal fish traps, Roman artefact scatters, and Holocene sediments. This section of coastline is defended and the SMP management option is to hold the existing defence line, although flooding as a result of sea-level rise may be a problem on this low-lying coast. Sites that would be affected by a change in management include the mid-nineteenth century Puckpool Battery which is a Scheduled Monument and several Grade II Listed Buildings.

Quarr

Using the predicted one hundred year erosion rates on the Wootton-Quarr coast the cliff edge will be approaching both the medieval and the modern abbey. Although both are nationally designated sites they are not given the same consideration as designated natural sites which have a requirement that they must be maintained or equivalent habitats recreated. However, the vast majority of the significant archaeology on this stretch of coastline is in the intertidal zone, and the effect of ongoing erosion and sea-level rise on this resource is difficult to quantify.

Newtown

Notwithstanding the effects of the potential breaching of the spits that protect the estuary as a whole, sites that will be lost at the mouth of the Newtown Estuary include prehistoric and Roman occupation remains in the eroding cliff face. The remains of a mid-nineteenth to mid-twentieth century brickworks including the brickmaker's house and the ruined kilns will be destroyed and the sites of saltworks will be impacted. To the west of the estuary, a concrete ramp dating from the Second World War and believed to have been used by troops training for the D-Day landings is at risk. If the protection of the spits is lost, the deserted medieval settlement of Newtown will be vulnerable to flooding. Once again, there are rich archaeological and palaeoenvironmental remains in the intertidal zone seaward of the coastline.

The quantification of heritage loss using projected rates of coastal erosion can only be applied on those stretches of coastline where archaeological sites are found inland of the coast edge. Sites in the intertidal zone are amongst the most vulnerable to coastal change although lateral measurement of coastal erosion does not allow quantification of how many will be impacted over the next century. Intensive survey on the Wootton-Quarr coast has identified Holocene sediments (Fig. 8.13), post structures dating from the Early Neolithic to the post medieval period, Late Mesolithic to Early Neolithic flint scatters, and Roman and later artefact scatters. Although not surveyed in the same detail a similar range of sites has been identified at the mouth of the Newtown Estuary, at Thorness Bay (Fig. 8.14) and at Springvale.

Figure 8.13 Intertidal peats and fallen trees at the mouth of Wootton Creek at Fishbourne

Figure 8.14 Iron Age hurdle structure on the beach at Thorness Bay (© IWCAHES)

8.2 Archaeological sites and the SMP

Having learnt lessons from the original SMPs and following guidance from Defra, the second round of SMPs place greater emphasis on the sustainable management of the coast by working with natural processes.

The Isle of Wight SMP revision is no exception to this. The first SMP placed only 32% of the open coast under a management option of ‘Do Nothing’ (Fig. 8.15).

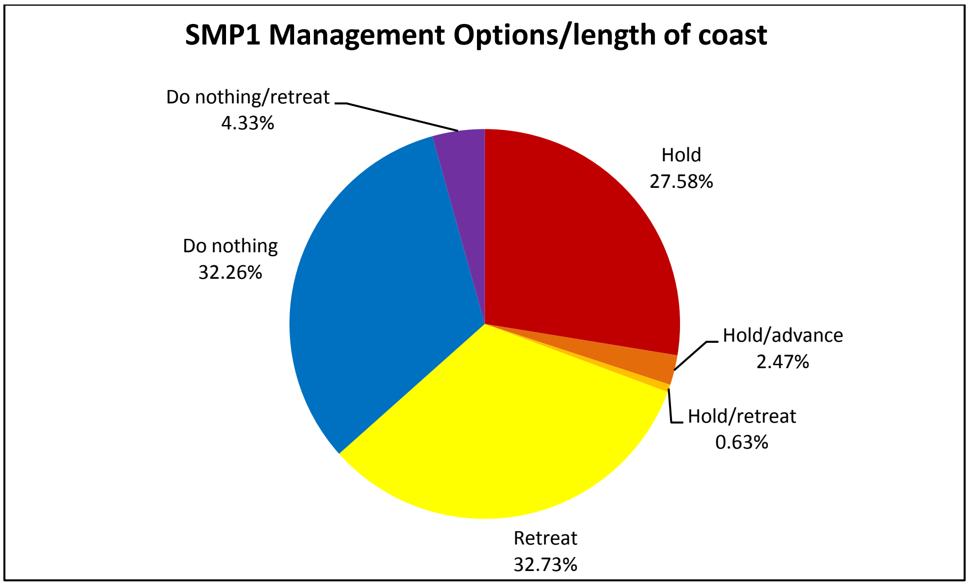


Figure 8.15 Isle of Wight SMP1 management options

In contrast in Epoch 1 (years 1-20) of the revised SMP, 71.5% of the coast falls under the management option ‘No Active Intervention’. In Epoch 2 (years 20-50) the figure is 73% and by Epoch 3 (years 50-100) this has risen to almost 74% (Fig. 8.16). This contrasts markedly with the original SMP where more than two thirds of the open coast was subject to a management option to hold, advance or retreat the line (Halcrow 1997).

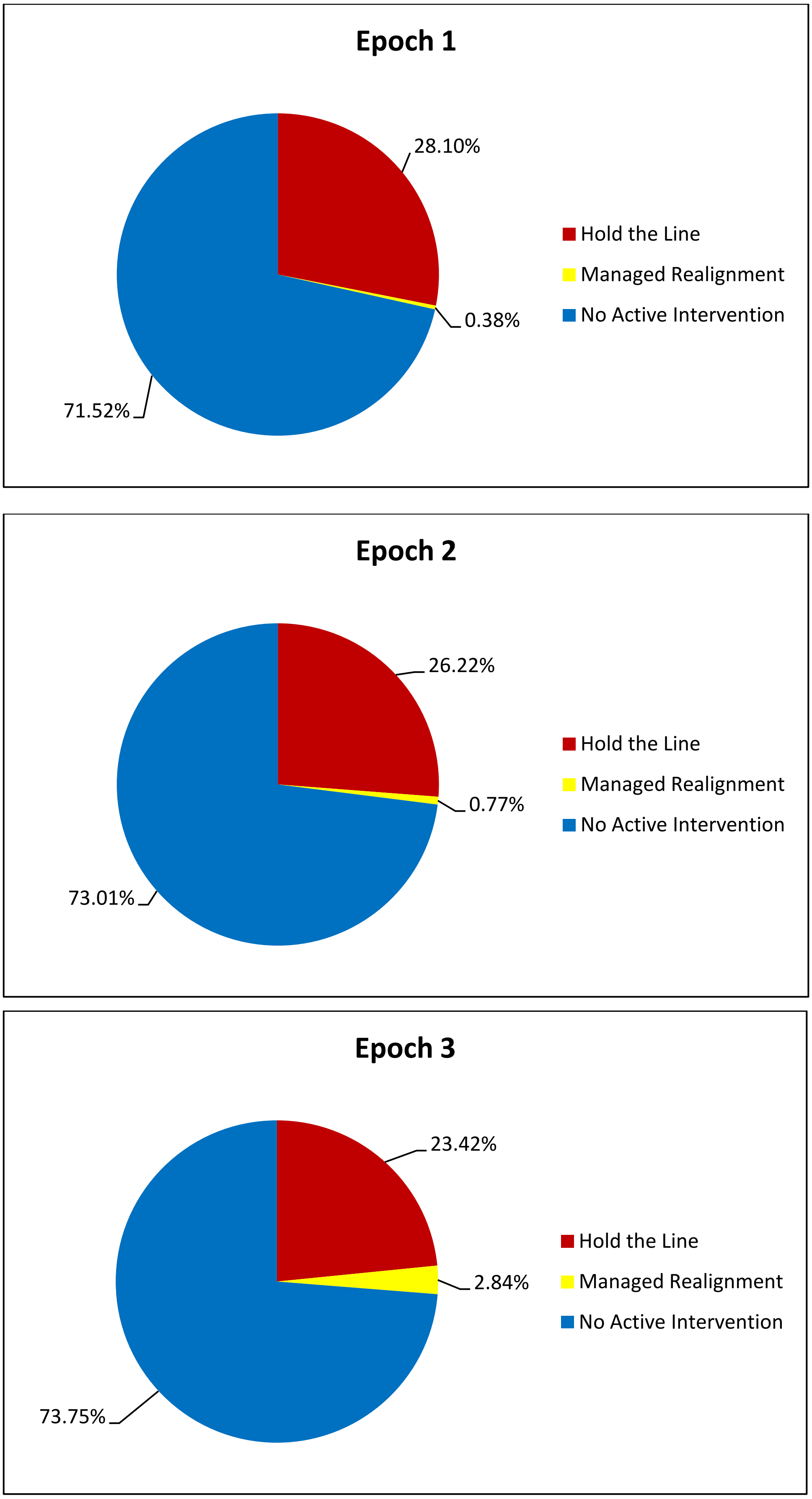


Figure 8.16 Isle of Wight SMP2 policy options by length of coast

The Isle of Wight Coastal Audit found that 42% of sites (excluding buildings) recorded in the HER on the open coast were within a SMP management option of ‘Do nothing’. This figure is considerably higher for the revised SMP, where the figure exceeds 62% by Epoch 3 (figs. 8.17 to 8.19).

Although the thematic studies accompanying the second round of SMPs are guided to include a review of the current status of the historic environment (Defra 2006b), the needs of the cultural heritage do not carry much weight in comparison with those of the natural environment. There are legal requirements under the Birds and Habitats Directives to compensate for any Natura 2000 designated sites that may be affected adversely by the proposed SMP policies. To put this in context, on the Isle of Wight more than 90% of the coast is covered by European environmental designations. This compares with a paltry 22 Scheduled Monuments, which account for less than 0.8% of the archaeological sites on the coast. Listed Buildings on the coast tend to be concentrated within the urban centres so consequently they are afforded more protection because they fall on sections of coastline with an interventive coastal management policy.

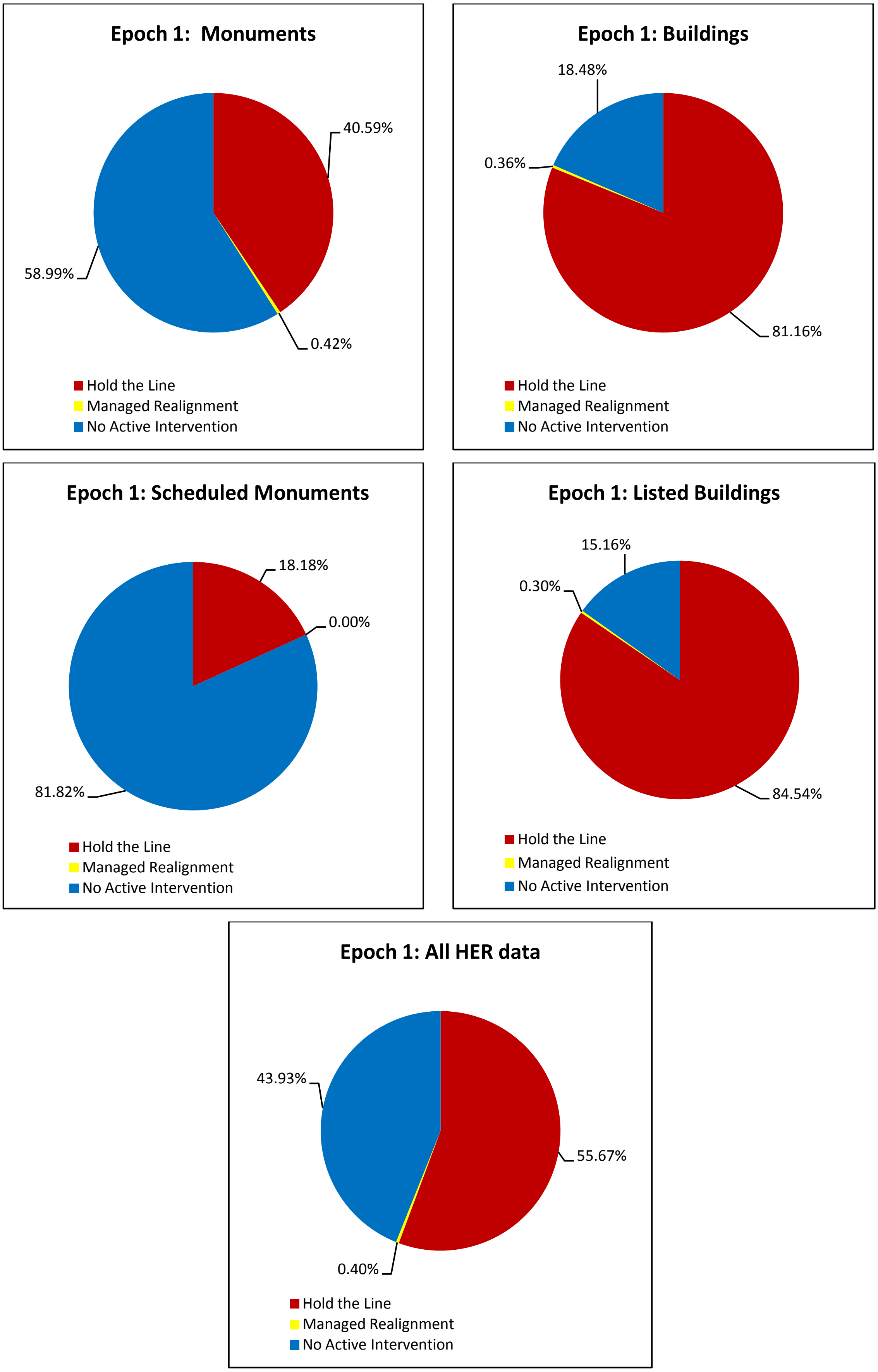


Figure 8.17 Percentage of monuments by SMP Policy Option: Epoch 1

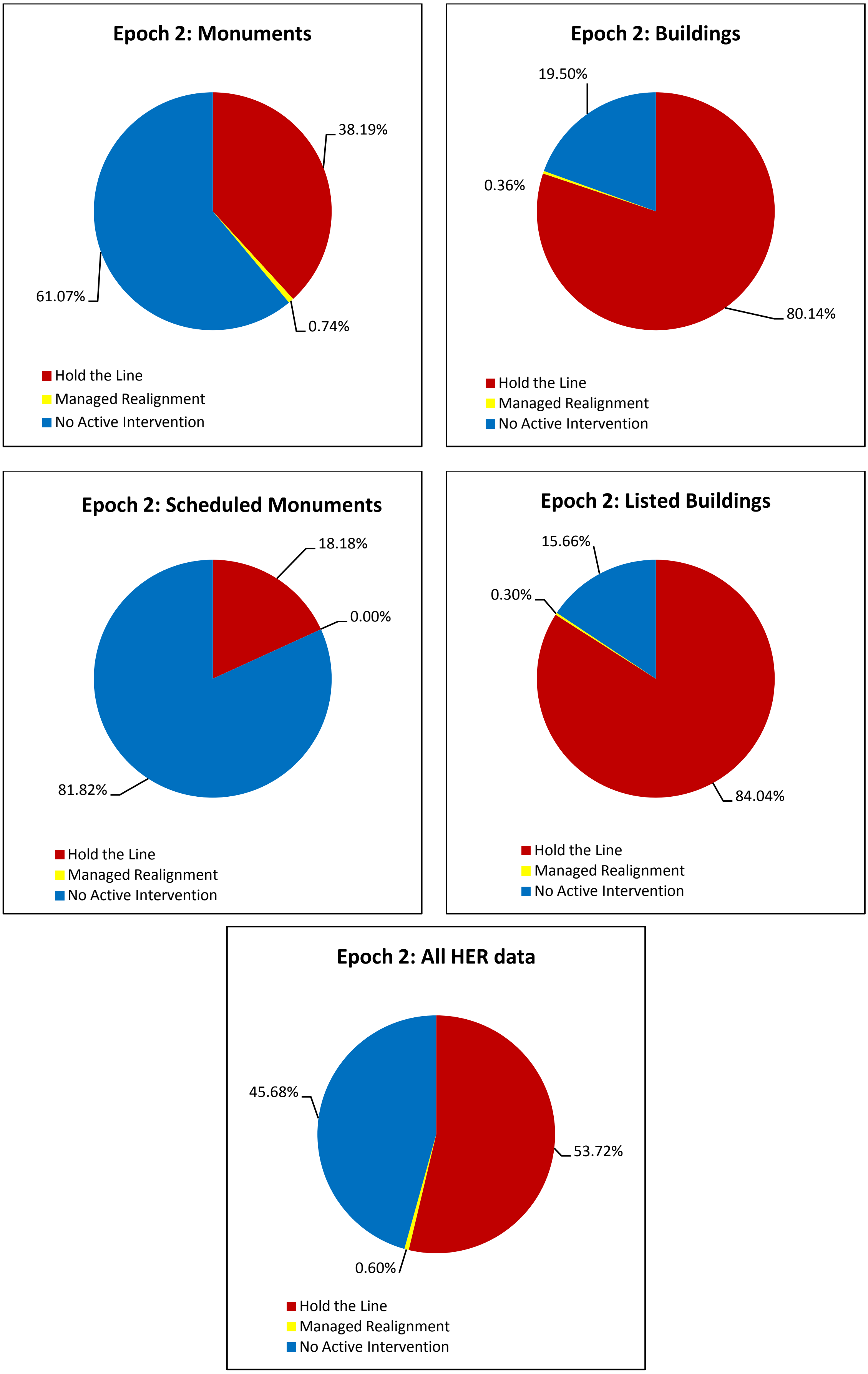


Figure 8.18 Percentage of monuments by SMP Policy Option: Epoch 2

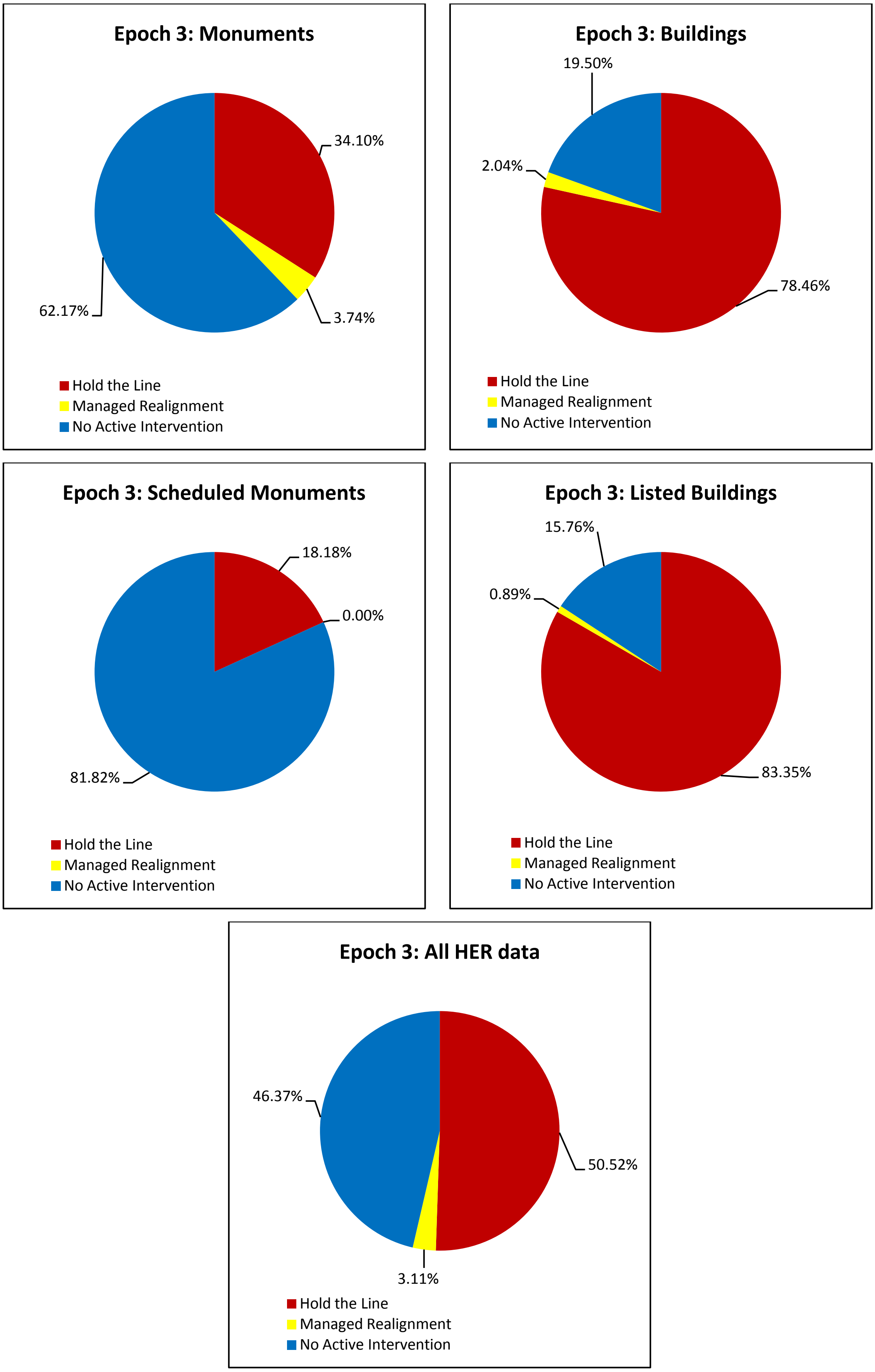


Figure 8.19 Percentage of monuments by SMP Policy Option: Epoch 3

8.3 Flood risk data

The figures discussed in the previous sections deal only with the future impacts of coastal erosion; they do not take into account the effects of flooding. The Isle of Wight Council has published *The Isle of Wight Strategic Flood Risk Assessment* (Entec 2010), in which it summarises flood risk on the Isle of Wight, taking into account the predicted impacts of climate change. In addition to the risks posed by fluvial flooding, surface water flooding and groundwater flooding the potential impacts of tidal flooding are considered. Maps have been produced which show the predicted scale of flooding in the years 2010, 2045, 2080 and 2115 at a 1 in 200 probability (equating to Flood Zone 3) and a 1 in 1000 probability (Flood Zone 2; Fig. 8.20). Whilst there are many archaeological sites that are threatened both by coastal erosion and flooding, it is in the latter scenario that the threat to historic buildings is greatest. Several of the island's towns, and above all Yarmouth, with many Listed Buildings in its core, are particularly at risk of flooding. A report produced by the Yarmouth Coastal Defence Working Group (2010) suggests that 49 Listed Buildings in the Western Yar Valley are at risk from coastal flooding.

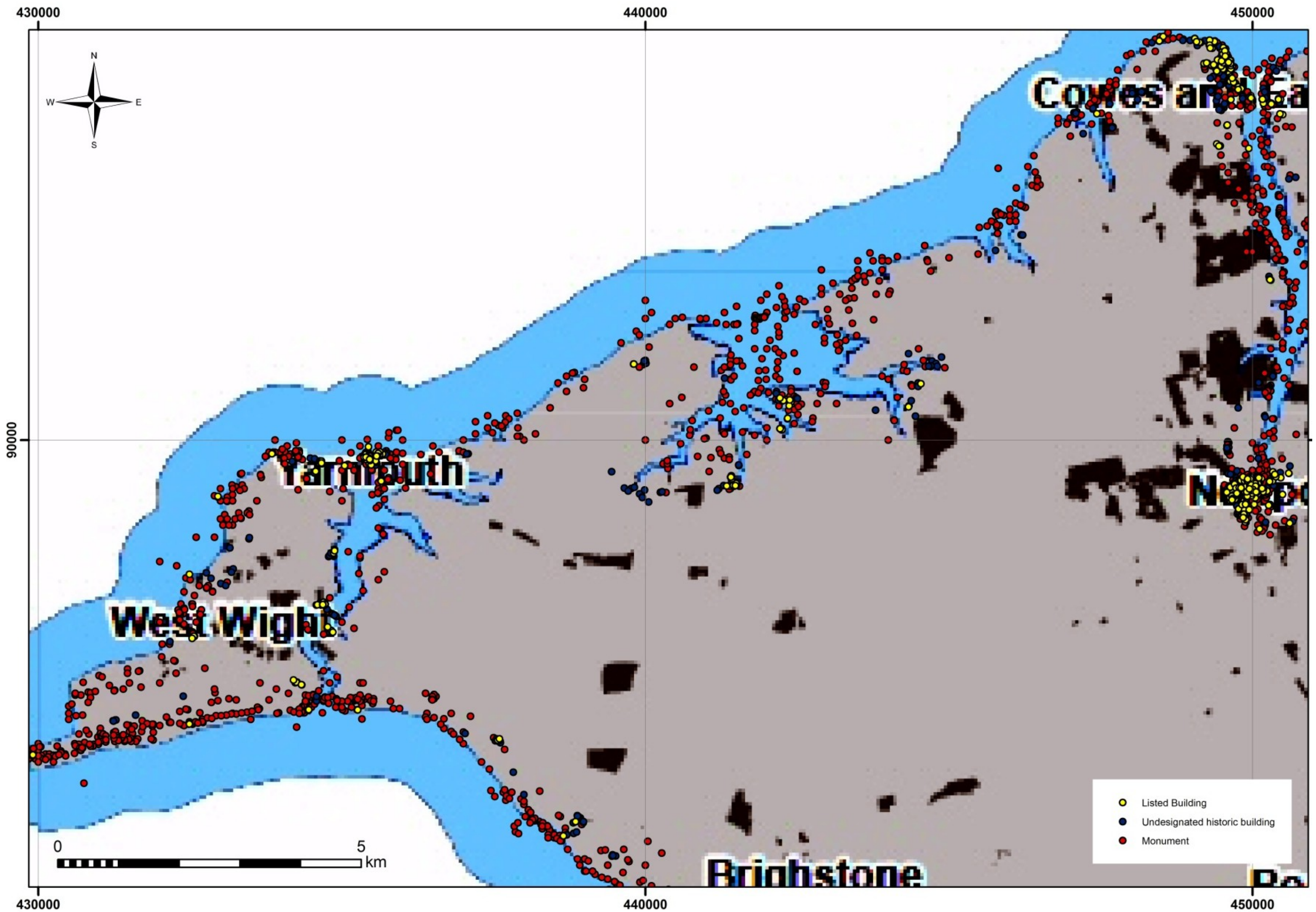


Figure 8.20 Isle of Wight SFRA 1 in 1000 risk of tidal flooding (adapted from Entec 2010)

9 Discussion

9.1 Assessment of choice of detailed study areas and the wider application of the results

The six study areas were chosen to reflect the archaeology of a variety of coastal geomorphological settings around the Isle of Wight, but which were felt to be representative of a much wider geographical area. In this respect, the Isle of Wight has proved to be an ideal location in which to develop case studies.

9.2 Discussion of the methodology and the results

The work that I have undertaken has shown that, although it is quite easy to calculate past coastal erosion rates and thereby predict both future rates of recession and potential heritage loss, there is always a degree of uncertainty in the results, which should be taken as a suggestion of potential trends rather than viewed as a precise indication.

When using cartographic sources, the scale of mapping and the detail shown on the maps precludes the use of most mapping pre-dating the first edition Ordnance Survey maps of the mid-nineteenth century. This severely limits the time frame over which calculations can be made. Apart from the errors caused by warping and physical damage to the maps, it is questionable how closely the maps are an accurate depiction of reality. This is particularly so of the low water and high water marks, which the Ordnance Survey also defines differently from those shown on Admiralty charts.

Baily (2011) has advised caution when using Ordnance Survey maps for assessing coastal change. He states that the high water mark and low water mark were defined primarily as boundary features delineating, for example, parish boundaries or the boundary of the foreshore which generally belongs to the Crown, and not ‘to record a geomorphological feature in the field’ (p.5). He also discusses the difficulty of actually surveying the high water and low water lines; the problems of accessibility and the variability caused by metrological conditions such as barometric pressure or high winds. The use of aerial photography and photogrammetry has standardised the mapping to some extent but cannot overcome the unpredictable nature of tides. This unpredictability is a problem frequently encountered during archaeological survey in the intertidal zone when work cannot proceed as planned because high winds or low pressure have held up the tide. Indeed, the concept of mean low water is in reality virtually meaningless.

The use of aerial photographs for assessing coastal change is beset by many of the same problems as cartographic sources, but in addition there can be errors with the rectification of photographs, and uncertainty of interpretation. Commercial photographs are taken to cater for the widest range of uses. For most purposes, photographs are taken in midsummer when the sun is overhead so there are no long shadows, but these are not ideal for archaeological purposes or for defining the coastline when vegetation is at its most lush. Orthorectified aerial photographs and satellite imagery do not have the same problems of rectification but again they are not usually taken at the optimum time of year for revealing archaeological features.

LiDAR survey data proved disappointing in this study, largely due to the resolution of the available data and the state of tide when surveys were undertaken. However, I do believe that the technique will only start to realise its full potential as data of a higher resolution become more accessible.

In the time since this research was started, relevant data have become much more widely available. At the outset, LiDAR data had to be requested from the Environment Agency and only limited coverage could be obtained. Now coastal LiDAR surveys can be downloaded without restrictions from the website of the Channel Coastal Observatory, together with orthorectified aerial photographs and other datasets including topographic surveys, hydrographic data, photogrammetric data, sediment distribution data and beach profiles. Aerial photographic surveys dating from 2001, 2005 and 2008 are available for the Isle of Wight. LiDAR coverage is incomplete but dates from 2004, 2005, 2007 and 2008, the first two surveys at 2m resolution and the latter two at 1m resolution.

Information held in HERs can be used quite successfully to calculate statistics about heritage loss but it must be asked, how useful is general HER data for quantitative purposes compared with that gathered through detailed survey? Often sites are not recorded fully and the grid reference may not be accurate due to the way in which it was recorded originally. It is often not possible to say when a site was damaged or destroyed due to the infrequency of site visits; hence regular monitoring is now advocated, although this is not without its problems (Heppell 2004; Loader 2008).

9.3 An assessment of the relevance of the methodology

Before starting this research, I believed that there were large amounts of data that were collected for other purposes, particularly associated with coastal management, which could be used for quantifying coastal heritage loss. I felt that it was a waste of limited resources for experienced coastal archaeologists to spend time gathering this type of data when they could be recording threatened sites, but at the same time it seemed that there were others far better qualified to do so. Whilst it is certainly true that a wealth of data is available, there are major limitations in using data not collected specifically for this purpose. For example, aerial photographs taken for non-archaeological purposes are usually not taken at the optimum time of year or state of tide and are generally vertical rather than oblique views. LiDAR surveys are not carried out at extreme low tide or are of too coarse resolution, and beach profiles are not recorded across archaeologically significant stretches of the intertidal zone.

Many datasets have been collected to inform the shoreline management planning processes, and as a consequence they tend to be focussed on the developed or protected coast which does not usually correspond with the areas or aspects of the coast that are archaeologically the most rich and/or vulnerable.

For example, the South East Strategic Coastal Monitoring Programme measures beach profiles around the Isle of Wight at irregular intervals but with significantly more measurements on frontages with a ‘hold the line’ management option (Isle of Wight Council 2005b). It takes no measurements along my Tennyson-High Down frontage, nor at Newtown, Brook, or St. Catherine’s Point (Fig. 9.1). At Springvale although five profiles are measured they do not extend to extreme low water. On the Wootton-Quarr coastline no measurements are taken along that part of the frontage where most archaeological sites are found (Fig. 9.2). From this, it is evident that those stretches of coastline which are more closely monitored and those with rich archaeology in the intertidal zone and on the coast edge rarely coincide.

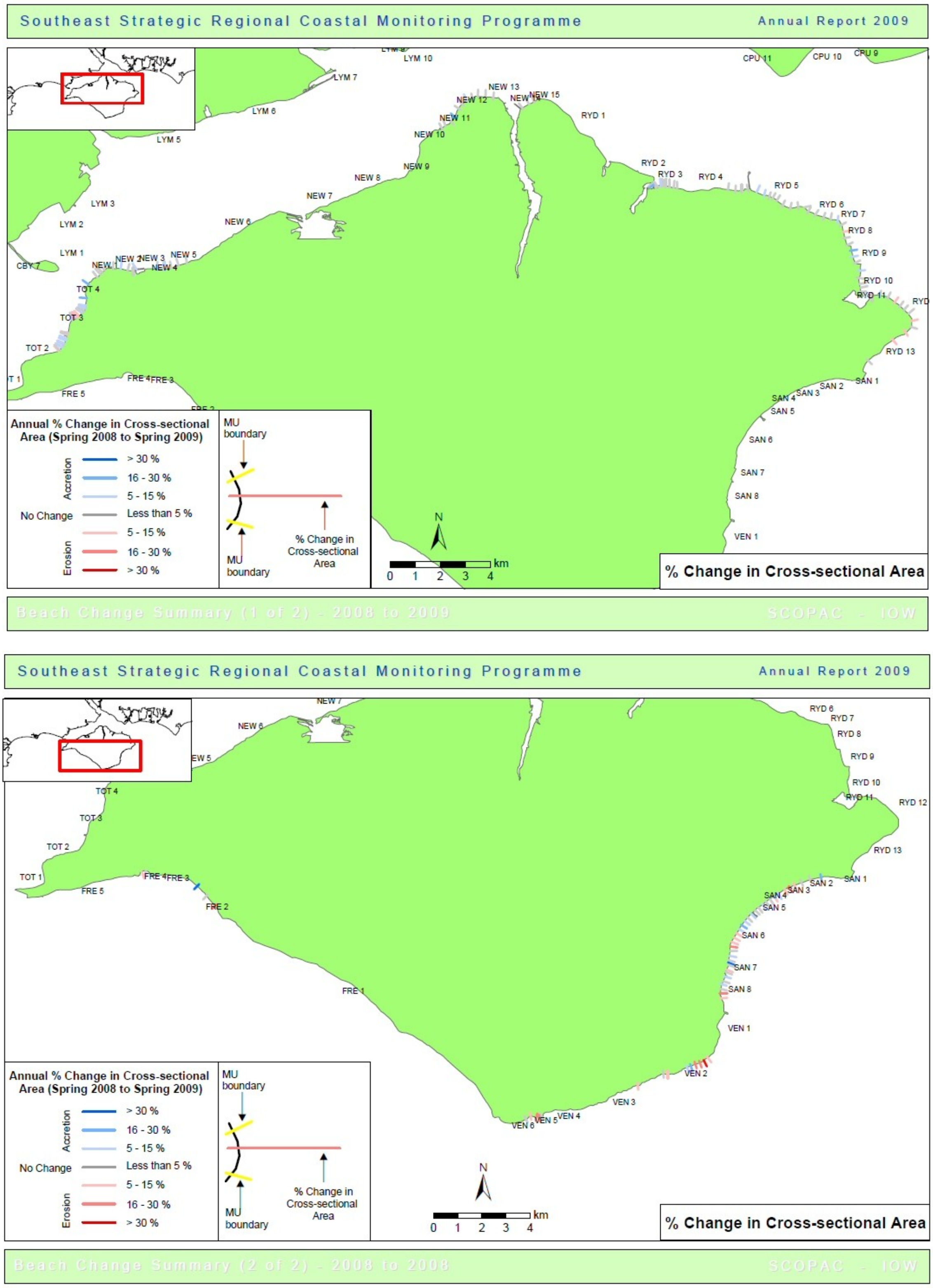


Figure 9.1 The location of beach profiles measured for the Southeast Strategic Regional Coastal Monitoring Programme (Case 2009)

The conclusions of such monitoring programmes can also be quite generalised and potentially misleading. The profiles measured for the South East Strategic Coastal Monitoring Programme on the Wootton-Quarr frontage, indicate that beach levels are stable (Case 2009), so it is assumed that this is so for the whole of the Management Unit, whereas surveys carried out during the Wootton-Quarr Beach Monitoring project (Loader 2008) show that erosion is occurring at Quarr and Binstead (see section 7.5.2).

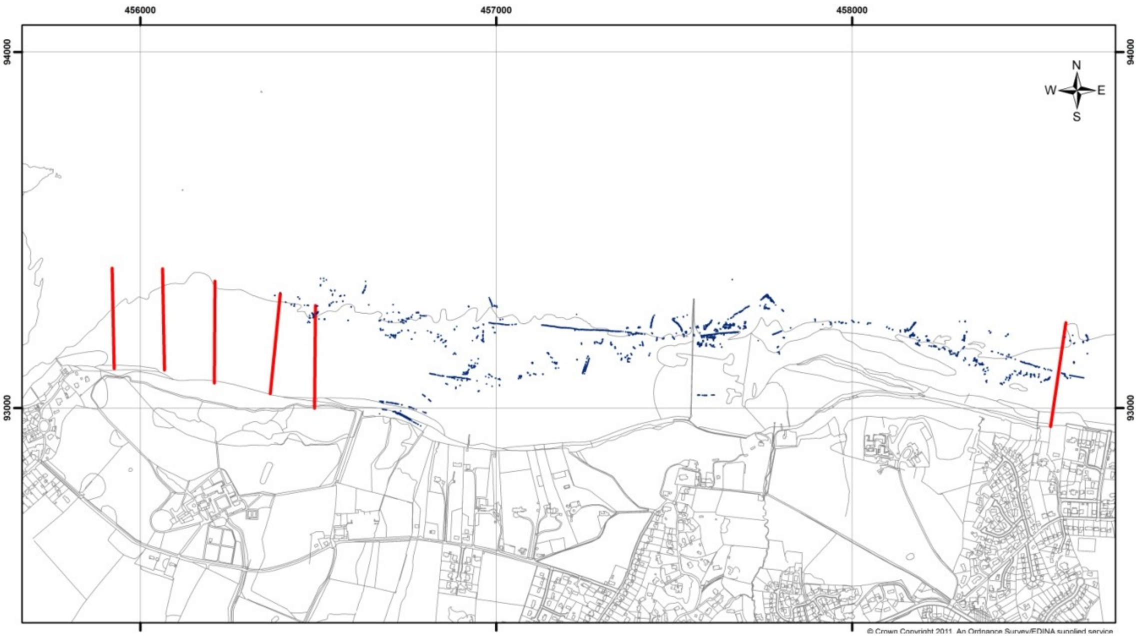


Figure 9.2 South East Strategic Monitoring Programme profiles at Wootton-Quarr. Intertidal archaeological sites are shown in blue

The South East Strategic Coastal Monitoring Programme’s surveys at the mouth of Wootton Creek were summarised in a technical report published in January 2012 (O’Connor 2012). Topographic change models were produced from baseline survey data and also LiDAR data. For both of these, it was stated that a height difference of <25cm was regarded as no change. However, in archaeological terms the loss of 25cm of sediment has considerable implications.

This thesis has also attempted to assess future coastal heritage loss by viewing data recorded in the Isle of Wight HER against an assessment of future coastal recession. There are various formulae used for calculating future rates of coastal erosion, all requiring figures for past sea-level rise, past recession rates, and predicted future sea-level rise. However, it has been found that there can be a wide discrepancy between the results obtained, largely due to the range of possible values which have been calculated for past sea-level rise, and differences in interpretation when plotting past recession rates from historic mapping. Whilst this technique can offer an indication of the rate of destruction of sites on the coast edge, the problem of calculating heritage loss in the intertidal zone has not been resolved. Repeated ground survey currently seems to be the only accurate option, although it is very time consuming and can be a diversion of limited resources.

I believe that this research has shown the importance of local knowledge. Some of the results obtained using remote methods are at odds with what can be seen on the ground and what is revealed by ground survey. I am sure if I had not been so familiar with the study areas and the archaeological records, having spent more than twenty years working with the Isle of Wight's coastal archaeology, I would have been willing to take some of the results at face value. Discrepancies such as the South East Strategic Monitoring Programme's claim that beach levels on the Wootton-Quarr frontage are stable, which contradicts the findings of archaeological survey during the Wootton-Quarr Beach Monitoring Project (see above) can be explained if one is familiar with the location of the archaeology and the measured profiles.

The threat of climate change and the effects of mitigation measures put in place to combat this threat means that it will be necessary to prioritise sites where funding will be provided for protection or recording (Murphy *et al* 2009). The ranking of sites is a thorny issue which has been discussed in Section 4.5. Attempts have been made assign values to sites with regard to their potential to provide information about past coastal change (McInnes *et al* 2000; Hampshire and Wight Trust for Maritime Archaeology, 2006). Archaeologists working on the coast have been reluctant to assign values to individual sites, preferring to highlight the potential of stretches of coast against their vulnerability.

One way of prioritising sites for recording or preservation would be to consider those heritage assets which are specific to the coast. Sites which are coast-specific can be defined as those which have a coastal or maritime function. This definition is probably most easily applied to post medieval and modern sites to which it is more easy to assign a function. Amongst these are lighthouses, port and harbour structures, coastal fortifications, sites associated with fishing and fish processing, salt production, coastal defence and reclamation, tourism and recreation. Other sites, particularly those from the earlier prehistoric periods, may or may not have been on the coast, but they are now seriously at threat from coastal erosion and rising sea-levels.

However, there are many other factors that need be taken into account, for example do the sites possess other special features that warrant recording or preservation, such as the survival of organic materials due to anaerobic waterlogged conditions. There are also sites which may not be coast specific but their location on the coast or their visibility from the sea may be significant. The mortuary enclosure on Tennyson Down may be an example of this. Other classes of sites are rare generally; the High Down rocket testing site falls under this category. Yet others – probably a large percentage of coastal sites – are too poorly understood to be assessed.

What most coastal sites of all periods have in common is their vulnerability to a range of threats including erosion, development pressure, and the direct and indirect effects of climate change, and the fact that on the whole they have not been subjected to vigorous research.

The anaerobic conditions found in intertidal or coastal wetlands can lead to the preservation of organic material. Sites of prehistoric date which find themselves on the coast now may or may not have been coastal originally but the fact that a greater range of artefacts and environmental evidence survives adds to their significance.

Intertidal features such as post alignments and other wooden structures are ubiquitous from the Late Mesolithic onwards. Scientific dating should be undertaken as a priority, but too often analysis stops there. Regardless of the function of individual structures the worked wood has the potential to yield much additional evidence regarding timber technology, woodland management and the environment. Neolithic and Bronze Age stakes recovered from the beach at Wootton-Quarr have been found to have bark still surviving, in some cases with identifiable lichens adhering to the surface, and their growth patterns suggested that they may have been coppiced (Darrah and Loader forthcoming). Structures such as the large coastal fish weirs and post alignments have sufficient numbers of individual components that meaningful conclusions could be drawn about the composition of the contemporary woodland, the choice of timber for specific uses, evidence for the management of woodland, and woodworking techniques. Such intertidal sites are of sufficient rarity, vulnerability and archaeological potential that their assessment should be a priority.

Another means of assigning limited resources would be to consider a site or class of site's ability to answer research questions, although see comment by Ashmore on page 106 who cautions that the importance of a site might be judged on 'modern (and possibly evanescent) research interests' (Ashmore 2003, 4). The forthcoming English Marine and Maritime Resource Assessment and Research Framework (Ransley *et al*) discusses a wide range of research priorities covering the periods from the early Palaeolithic to the twentieth century. Whilst it is perhaps easier to justify focussing resources on the more conventional archaeological sites there are large numbers of sites relating to trade, industry, defence and coastal recreation which are poorly recorded and understood.

To take a small area like the Isle of Wight as an example, stone quarrying is known to have been important on the island's coast since at least the early Roman period, with the use of Bembridge limestone being widespread in buildings on the mainland and locally produced stone mortars being traded as far as King's Lynn in the thirteenth and fourteenth centuries (Dunning 1977). A small number of quarries were recorded during the Wootton-Quarr survey, and others have been added to the local HER using cartographic sources, but very little is known about the industry. Similarly, there are references to the exploitation of small seams of poor quality coal in Alum and Whitecliff Bays (IWHER 2942 and 4568) yet again this has not been adequately researched. There are records of more than twenty saltmaking sites in the county HER but we know little about them. The extent that individual industries have been researched depends to a large extent on the presence of individuals in an area with an interest in that industry, thus post medieval shipbuilding and the later construction of flying boats and hovercraft in Cowes and East Cowes is well documented. There are no doubt other researchers who have information about other industries or aspects of coastal life but are more reticent to share their knowledge.

It would be an extremely useful tool if the likelihood of survival of archaeological features on the coast, and in particular the intertidal zone, could be predicted. Tomalin (2000c and forthcoming) has identified 'mud coasts' on Ordnance Survey mapping which have the potential to preserve archaeological material in the intertidal zone. These include on the Isle of Wight the Wootton-Quarr coast, Thorness Bay, the Newtown, Western Yar and Medina Estuaries, Kings Quay and Bembridge Harbour, and Langstone Harbour in Hampshire. Whilst this does provide a useful starting point, it is very crude and there are stretches of coast, such as at Springvale, which are rich in archaeology but where the 'mud' is masked by sand. Since most of the sites are related to palaeochannels crossing the foreshore the distribution can be refined by selecting features in MasterMap representing 'Inland Water' (Fig.9.3).

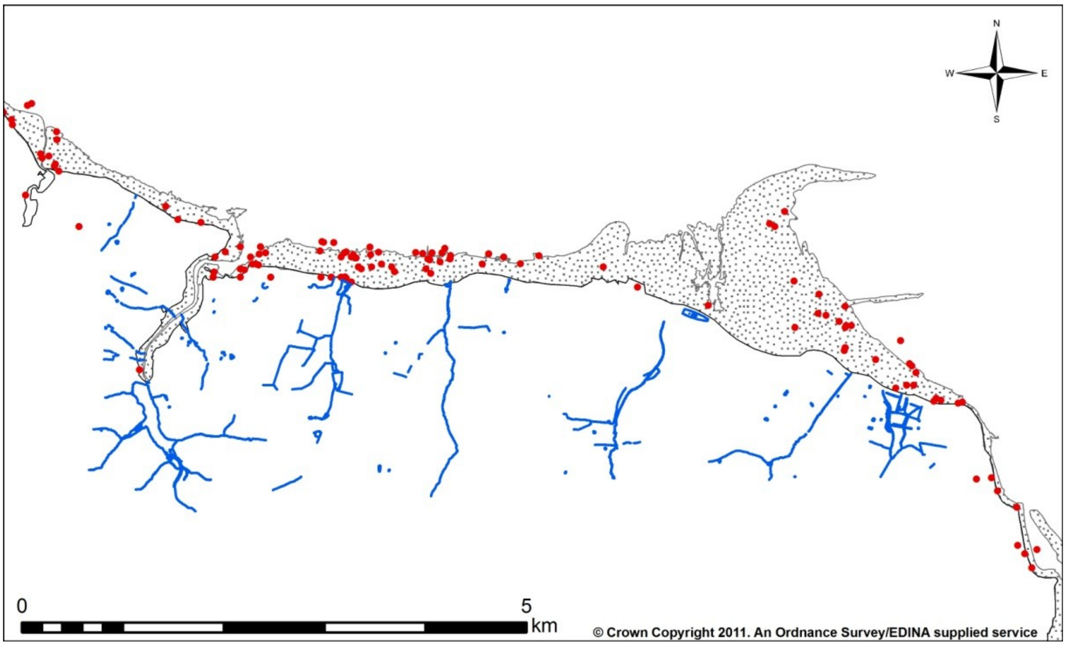


Figure 9.3 Intertidal archaeological features in relation to water courses in the Wootton-Quarr and Springvale study areas

9.4 The importance of some key Isle of Wight sites

Due to its geological variability and strategic location the archaeology of the Isle of Wight is of greater significance than might be expected for a small offshore island.

The island's Pleistocene deposits have been identified as having great potential for answering many research questions relating to the Palaeolithic occupation of the region, but progress is hampered by the lack of modern mapping and investigation (Wenban-Smith and Loader 2007). Marine and fluvial gravels are mapped along much of the northern coast but they have only been examined at Priory Bay and Bembridge where they are under threat due to coastal recession. A further significant site was identified at West High Down but this has not been subject to modern investigation (Warren 1900) and a Pleistocene faunal assemblage has been recovered from the mouth of the Newtown Estuary (Munt and Burke 1986).

The Holocene sediments of the island's northern coast are key to our understanding of the formation of the Solent and post-glacial sea-level rise. Detailed survey has been undertaken on the Wootton-Quarr coast where archaeological and palaeoenvironmental remains of all dates from Palaeolithic to post medieval were recorded (Tomalin *et al* forthcoming). The Wootton-Quarr survey has also provided important evidence for trade, both to and from the island. The range of imported ceramics from what was a relatively minor landing place in the Late Iron Age and Roman period is surprising, whilst in the medieval period, the sources of imported pottery confirm the documentary evidence for Quarr Abbey's trading interests.

Although less intensively studied, a similar range of intertidal deposits have been identified at the mouth of the Newtown Estuary, at Thorness Bay, and at Springvale, whilst investigations at Bouldnor highlight the significance of the offshore resource (Momber *et al* 2011).

On the south coast of the island palaeoenvironmental deposits relating to the Western Yar tributary which survive between Shippards Chine and Chilton

Chine, and human activity associated with the former river valley are a unique resource with great potential to inform about environmental conditions and human adaptation from the Early Mesolithic to the Bronze Age. Due to the nature of the cliffs and the rate of erosion along this coastline, there is only a narrow window of time to record sites before they are lost (Fig. 9.4).

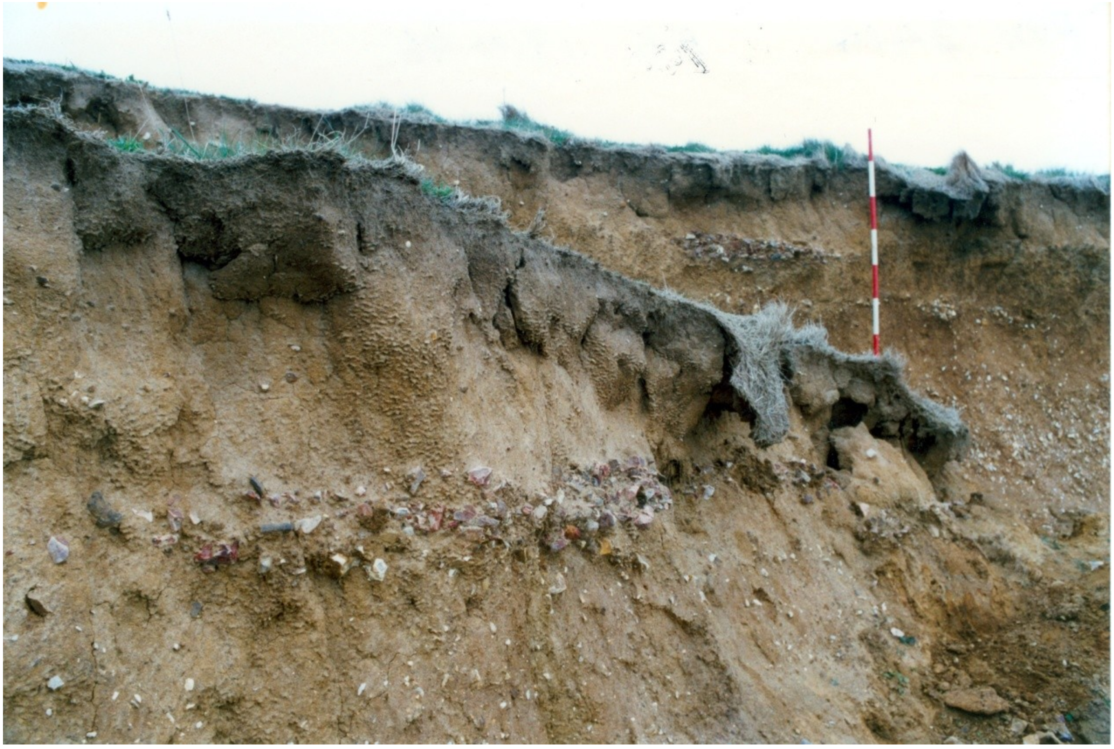


Figure 9.4 Lens of firecracked flint IWHER 2414 at Chilton Chine photographed in 1996. The feature was lost to coastal erosion before it could be fully recorded and sampled (© IWCAHES)

From a military perspective the Isle of Wight has always been strategically important but the earliest coastal fortifications to survive are the Henrician forts of Yarmouth Castle and West Cowes Castle, which has been extensively altered and is now home to the Royal Yacht Squadron.

Nineteenth century fortifications along the Solent coast and in Sandown Bay were built to control the movement of shipping into the Solent and to protect the naval dockyard at Portsmouth and port of Southampton, largely against the French. Most were constructed during the 1860s as a result of recommendations made in the 1860 report of the Royal Commission on the Defence of the United Kingdom. Additional works in the 1890s include the New Needles and Steynewood Batteries, and experimental searchlight positions were built in association with the existing fortifications in the Western Solent. Bouldnor Battery, a Scheduled Monument, is one of the few fortifications of its type built in the twentieth century (Saunders 1998).

The coastal forts were adapted for use during both World Wars, and additional structures including anti-aircraft emplacements, radar stations, pillboxes, and anti-landing obstacles were constructed. Many have been demolished or have succumbed to coastal erosion (Fig. 9.5). In addition the PLUTO pipeline crossed the island, and traces remain on the beach at Thorness and in Shanklin Chine.

Figure 9.5 Second World War anti-aircraft gun emplacement which was originally on the low cliff top at Bembridge. Deposits of Ipswichian date relating to the Bembridge raised beach are exposed in the cliff section

The island played an important part in the development of rocket technology, and between 1956 and 1974 the New Needles Battery was used as a testing facility for the Black Knight and Black Arrow rockets (Cocroft 2007). Although some of the associated buildings have been cleared away, a significant part of the site survives.

Tourism has been important to the Isle of Wight's economy since the eighteenth century when the wealthy developed an interest in the picturesque and unexplored parts of the country and it became fashionable to own a rustic seaside villa (McInnes 2006). At around the same time sea bathing became popular and the Isle of Wight was an ideal destination. The island became even more fashionable during the nineteenth century, when Queen Victoria had Osborne House rebuilt and numerous poets, authors and artists spent time here. Many of the seaside resorts developed during this time. With the demise of the British seaside holiday in the second half of the twentieth century, the resorts went into decline but on the whole they have managed to retain their character until now.

9.5 Coastal heritage and the planning system

Despite the ethos behind PPS5 and the requirement for planning applications affecting heritage assets to be accompanied by a Heritage Statement, the character of the built historic environment of the coast is still in danger of being eroded by inappropriate development where economic development takes precedence over the heritage value and character of coastal settlements. Development on the Isle of Wight is a good example of this. The island is sold as a rather quaint tourist destination described as being stuck in the 1970s and 'a mix of the kitsch and the cool'. Whilst there are many examples of sensitive restoration and development which pays homage to the island's history, there are too many cases where development takes little account of the setting. In Cowes alone, in recent years at least three Victorian villas on the waterfront and in the Conservation Area have been demolished and replaced with large apartment blocks (Fig. 9.6 and The Georgian Group 2010).

Figure 9.6 Photograph from an advertisement in the 'Island Life' Magazine, September 2011 showing a newly-constructed apartment block on Cowes seafront. The Royal Yacht Squadron (formerly West Cowes Castle), a grade II Listed Building, is adjacent to the east. The white painted villa to the west is now threatened with demolition and redevelopment*

On a smaller scale, in the spring of 2011 a late nineteenth century position finding cell at Springvale was demolished shortly after it was added to the Local List and before it could be assessed for national designation (Fig. 9.7). The structure, which was associated with the Puckpool Battery, is to be replaced with a 'New England' style, cedar clad boathouse (Isle of Wight Council Planning Application TCP/23076/B, P/01864/10) which, it was claimed, would improve the street scene.

The planning proposal had been accompanied by a Heritage Statement, although the local HER had not been consulted. The philosophy of PPS5 extends the consideration of the effects of development to all heritage assets, not just those with national designations. However, with the inability of Local Listing to offer any protection, and this structure not requiring planning permission for demolition, the system has not been successful in this case.

Figure 9.7 Google maps image of the position finding cell adjacent to the Coastguard Cottages at Springvale. The structure has now been demolished

9.6 Archaeology and the shoreline management process

It has to be questioned whether the shoreline management planning process is a suitable mechanism for managing the coastal heritage. Although SMP thematic studies include a review of the historic environment, with increasingly limited funds available it is highly unlikely that anything other than nationally designated sites that will be directly affected by policy decisions will be taken into account when setting policies for individual stretches of coast. This is particularly so because of the very strict regulations protecting the designated natural environment.

It could be argued that the SMP is a broad-brushed document, and it is not until the following phases of strategy plans and individual schemes that the real details will be considered. However, it is at the SMP level that policies are set, and as has been stated previously the emphasis has shifted towards working with natural processes rather than trying to maintain hard defences. To allow the coast to erode naturally should not be harmful to the natural environment; a gradual rolling back of the coastline should in theory allow habitats to evolve and adjust. Thus, the option of ‘no active intervention’ is advantageous. This is obviously not the case for the historic environment, but the question of mitigation for heritage assets falling on coastlines with this management option is not being addressed.

Flatman (2009, 10) suggests that ‘there is an urgent need to raise the ‘visibility’ of the historic environment in a similar manner to that of the natural environment, through sustained and targeted lobbying, proactive involvement of the historic environment lobby that is more sophisticated, higher-level and higher-profile’. It does seem that the historic environment is not taken as seriously as the natural environment. In the SMP process the need to maintain environmental sites designated under the Habitats Regulations is accepted without question – sometimes even at the expense of protecting the built environment. Archaeology is regarded more for its interest and entertainment value rather than something to be treated with respect and protected for the future.

9.7 How can the coastal heritage be managed?

There are many sites in the coastal zone, and it is unrealistic to imagine that they can all be protected, but there are very limited resources available to record and monitor them. The problem is likely to get worse due to the predicted effects of climate change.

Sidell and Haughey (2007) state that it is unlikely that recording of intertidal sites will be satisfactorily funded through the planning process; national heritage organisations have to prioritise nationally and their resources are severely stretched, with most going into rapid surveys. They state that the intertidal zone is not attractive for academic study and they conclude that the recording of intertidal archaeological sites is ideal for volunteers and local societies as it enables participation by community groups at a time when there are fewer opportunities for them to participate in archaeological fieldwork otherwise because of developer funding and the increasing costs of training excavations.

It was said at a CBA climate change seminar in 2007 that coastal sites will be destroyed anyway so it is not such a problem if amateur groups make mistakes.

It cannot be denied that sites will be lost otherwise but the same can be said for any sites under threat. Intertidal surveys such as those undertaken in the Severn Estuary, on the Essex coast, in Langstone Harbour and at Wootton-Quarr, have shown the enormously valuable role that knowledgeable and experienced amateurs can play, but have also shown that an unexpectedly huge wealth of data can be amassed using multi-disciplinary teams with suitable survey equipment and with adequate provision for scientific dating and analysis. Without this we are returning to the methods and standards of the nineteenth and early twentieth century antiquarians.

One of the fundamentals that is taught to every archaeology undergraduate is that excavation is destructive, it should not be undertaken lightly and we have a moral obligation to carry out the work to the best of our ability and to disseminate the results in an appropriate manner. If the best that we can aspire to is to make any, possibly inadequate, record of a site before it is destroyed then I think we have to question whether we should be doing it at all.

Well publicised projects like Shorewatch and the Thames Discovery Programme have taken place in areas where the archaeology appears to be well suited to community involvement. The sites are relatively accessible. On the Scottish coast, although sites are threatened they are otherwise quite robust and their location, often on low cliffs, is easy to access and relatively hazard-free. Access to the Thames foreshore is also comparatively easy.

Many sites in the intertidal zone are unsuitable for large scale public participation for a number of reasons. Firstly, the necessary timing of intertidal survey is not appropriate for volunteers who might wish to spend their summer holidays on an archaeological excavation. Unlike excavations on terrestrial sites, which can take place as an intensive exercise carried out over a short period of time, intertidal work is dependent on the vagaries of the tides. Thus it might be possible to spend just two or three hours on site over a period of several days, and then sites may be inaccessible for a week or more. Fieldwork invariably occurs at inconvenient times of the day, and unappealing times of the year. Often conditions mean that you cannot achieve what you had hoped to do.

Secondly, even walking to the site can be arduous. Features such as trackways or fish traps are by their very nature located in areas of soft mud which are dangerous to the unfamiliar (Fig. 9.8). Frequently they are at extreme low water, so they will rarely be visible, and when they do appear they are often only exposed for half an hour at most. In this situation there is no time to explain the sites or train volunteers in their recording. In locations like the Isle of Wight, where the lowest tides occur very early in the morning or late in the evening in early spring or autumn when the weather is often inclement, and in freezing temperatures, it is an exceptional volunteer who can be relied on to brave the intertidal mud on a regular basis. But at the same time, it is these exceptional volunteers whose patience, knowledge and observational skills has led to the discovery of significant archaeology which would otherwise have gone unrecorded.

Figure 9.8 Recording a hurdle at extreme low water at Quarr. The site, in deep soft mud, is rarely exposed so recording has to be swift (© IWCAHES)

Monitoring of coastal archaeological sites is another aspect of heritage management which is viewed as essential by most of those archaeologists working on the coast (for example Northumberland County Council 1994, Wilkinson and Murphy 1995, Fulford and Champion 1997, Bell 1997, Tyson *et* *al* 1997, Turner *et al* 2000, Chapman *et al* 2001, Wilson 2003, Ashmore 2003, and Flatman 2009). This is a task that increasingly seems to be falling to volunteer groups.

The Thames Discovery Programme aimed to train volunteers so as to enable ‘public participation’ in the monitoring of sites when the funding for the project had finished (Richardson 2009). English Heritage, too, is encouraging volunteer involvement in its RCZAS programme ‘with a view to establishing local groups who can continue to monitor sites, after the main phases of survey, and report significant new finds’ (English Heritage undated c). However, these local groups will still need professional support, and, no matter who carries out the monitoring, it is of limited value without the means to respond to threats rapidly and to an acceptable standard. Volunteers will soon become demoralised if this next stage does not take place.

Attempts have been made to assist management of the coastal historic environment by synthesising available data. Projects such as the SCOPAC *Archaeology and Coastal Change* project (Hampshire and Wight Trust for Maritime Archaeology 2006), *Artefacts from the Sea*, (Wessex Archaeology 2008), and to a lesser extent *England’s Historic Seascapes* (English Heritage undated b), put considerable funds into synthesis and interpretation of records, and it is invariably concluded that the available information is inadequate. As one whose job it is to provide information via the HER and who has carried out archaeological projects on the coast for many years, it is frustrating to read such conclusions which could often have been predicted before the projects started, and which are to a large extent due to the fact that data are usually requested in one line, summary form. These are then assessed remotely without looking at any additional back up information that the record holds and with no input from the local curators. Despite the conclusion that the records are lacking, resources are rarely made available to improve them.

10 Conclusion

10.1 Overview of the success of the methodology

The overall aim of this thesis was to produce a quantitative assessment of the effects of coastal processes and other natural and anthropogenic threats on the coastal heritage resource.

The research had three objectives. The first was to devise a methodology for quantifying coastal heritage loss, including an evaluation of the techniques used more generally in both cultural resource management and in coastal management.

A range of techniques were identified which are used regularly both by archaeologists working on the coast and by coastal managers. These include the use of historic maps and aerial photographs to calculate past rates of coastal recession and thereby previous heritage loss. An assessment was made of the effectiveness of LiDAR data for identifying archaeological features on the coast. Archaeological data assessed included HER data and more detailed survey records. All datasets were input into a GIS where they could be viewed together in various combinations.

It was found that it was relatively easy to produce a quantification of past coastal recession and heritage loss, and to use this data to predict future losses, but the results should be used with caution because of the errors inherent to the datasets and the unpredictable nature of coastal erosion. Due to the nature of many coastal archaeological sites, which may only be revealed as they become threatened, the number of sites recorded in even the most comprehensive coastal HERs is likely to be an underestimate.

The second objective was to test the methodology in a defined study area using readily available data.

The methodology was tested using data relating to the Isle of Wight. As an island this is a particularly easily defined study area. Its geomorphological and topographic variability and its similarity to mainland southern England means that the results are relevant to a much wider area. Having worked on archaeological projects around the island's coast for more than 20 years, I could also apply a considerable amount of local knowledge which proved invaluable when assessing the strengths and weaknesses of the methodology.

The methodology was evaluated using data from the Isle of Wight HER and other digital datasets which could be obtained with comparative ease. During the course of this research, the availability of datasets such as orthorectified aerial photographs and LiDAR surveys became more readily available, and could be downloaded free of charge and without restriction from portals such as the Channel Coastal Observatory.

The data were input and manipulated in ArcGIS, chosen because it is a program that is widely used by heritage professionals and data are easily shared and can be viewed by others who do not have access to the full program using ArcReader which is freely available. It was relatively easy to manipulate and display different combinations of datasets, and to produce calculations of past and future coastal recession and heritage loss. However, some of the results proved to be contradictory and at variance with what could be seen on the ground.

The available means of assessing past and future coastal heritage loss were shown to be flawed, but in the absence of other more suitable methods can offer an indication of likely trends.

The final objective of the research was to make recommendations about the management of the coastal heritage resource.

It is inevitable that the archaeology of the coast will continue to be destroyed by a number of natural and anthropogenic threats, many of which are likely to get worse due to the direct or indirect effects of climate change. I believe that the archaeology of the intertidal zone is the most threatened, the most neglected and the most poorly understood and has the potential to be the most informative about past human adaptation to coastal change, but in order to reap these rewards needs the most input in terms of specialist analysis and scientific dating.

The shoreline management planning process has been shown to be not the best means of managing the coastal heritage. Whilst protection will be given to those areas in which it is economically viable and environmentally sustainable, and there is an obligation to protect designated environmental sites or, if this is not possible, to provide compensatory habitats, the historic environment seems very much the poor relation. With such a small percentage of sites having any statutory protection, and with more of the coast falling under the SMP management option of ‘no active intervention’, coastal heritage assets require an alternative form of management.

Funding for archaeological work is becoming increasingly limited, and the onus of monitoring and recording threatened archaeological sites seems to be falling more on voluntary groups. Whether this can be sustained remains to be seen. However, whether work is carried out by professional archaeologists or volunteers, there needs to be the means to react to threats, with sufficient resources for appropriate mitigation including scientific dating and analysis.

10.2 What is the future for the historic environment of the coast?

Of all the techniques examined during the course of this research, LiDAR would appear to have the most untapped potential in coastal archaeological prospection, although the results have proved disappointing in this instance. The value of the technique is likely to increase as data of a higher resolution become more widely available. Surveys that are more targeted towards archaeological requirements and carried out during extreme low tides might offer significant improvements, and the potential of terrestrial LiDAR scanning in the intertidal zone is still unproven. However, research is underway to assess in more detail the effectiveness of airborne and terrestrial laser scanning in recording the archaeology of the coast (Papworth 2010).

Although much is said about the risks to the heritage of the coast in the future from predicted climate change, the fact is that the loss of archaeological sites through coastal erosion is nothing new. In many ways, the emphasis on future change is distracting and is drawing attention from the problems of today. Numerous archaeological sites of great significance around the coast are currently being destroyed. In an ideal world, the funding of multi-disciplinary coastal archaeological projects would be commonplace and, in my experience, this drawing together of different specialisms is needed to do justice to the significance of the resource. Currently, the limited amount of national funding that is available is largely going into completing the RCZAS programme in order to feed into flood and coastal risk management, for future research and for development control purposes (English Heritage undated c). It will be interesting to see which direction will be taken when this is completed.

Although the historic environment is considered in the shoreline management planning process, the protection that this affords it is poor compared with the natural environment. Perhaps in the future archaeologists should take more responsibility for managing the coastal heritage. One possible way forward is through the production of action plans, in a similar way that CHaMPs are produced for the natural environment. Historic Environment Action Plans (HEAPs) are being produced by local authorities and other organisations (for example for the Isle of Wight, West Berkshire, the Cranborne Chase and West Wiltshire Downs AONB, and the East Durham Magnesian Limestone Plateau). The Isle of Wight HEAPs cover geographic areas and also landscape ‘types’ (Isle of Wight Council 2008); the HEAP type report for the coast is in preparation (Loader in preparation). The HEAP sets out objectives for the sustainable management of the historic environment and has been adopted as background evidence for the Isle of Wight Local Development Framework. However, the question of how any recommendations might be funded remains unresolved.

11 Appendix 1 Historic coastal change from Ordnance Survey mapping

(Measurements are in metres. Positive values indicate landward movement, negative values indicate seaward movement)

Tennyson Down-High Down

	MLW							*MHW*							*Coast*						
Easting	**1866**	**1898**	**1909**	**1946**	**1975**	**2005**		**1866**	**1898**	**1909**	**1946**	**1975**	**2005**		**1866**	**1898**	**1909**	**1946**	**1975**	**2005**	**2008**
429900	0	-2	-4		9	9		0	-2	-4		12	12		0	-2	-2		0	-5	
430000	0	1	0		16	16		0	1	0		16	16		0	-2	-2		-2	-4	2
430100	0	0	-2		9	9		0	0	-2		10	10		0	-1	-1		10	7	10
430200	0	0.5			12	12		0	0			12	12		0	0			5	0	7
430300	0	1			28	28		0	1			28	28		0	1			0	6	4
430400	0	2			8	8		0	4			22	22		0	0			-7	-5	-2
430500	0	16			14	14		0	8			24	24		0	-1			-10	-5	-2
430600	0	6			0	0		0	0			1	1		0	2			-4	2	3
430700	0	3			17	17		0	0			18	18		0	1			2	4	
430800	0	6			7	7		0	-1			10	10		0	-5			-4	0	1
430900	0	6			17	17		0	-2			25	25		0	-2			2	2	3
431000	0	8			10	10		0	0			21	21		0	1			-4	-3	0
431100	0	2			11	11		0	-1			18	18		0	-8			4	4	4
431200	0	1			15	15		0	1			20	20		0	0			9	9	11
431300	0	-1			2	2		0	-1			18	18		0	0			-8	-7	-2
431400	0	-1			1	1		0	-1			10	10		0	0			-7	-6	-3
431500	0	-3			0	0		0	-2			14	14		0	-1			0	0	1
431600	0	-2			7	7		0	-3			16	16		0	-1			0	1	2
431700	0	-1			7	7		0	-1			12	12		0	-2			0	1	-1
431800	0	-1			-7	-7		0	-1			19	19		0	-5			-8	-8	-2
431900	0	5			-21	-21		0	0			5	5		0	0			-7	-4	-7
432000	0	7			-5	-5		0	0			-7	-7		0	2			0	-4	0

	MLW							***MHW***							***Coast***						
Easting	**1866**	**1898**	**1909**	**1946**	**1975**	**2005**		**1866**	**1898**	**1909**	**1946**	**1975**	**2005**		**1866**	**1898**	**1909**	**1946**	**1975**	**2005**	**2008**
432100	0	3			-8	-8		0	1			-1	-1		0	-3			6	8	10
432200	0	4			2	2		0	-1			-2	-2		0	0	0		0	1	0
432300	0	5			-18	-18		0	1			-14	-14		0	1	-4		14	15	7
432400	0	5	5		-6	-6		0	0	0		-10	-10		0	-1	0		3.5	5	4
432500	0	9	10		-10	-10		0	0	2		-15	-15		0	-2	-5		6	8	2
432600	0	9	8		3	3		0	-1	0		-10	-10		0	3	1		4	5	2
432700	0	16	13		23	23		0	4	1		10	10		0	4	1		5	6	8
432800	0	14	13		21	21		0	6	3		18	18		0	5	1		5	4	4
432900	0	20	19		25	25		0	7	3		8	8		0	2	4		34	34	34
433000	0	26	23		21	21		0	6	2		6	6		0	6	3		44	43	43
433100	0	32	30		27	27		0	6	0		12	12		0	6	3		11	9	13
433200	0	33	30		38	38		0	7	3		14	14		0	7	2		20	24	22
433300	0	35	33		38	38		0	6	1		14	14		0	5	0		21	22	22
433400	0	24	20		12	12		0	6	1		8	8		0	5	1		16	35	31
433500	0	19	14		13	13		0	6	0		22	22		0	6	0		8	12	7
433600	0	16	12		10	10		0	6	2		15	15		0	-7	1		-6	4	4
433700	0	14	8		8	8		0	6	1		3	3		0	8	3		9	26	12
433800	0	20	20		16	16		0	7	2		13	13		0	5	1		3	16	5
433900	0	20	16		23	23		0	8	3		10	10		0	4	1		2	1	6
434000	0	19	14		20	20		0	6	3		10	10		0	5	0		4	5	6
434100	0	18	13		13	16		0	7	2		10	10		0	7	2		2	7	7
434200	0	15	10		11	15		0	8	3		16	16		0	6	3		3	7	5
Average	0	10	14			10		0	2	1		10	10		0	1	0.5		4	6	7

Brook

	MLW							MHW							Coast						
	1866	**1898**	**1909**	**1946**	**2005**			**1866**	**1898**	**1909**	**1946**	**2005**			**1866**	**1898**	**1909**	**1946**	**1975**	**2005**	**2008**
437000	0	0	-5		73			0	0	7		35		**437000**	0	6	6			10	20
84700	0	0	-1		85		**84835**	0	1	3		30		**84980**	0	8	7		23	14	18
84630	0	1	-1		69		**84757**	0	1	7		32		**84900**	0	15	15		60	60	11
84560	0	0	-3		67		**84682**	0	1.5	7		31		**84806**	0	25	19		87	87	59
84500	0	0	-15		60		**84606**	0	1	1.5		33		**84716**	0	5	6		41	49	62
84420	0	0	-49		47		**84527**	0	-1	2		37		**84642**	0	-1	-3		21	41	35
84330	0	2	-34		61		**84442**	0	-4	8		45		**84588**	0	-4	2		9	8	5
84240	0	2	-3		74		**84362**	0	1.5	15		50		**84513**	0	0	3		14	15	2
84168	0	0	0		52		**84286**	0	9	10		53		**84407**	0	2	30		88	99	100
84100	0	0	-3		47		**84210**	0	12	12		52		**84323**	0	16	12		43	71	68
84000	0	-0.5	-0.5		100		**84130**	0	10	16		57		**84242**	0	12	16		47	58	46
83907	0	0	-1		119		**84040**	0	9	10		68		**84164**	0	15	17		49	70	67
83818	0	0	0		95		**83950**	0	8	8.5		168		**84079**	0	36	45		45	77	90
83730	0	0	0		124		**83861**	0	14	12		82		**83987**	0	13	23		50	72	73
83630	0	-2	0		125		**83780**	0	17	17		78		**83900**	0	15	22		56	76	82
83530	0	0	2		308		**83697**	0	12	17		87		**83822**	0	15	17		61	85	78
83500	0	0	0		256		**438000**	0	10	15		64		**83745**	0	4	7		50	66	50
83527	0	0	0		150		**438100**	0	10	17		64		**438000**	0	27	30		64	66	50
83521	0	0	0		132		**438195**	0	12	16		57		**438100**	0	17	22		60	59	51
83550	0	0	0		82		**438288**	0	8	12		49		**83681**	0	13	18		40	46	42
83530	0	1	-1	38	68		**83572**	0	12	12		50		**83643**	0	10	13		35	45	48
83435	0	1	1	106	116		**83500**	0	17	20	31	50		**83586**	0	14	19		50	50	53
83355	0	3	0	94	107		**83416**	0	21	23	31	51		**83500**	0	29	28	58	60	62	62
83280	0	5	0	80	100		**83335**	0	25	19	27	52		**83424**	0	16	18	38	53	54	40
83184	0	4	0	145	129		**83251**	0	18	16	30	47		**83367**	0	25	23	40	43	44	36
83098	0	5	4	161	158		**83177**	0	11	9	21	39		**83317**	0	15	14	28	38	38	40

	MLW							MHW								Coast						
	1866	**1898**	**1909**	**1946**	**2005**			**1866**	**1898**	**1909**	**1946**	**2005**			**1866**	**1898**	**1909**	**1946**	**1975**	**2005**	**2008**
83043	0	2	0	125	117		**83103**	0	13	11	26	38		**83230**	0	7	6	13	58	59	46
82970	0	4	2	130	130		**83029**	0	18	15	26	43		**83184**	0	10	9	18	45	48	52
82920	0	-3	-3	182	193		**82963**	0	15	14	23	43		**83095**	0	9	7	28	46	51	77
82835	0	2	2	218	235		**82900**	0	14	13	19	36		**83009**	0	24	24	58	62	62	56
82748	0	4	4	228	249		**82835**	0	16	16	31	45		**82967**	0	16	16	26	22	22	50
82670	0	3	5	265	271		**82780**	0	8	8	28	42		**82898**	0	9	12	30	28	30	18
82610	0	6	6	260	258		**82737**	0	6	7	27	39		**82815**	0	10	12	29	32	32	33
82628	0	1	0	193	181		**82696**	0	15	13	37	48		**82771**	0	7	21	25	30	46	29
82645	0	7	4	122	117		**82660**	0	12	12	38	44		**82747**	0	8	12	24	31	31	27
Average	0	1	-2.5	156	130		**Average**	0	10	12	28	52		**Average**	0	13	16	32	45	52	48

St. Catherine's Point

	MLW						MHW						Coast					
Easting	**1866**	**1898**	**1909**	**1946**	**2005**		**1866**	**1898**	**1909**	**1946**	**2005**		**1866**	**1898**	**1909**	**1946**	**1977**	**2005**
449400	0	1	41	96	89		0	2	0	10	11		0	0	13	27	20	21
449500	0	0	0	37	51		0	0	3	8	7		0	-1	1	11	14	8
449600	0	0	-1	46	41		0	0	3	3	12		0	3	2	10	13	13
449700	0	-2	-3	30	31		0	-3	-10	-9	14		0	-2	3	2	14	23
449800	0	-1	-1	30	26		0	-2	-10	-7	6		0	0	3	4	8	7
449900	0	-2	-1	28	28		0	-3	-13	-9	-1		0	-1	0	3	5.5	3
450000	0	-3	-3	28	21		0	-1	-13	-6	-4		0	0	0	0	-1.5	0
450100	0	1	-1	9	28		0	-1	-10	-2	-1		0	-1	5	6	9	8
450200	0	0	-2	22	-12		0	-1	-10	-3	2		0	0	10	11	15	17
450300	0	-1	-2	20	15		0	-2	-9	-5	2		0	0	2	3	13	13
450400	0	0	0	26	14		0	1	-10	-1	9		0	6	4	18	28	30
450500	0	2	27	-2	-5		0	3	-18	-10	-6		0	5	7	7	5	7
450600	0	-1	5	31	17		0	-1	-5	31	46							
450700	0	-3	16	55	59		0	-2	1	16	36							
450800	0	0	10	47	52		0	0	3	3	23							
450900	0	-1	-3	42	54		0	-1	-1	5	24							
451000	0	-1	-2	35	50		0	0	-12	0	7							
451100	0	2	2	5	-33		0	2	0	-5	41							
451200	0	7	5	17	5		0	2	1	12	12							
451300	0	0	-1	8	-1		0	-1	-6	8	16							
451400	0	0	-1	23	10		0	0	-9	7	24							
451500	0	8	8	26	2		0	1	-2	6	14							
451600	0	1	-1	21	25		0	1	-7	11	18							
451700	0	1	1	8	11		0	1	-14	20	20							
451800	0	2	1	18	-2		0	1	-10	4	3							
451900	0	11	16	24	14		0	1	-6	8	5							

	MLW						MHW						Coast					
Easting	**1866**	**1898**	**1909**	**1946**	**2005**		**1866**	**1898**	**1909**	**1946**	**2005**		**1866**	**1898**	**1909**	**1946**	**1977**	**2005**
452000	0	-12	-14	20	20		0	0	-5	-3	22							
452100	0	-14	-15	27	-21		0	0	-2	15	37							
452200	0	2	0	55	46		0	5	3	1	4							
452300	0	2	0	34	4		0	1	-5	0	17							
452400	0	2	0	43	34		0	2	1	5	20							
452500	0	1	0	39	6		0	2	0	2	-1							
452600	0	4	0	33	-9		0	3	0	5	3							
452700	0	3	1	26	-22		0	3	1	-6	1							
452800	0	3	2	-10	40		0	2	0	-1	5							
Average	0	0	2	28	20		0	0	-5	3	13		0	1	4	8		12

Springvale/Puckpool

	MLW						MHW						Coast				
Easting	**1866**	**1898**	**1909**	**1946**	**2005**		**1866**	**1898**	**1909**	**1946**	**2005**		**1866**	**1898**	**1909**	**1946**	**2005**
461300	0	65	12		84		0	-2	0	0	2		0	-2	0	0	1
461400	0	-17	273	-118	155		0	0	1	0	0		0	0	-1	0	7
461500	0	-13	173	-13	320		0	2	2	3	1		0	2	2	2.5	5
461600	0	22	128	245	355		0	1	0	3	-5		0	1	0	3	0
461700	0	64	81	258	432		0	1	3	3	29		0	1	1	3	0
461800	0	94	-9	26	544		0	0	0	2	-20		0	0	0	2	0
461900	0	130	-62	313	657		0	-1	1	3	-3		0	-1	1	3	-1
462000	0	135	-62	443	691		0	-3	-3	-7	-1		0	-1	5	7	0
462100	0	136	39	607	742		0	2	-2	-2	-26		0	2	4	4	0
462200	0	220	70	681	785		0	-2	-3	-3	0		0	-2	0	0	0
462300	0	128	53	710	804		0	-1	0	-1	1		0	-1	0	0	2
462400	0						0	0	2	-2	-3		0	0	2	1	3
462500	0						0	0	1	-2	-9		0	0	2	3	3
462600	0						0	0	0	-1	0		0	0	0	-1	0
462700	0						0	2	2	1	2		0	1	1	0	1
462800	0	476	498	502	538		0	1	0	0	0		0	1	0	0	2
462900	0	58	58	48	74		0	1	0	2	2		0	0	0	-2	-6
Average	0	115	96	308	475		0	0	0	0	-2		0	0	1	1.5	1

Wootton-Quarr

	LWM						MHW						Coast				
Easting	**1866**	**1898**	**1909**	**1946**	**2005**		**1866**	**1898**	**1909**	**1946**	**2005**		**1866**	**1898**	**1909**	**1946**	**2005**
455800	0	0.4	-7	-5	0		0	-3	-1	-3	0		0	-1	-1	-1	0
455900	0	-3	-4	-1	36		0	-1	-3	-4	3		0	-3	-1	-3	6
456000	0	0	-1	36	66		0	-1	1	0.5	5		0	-1	-3	0	10
456100	0	-6	1	74	89		0	-2	-0.5	0	8		0	-2	0	0	8
456200	0	-6	28	139	147		0	-2	1	0	1.5		0	-2.5	-1	-1	2
456300	0	-0.5	22	178	193		0	-1	1	-0.5	-1		0	-2	0	0	0
456400	0	0.3	3	186	199		0	-1	0	-1	3		0	-1	0	1	4
456500	0	0	2	192	219		0	-0.5	1	-0.5	-7		0	-1	0	-1	3
456600	0	1	1.5	192	170		0	-0.5	0	-1	3		0	-0.5	0.5	0	9
456700	0	0	0.5	161	185		0	0.5	-3	0	1		0	0	0	-1	21
456800	0	0.5	0	136	145		0	-4	-7	-8	-34		0	0.5	-3	0	5
456900	0	1	2	126	134		0	-1	-1	-5	-8		0	-4	-2	3	3
457000	0	0	2	135	135		0	1	-5	-3	-8		0	-0.5	-0.5	3	0
457100	0	-0.7	1	125	138		0	-1.5	-5	-11	-1.5		0	1	1	-1	0
457200	0	0	2	124	127		0	0	7	-5	15		0	-2	0	0	23
457300	0	1	4	73	74		0	2	-5	-4	-4		0	8	15	15.5	4
457400	0	-59	-17	57	83		0	1	2	3	5		0	2.5	5	6	12
457500	0	-74	-18	58	97		0	2	2	2	0		0	2.5	8	8	6
457600	0	-152	-27	16	20		0	3	0	-1	6		0	2	3	5	8
457700	0	-160	-24	36	42		0	3	5	6	8		0	3	5	4.5	10
457800	0	na	44	126	105		0	-18	-17	-18	-17		0	3	4	4	-4
457900	0	na	45	145	115		0	3	3	3	4		0	6	-4	-4	9
458000	0	na	66	184	191		0	1	4	3.5	3		0	3	9	9.5	8
458100	0						0	-2	3	4	-4		0	7	10.5	10	-1
458200	0						0	-3	2	13	6		0	-2	3	5	6

	LWM						MHW						Coast				
Easting	**1866**	**1898**	**1909**	**1946**	**2005**		**1866**	**1898**	**1909**	**1946**	**2005**		**1866**	**1898**	**1909**	**1946**	**2005**
458300	0						0	-2	3	4	4		0	-3	1.5	8	-12
458400	0						0	-3	0	-7	-3		0	-2	3	2.5	-9
458500	0	30	98	281	283		0	-13	0.5	4	0.5		0	-1.5	2	2	7
458600	0	28	104	268	251		0	0	-7	0	-2		0	-0.5	3	3	0
458700	0	9	104	251	198		0	-2	-3	-1	-1.5		0	7	0	0	-2
458800	0	-0.5	96	232	175		0	-4.5	-4	-4	-1.5		0	0	0	0	-1
458900	0	-1	79	202	138		0	-4	-4	-2.5	-1		0	0.5	2	2.5	4
459000	0	44	87	222	116		0	-3	-5	-4	-1		0	0.5	2	2.5	4
459100	0	71	106	246	99		0	1	2	1	4						
459200	0	31	122	264	59		0	1	0	1	-18						
Average	0	-9	30	144	130		0	-1.5	-1	-1	-1						

Newtown

	LWM						MHW						Coast				
	1866	1898	1909	1946	2005		1866	1898	1909	1946	2005		1866	1898	1909	1946	2005
	0	2	2.5		32.5		0	2	-1.5		19		0	0	0		65
	0	-1	0		30		0	1.5	0.5		29		0	2	1		114
	0	-15	-15		34		0	-2	0.5		22.5		0	-4	27		101
	0	1	1		64		0	-0.5	1.5		29		0	2.5	94		129
	0	-1	0		-1		0	-1	1		18		0	2.5	3		107
	0	-3	-1		20		0	-1.5	2.5		18		0	4.6	4		47
	0	0.5	2		50		0	-1.5	2		25		0	0	1		75
	0	1.5	2.5		26		0	0	3.5		3.5		0	0	4		44
	0	0.5	3		-13		0	0	-2	3	15		0	1	6		24
	0	-1	2		25		0	-1.5	2		0		0	-1	3		25
	0	0	2		54		0	-0.5	2.5		21		0	0	1.5		42
	0	-0.5	1		81		0	0.5	3.5		55.5		0	0	3.5		103
	0	-0.5	2.5		108		0	0	2.5		82		0	0	3		122
	0	0.5	2		217		0	0	2		-13		0	0	0	2.5	130
	0	1	-0.5		212		0	-1	2.5		-4		0	0	2		155
	0	1	1		188		0	-3	-0.5		-6		0	-1	2		143
	0	-3	-0.5		400		0	-2	0		-2		0	0	0		65
	0	-1	-4		152		0	-2	0		-19		0	-141	-141		-141
	0	-1.5	-3		61		0	0	0		-11		0	-118	-118		
	0	-2	-2		290		0	1	1		-9		0	6	10		9
	0	-2.5	-3		133		0	-2	-2		10		0	13	15		46
	0	-3	-3		106		0	-3	-1		7		0	35	34.5		54
	0	-3	-5		65		0	-4	-1		1		0	-2	1		37.5
	0	-2	-4		82		0	-3	-1		21		0	1.5	0		39
	0	0	0		52		0	4.5	9		20		0	1	7		69
	0	0.5	3		216		0	1.5	1		41		0	0	22		90

	LWM						MHW						Coast				
	1866	**1898**	**1909**	**1946**	**2005**		**1866**	**1898**	**1909**	**1946**	**2005**		**1866**	**1898**	**1909**	**1946**	**2005**
	0	0.5	1.5		154		0	-1	-4		33		0	0	23		96
	0	-1	-1		128		0	1.5	14		37		0	0	3		63
	0	1	1.5		183		0	1.5	20		57		0	0	1		66
	0	2	2		121		0	1	25.5		87		0	2	4		45
	0	1	1		102		0	1	36		94		0	2	5		40
	0	3	3		135		0	-2.5	37.5		100		0	17	22		60
	0	0	-1.5		130		0	0.5	15		73		0	25	30		40
	0	1	1.5		100		0	0	13		70		0	41	41		48
Average	0	0.5	-0.25		110		0	-0.5	5.5		27		0	-3	3		65

12 Bibliography

ABPmer, 2008: *Wightlink – replacement Lymington to Yarmouth ferries: information for Appropriate Assessment*, Southampton: ABPmer, project no. R/3772/1, Report no.R1472

Adams, J.C. and Chandler, J.H. 2002: Evaluation of lidar and medium scale photogrammetry for detecting soft-cliff coastal change, *Photogrammetric Record*, **17** (99), 405-418

ALGAO, 1996: *Curating the coastal archaeological heritage: a review of current issues,* unpublished document

Allen, J.R.L. 2002: Retreat rates of soft-sediment cliffs: the contribution from dated fishweirs and traps on Holocene coastal outcrops, *Proceedings of the Geologist's Association*, **113**, 1-8

Allen, L.C. and Gibbard, P.L. 1993: Pleistocene evolution of the Solent River of Southern England, *Quaternary Science Reviews*, **12**, 503-528

Allen, M.J. 2005: Beaker settlement and environment on the chalk downs of Southern England, *Proceedings of the Prehistoric Society*, **71**, 219-245

Allen. M.J. and Adam, N.J. 2000: Archaeological work in the terrestrial and intertidal zones, *in* Allen, M.J. and Gardiner, J. *Our changing coast: a survey of the intertidal archaeology of Langstone Harbour, Hampshire*, York: CBA Research Report 124, 221-222

Allen, M.J. and Gardiner, J. 2000: *Our changing coast: a survey of the intertidal archaeology of Langstone Harbour, Hampshire*, York: CBA Research Report 124

Ashmore, P. 1994: *Archaeology and the coastal erosion zone: towards a Historic Scotland policy*, Edinburgh: Historic Scotland

Ashmore, P. 2003: Archaeology and the coastal zone, *in* Dawson, T. (ed), *Coastal archaeology and erosion in Scotland*, Edinburgh: Historic Scotland, 1-5

Atkins, 2004 *ICZM in the UK: a Stocktake*, final report (archive.defra.gov.uk/environment/marine/documents/protected/iczm/st-full-report.pdf) [accessed 12 September 2011]

Bacilieri, C. Knight, D. and Radford, S. 2008: *North East Coast Rapid Coastal Zone Assessment Survey; air survey mapping report*, Gateshead: Archaeological Research Services Ltd

Bacilieri, C. Knight, D, and Williams, S. 2009: *North West Coast Rapid Coastal Zone Assessment Survey; air survey mapping report,* Swindon: English Heritage and Archaeological Research Services Ltd

Baily, B. 2011: Ordnance Survey data collection and mapping of tidal features, *Sheetlines*, **90**, 4-17

Baker, M.V. Tapper, B. Johns, C. and Herring, P. 2007: *England's Historic Seascapes, Scarborough to Hartlepool and adjacent marine types,* Truro: Historic Environment Service, Cornwall County Council

Barnes, I. 2003: Aerial remote-sensing techniques used in the management of archaeological monuments on the British Army's Salisbury Plain Training Area, Wiltshire, UK, *Archaeological Prospection* **10**, 83-90

Barter, P.W.J. Burgess, K.A. Jay, H. and Hosking, A.S.D. 2003: Futurecoast: predicting the future coastal evolution of England and Wales, (www.irtces.org/pdf-hekou/019.pdf), [accessed 15 February 2010]

Barton, M.E. and McInnes, R. 1988: Experience with a tiltmeter-based early warning system on the Isle of Wight, *Proceedings of the 5th international symposium on landslides (Lausanne)*, 379-382

Basford, F. And Loader, R. 2000: Archaeological news from the Isle of Wight, *CBA Wessex News, October 2000*, 51-52

Basford, H.V. 1980: *The Vectis Report: a survey of Isle of Wight Archaeology*, Newport, Isle of Wight: Isle of Wight County Council

Basford, V. 2008: *Isle of Wight Historic Landscape Characterisation Final Report: Volume 1, method and analysis*, Newport, Isle of Wight: Isle of Wight Council/English Heritage

Bates, M.R. Wenban-Smith, F.F. Briant, R. and Marshall, G. 2004: *Palaeolithic archaeology of the Sussex/Hampshire coastal corridor*, unpublished report submitted to English Heritage

Battiau-Queney, Y. Billet, J.F. Chaverot, S and Lanoy-Ratel, P. 2003: Recent shoreline mobility and geomorphic evolution of macrotidal sandy beaches in the north of France, *Marine Geology*, **194**, 31-45

Bedwin, O, 1980: Neolithic and Iron Age material from a coastal site at Chidhall, West Sussex 1978, *Sussex Archaeological Collections*, **118**, 163-170

Bell, M. 1994: Field survey and excavation at Goldcliff, Gwent, 1994, *in* Bell, M. *Archaeology in the Severn Estuary 1994 (volume 5)*, Annual Report of the Severn Estuary Levels Research Committee, 115-144

Bell, M. 1997: Environmental archaeology in the coastal zone, *in* Fulford, M, Champion, T. and Long, A. (eds), *England's Coastal Heritage: a survey for English Heritage and the RCHME*, London: English Heritage, 56-73

Bell, M. and Neumann, H. 1999: Intertidal survey, assessment and excavation of a Bronze Age site at Redwick, Gwent, *in* Rippon, S. (ed), *Archaeology in the Severn Estuary 1999 (volume 10)*, Annual Report of the Severn Estuary Levels Research Committee, 25-37

Bell, M. Caseldine, A. and Neumann, H. 2000: *Prehistoric intertidal archaeology in the Welsh Severn Estuary*, CBA Research Report 120, York: Council for British Archaeology

Bellamy, A.G. 1995: Extension of the British landmass: evidence from shelf sediment bodies in the English Channel, *in* Preece, R.C. (ed) *Island Britain: a Quaternary perspective*, Geological Society of London, Special Publications, **96**, 47-62

Bewley, R.H. Crutchley, S.P. and Shell, C.A. 2005: New light on an ancient landscape: lidar survey in the Stonehenge World Heritage Site, *Antiquity*, **79**, 636-647

Bird, E. 2000: *Coastal Geomorphology*, Chichester: John Wiley & Sons

BMAPA, undated,a: *Aggregates from the Sea drawing strength from the depths*, London: BMAPA

BMAPA, undated,b *What are the issues?: Coastal erosion*, (www.bmapa.org/issues_coastal01.php) [accessed 28 May 2009]

BMAPA and English Heritage, 2003: *Marine aggregate dredging and the historic environment: guidance note,* London: British Marine Aggregate Producers Association and English Heritage

Borlase, W. 1753: An account of the great alterations which the Islands of Scilly have undergone since the time of the ancients, who mention them, as to their number, extent and position: in a letter to the Rev. Thomas Birch, D.D. Sec. R.S. *Philosophical Transactions of the Royal Society*, **48**, 55-69

Borlase, W. 1757: An account of some trees discovered under-ground on the shore at Mount's-Bay in Cornwall: in a letter from the Rev. Mr William

Borlase, F.R.S. to the Rev. Dr. Lyttleton, Dean of Exeter, *Philosophical Transactions of the Royal Society*, **50**, 51-53

Bradbury, A.P. Colenutt, A.J. Cross, J. Eastick, C. and Hume, D. 2003: Evaluation of coastal process impacts arising from nearshore aggregate dredging for beach recharge – Shingles Banks, Christchurch Bay, (www.channelcoast.org/data_management/reports/case_studies/evaluation%20of%20coastal%20process%20impacts.pdf) [accessed 12 September 2011]

Bradley, R. and Hooper, B. 1973: Recent discoveries from Portsmouth and Langstone Harbours: Mesolithic to Iron Age, *Proceedings of the Hampshire Field Club and Archaeological Society*, **30**, 17-27

Brampton, A.H. 1993: *South Coast seabed mobility study: summary report*, H R Wallingford

Brampton, A.H. and Evans, C.D.R. 1998: *Regional seabed sediment studies and assessment of marine aggregate dredging*, (C505), London: CIRIA

BRANCH Partnership, 2007: *Planning for biodiversity in a changing climate – BRANCH project final report*, UK: Natural England

Bray, M.J. 2003: *Ferry operations: potential impacts on European site features at Wootton Creek and Quarr foreshore*, English Nature

Bray, M. and Cottle, R. 2003: *The Solent Coastal Habitat Management Plan: final report*, (2 volumes), Peterborough: Posford Haskoning Ltd.

Bray, M.J. and Hooke, J.M. 1997: Prediction of soft-cliff retreat with accelerating sea-level, *Journal of Coastal Research*, **13(2)**, 453-467

Breen, C. and Forsythe, W. 2001: Management and protection of the maritime cultural resource in Ireland, *Coastal Management*, **29**, 41-51

Bridgeland, D.R. 1999: Analysis of the raised beach gravel deposits at Boxgrove and related sites, *in* Roberts, M.B. and Parfitt, S.A. *Boxgrove: a Middle Pleistocene Hominid Site at Eartham Quarry, Boxgrove, West Sussex*, London: English Heritage, p.100-111

Brigham, T. Buglass, J, and George, R. 2008: *Rapid Coastal Zone Assessment Survey Yorkshire and Lincolnshire: Bempton to Donna Nook*, Kingston Upon Hull: Humber Field Archaeology. Humber Archaeology Report no.235

British Museum, undated: Happisburgh: the earliest humans in northern Europe. (www.britishmuseum.org/happisburgh), [accessed 3 July 2011]

Bromhead, E.N. Chandler, M.P. and Hutchinson, J.N. 1991: The recent history and geotechnics of landslides at Gore Cliff, Isle of Wight, *in* Chandler, R.J. (ed) *Slope stability engineering: developments and applications. Proceedings of the International Conference on Slope Stability*, London: Thomas Telford, 189-196

Brown, K. Few, K. and Tompkins, E.L. 2005: *Responding to climate change: inclusive and integrated coastal analysis*, Tyndall Centre for Climate Change Research Technical Report 24

Brunning, R. 2007a: Monitoring waterlogged sites in peatlands: where, how, why and what next? *in* Barber, J. Clark, C. Cressey, M. Crone, A. Hale, A. Henderson, J. Housley, R. Sands, R. and Sheridan, A. (eds) *Archaeology from the wetlands: recent perspectives. Proceedings of the 11th WARP conference, Edinburgh 2005*, Edinburgh: Society of Antiquaries of Scotland, 41-47

Brunning, R. 2007b: Monuments at risk in Somerset's peatlands, *in* Barber, J. Clark, C. Cressey, M. Crone, A. Hale, A. Henderson, J. Housley, R. Sands, R. and Sheridan, A. (eds) *Archaeology from the wetlands: recent perspectives. Proceedings of the 11th WARP conference, Edinburgh 2005*, Edinburgh: Society of Antiquaries of Scotland, 191-197

Brunning, R. and Farr-Cox, F. 2005: The River Siger rediscovered: LIDAR survey and relict landscape on the Somerset claylands, *Archaeology in the Severn Estuary* **16**, 7-15

Buglass, J. And Brigham, T. 2007a: *Rapid Coastal Zone Assessment Survey Yorkshire and Lincolnshire: Donna Nook to Gibraltar Point*, Kingston Upon Hull: Humber Field Archaeology. Humber Archaeology Report no. 236

Buglass, J. And Brigham, T. 2007b: *Rapid Coastal Zone Assessment Survey Yorkshire and Lincolnshire: Gibraltar Point to Norfolk*, Kingston Upon Hull: Humber Field Archaeology. Humber Archaeology Report no.237

Buglass, J. And Brigham, T. 2008a: *Rapid Coastal Zone Assessment Survey Yorkshire and Lincolnshire: Bempton to Donna Nook*, Kingston Upon Hull: Humber Field Archaeology. Humber Archaeology Report no. 235

Buglass, J. And Brigham, T. 2008b: *Rapid Coastal Zone Assessment Survey Yorkshire and Lincolnshire: Whitby to Reighton*, Kingston Upon Hull: Humber Field Archaeology. Humber Archaeology Report no. 238

Cadw, 1999: *Caring for coastal heritage*, Cardiff: Cadw

Camden, W. 1586: *Britannia*, London

Camfield, F.E. and Morang, A. 1996: Defining and interpreting shoreline change, *Ocean and Coastal Management*, **32(3)**, 129-151

Campbell, A.C. 1989: *The Hamlyn Guide to seashores and shallow seas of Britain and Europe*, London: the Hamlyn Publishing Group Ltd (10th impression)

Carr, A.P. 1980: The significance of cartographic sources in determining coastal change, *in* Cullingford, R.A. Davidson, D.A. and Lewin, J. (eds) *Timescales in Geomorphology*, John Wiley and Sons, 69-78

Cartwright, C.R. 1982: Field survey of Chichester Harbour, *Sussex Archaeol Coll*, **122**, 23-27

Case, C. 2009: *Southeast Strategic Regional Coastal Monitoring Programme: Annual Report 2009, Isle of Wight*, Southampton: Channel Coastal Observatory

Cassar, M. 2005: *Climate change and the historic environment*, London: Centre for Sustainable Heritage, UCL

Catchpole, T. and Chadwick, A.M. 2010a: *Severn Estuary Rapid Coastal Zone Assessment Survey: Phase 2a pilot fieldwork report*, Gloucestershire County Council/Somerset County Council, HEEP Project no. 3885

Catchpole, T. and Chadwick, A.M. 2010b: *Severn Estuary Rapid Coastal Zone Assessment Survey: Updated Project Design for Phase 2 fieldwork*, Gloucestershire County Council/Somerset County Council, HEEP Project no. 3885

CBA undated: Climate change (www.britarch.ac.uk/conservation/climate) [accessed 15 September 2009]

CEFAS 2008: Southern North Sea sediment transport study project (www.cefas.co.uk/projects/southern-north-sea-sediment-transport-study-project.aspx) [accessed 14 April 2009]

Challis, K. 2006: Airborne laser altimetry in alluviated landscapes, *Archaeological Prospection*, **13**, 103-127

Challis, K, Kokalj, Z. Kincey, M. Moscrop, D. and Howard, A.J. 2008: Airborne lidar and historic environment records, *Antiquity*, **82**, 1055-1064

Champion, T. and O'Regan, D. 1997: The coastal zone, *in* Fulford, M. Champion, T. and Long, A.(eds) *England's Coastal Heritage: a survey for*

English Heritage and the RCHME, London: English Heritage Archaeological Report 15, 22-24
Channel Coastal Observatory, 2003a: *Southeast Coastal Monitoring Programme. LIDAR surveys of cliffs and saltmarsh systems* (www.channelcoast.org/southeast/survey_techniques/airborne_remote_sensing_topographic_surveys/?link=lidar_surveys_of_cliffs_and_saltmarsh_systems.html) [accessed 9 May 2008]
Channel Coastal Observatory, 2003b: *Southeast Coastal Monitoring Programme. Survey techniques* (www.channelcoast.org/southeast/survey_techniques/land_based_topographic_surveys/?link=survey_techniques.html#levelling) [accessed 21 December 2009]
Chapman, H.P. and Cheetham, J.L. 2002: Monitoring and modelling saturation as a proxy indicator for *in situ* preservation in wetlands – a GIS-based approach, *Journal of Archaeological Science*, **29**, 277-289
Chapman H.P. Fletcher, W.G. and Thomas, G. 2001: Quantifying the effects of erosion on the archaeology of intertidal environments: a new approach and its implications for their management, *Conservation and Management of Archaeological Sites,* **4**, 233-240
Churchill, D.M. 1965: The displacement of deposits formed at sea-level, 6,500 years ago in Southern Britain, *Quaternaria*, **7**, 239-249
Clark, J. Darlington, J. and Fairclough, G. 2004: *Using Historic Landscape Characterisation*, English Heritage and Lancashire County Council
Clarke, W.R. 1838: On the peat bogs and submarine forests of Bournemouth, Hampshire and in the neighbourhood of Poole, Dorsetshire, *Proceedings of the Geological Society*, **2**, 599-601
Clifford, M.H. 1936: A Mesolithic flora in the Isle of Wight, *Proceedings of the Isle of Wight Natural History and Archaeological Society* **2**, 582-94
Cocroft, W. 2007: *High Down Test Site, the Needles, Isle of Wight: rocket test site*, English Heritage, Research Department Report Series no.90-2007
Codrington, T. 1870: On the superficial deposits of the south of Hampshire and the Isle of Wight, *Quarterly Journal of the Geological Society*, **26**, 528-551
Colenutt, G.W. 1938: Fifty years of Island coast erosion, *Proceedings of the Isle of Wight Natural History and Archaeological Society* **3**, 50-57

Coles, J. 2000: Celebration and reflection: the Severn Estuary Levels after ten years, *in* Rippon S. (ed) *Estuarine Archaeology: the Severn and beyond*, Archaeology in the Severn Estuary 11, Severn Estuary Levels Research Committee, 209-211

Commission of the European Communities, 2000: *Communication from the Commission to the Council and the European Parliament on Integrated Coastal Zone Management: a strategy for Europe*, Brussels, Com (2000) 547 final

Council of Europe, 1999a: *Model Law on sustainable management of coastal zones*, Strasbourg: Council of Europe

Council of Europe, 1999b: *European code of conduct for coastal zones*, Strasbourg: Council of Europe

Cracknell, A.P. 1999: Remote sensing in estuaries and coastal zones – an update, *International Journal of Remote Sensing*, **19** (3), 485-496

Crawford, O.G.S. 1927: Lyonesse, *Antiquity*, **1(1)**, 5-14

Crow, P. 2008: *Historic environment surveys of woodland using LiDAR*, Forest Research (www.forestresearch.gov.uk/pdf/LiDAR_FC_note_web_2008.pdf/$FILE/LiDAR_FC_note_web_2008.pdf) [accessed 2 May 2008]

Crowell, M. Leatherman, S.P. and Buckley, M.K. 1991: Historical shoreline change: error analysis and mapping accuracy, *J Coastal Research*, **7(3)**, 839-852

Crowther, S. And Dickson, A. 2008: *Severn Estuary Rapid Coastal Zone Assessment Survey: National Mapping Programme*, Gloucester: Gloucestershire County Council, English Heritage, Somerset County Council

Crutchley, S. 2006: Light detection and ranging (lidar) in the Witham valley, Lincolnshire: an assessment of new remote sensing techniques, *Archaeological Prospection*, **13**, 251-257

Darrah, R. and Loader, R.D. forthcoming: The intertidal wooden structures, *in* Tomalin, D.J. Loader. R.D. and Scaife. R.G. (eds), *Coastal archaeology in a dynamic setting: a Solent case study*, Oxford: BAR

Darvill, T.C. 1988: *Monuments Protection Programme Monument Evaluation Manual. Part II: single monuments*, English Heritage

Darvill, T. and Fulton, A.K. 1998: *MARS: The Monuments at Risk Survey of England, 1995*, Bournemouth and London: School of Conservation Sciences, Bournemouth University and English Heritage

Davidson, A. (ed) 2002: *The coastal archaeology of Wales*, York: CBA Research Report 131

Dawson, T. (ed) 2003: *Coastal archaeology and erosion in Scotland*, Edinburgh: Historic Scotland

De Brisay, K.W. 1978: The excavation of a red hill at Peldon, Essex, with notes on some other sites, *Antiquaries Journal,* **58**, 31-60

Deegan, A. 2007: *The Yorkshire Coast and Humber Estuary Rapid Coastal Zone Assessment Project (3729). Air photo mapping project. Management overview: summary of resources and results*, Bradford

Defra, 2001: *Shoreline Management Plans: a guide for coastal defence authorities*, London: Defra

Defra, 2004a: *Managing coastal activities: a guide for local authorities*, London: Defra

Defra, 2004b: Pump scoop dredging banned to protect Solent Marine Site, *Marine Pollution Bulletin*, **49**, 883-886

Defra, 2005: *High level targets for flood and coastal erosion risk management*, (www.Defra.gov.uk/environ/fcd/hltarget/default.htm) [accessed 7 July 2007]

Defra, 2006a: *Shoreline Management Plan Guidance. Volume 1: aims and requirements*, London: Defra

Defra, 2006b: *Shoreline Management Plan Guidance. Volume 2: procedures*, London: Defra

Defra, 2006c: *Promoting an integrated approach to management of the coastal zone (ICZM) in England: a consultation document of the Department for Environment, Food and Rural Affairs*, London: Defra (www.Defra.gov.uk/environment/water/marine/uk/iczm/pdf/iczm-consultation.pdf) [accessed 8 July 2008]

Defra, 2006d: *Unlicensed Activities: a review to consider the threats to marine biodiversity. Building the evidence base for the Marine Bill*, London: Defra

Defra, 2006e: *Flood and Coastal Defence Appraisal Guidance, FCDPAG3 Economic Appraisal: Supplementary note to Operating Authorities – Climate Change Impacts, October 2006*, London: Defra

Defra, 2007: *Summary of responses to the consultation on proposals to improve access to the English coast*, London: Defra

Defra, 2008a: Making Space for Water: Outcome Measures (www.Defra.gov.uk/environ/fcd/policy/strategy/sd4/default.htm) [accessed 8 May 2008]

Defra, 2008b: *A strategy for promoting an integrated approach to the management of coastal areas in England*, London: Defra

Defra, 2009: *Marine and Coastal Access Bill Policy Document. Last updated: 29 June 2009*, London: Defra

Defra/Halcrow, 2002: *FutureCoast*

Department for Communities and Local Government, 2002: *Marine Minerals Guidance 1: Extraction by dredging from the English seabed*, London: TSO

Department for Communities and Local Government, 2006a: *Planning Policy Statement 25: Development and Flood Risk*, London: TSO

Department for Communities and Local Government, 2006b: *Minerals Policy Statement 1: Planning and Minerals*, London: TSO

Department for Communities and Local Government, 2007: *Statutory Instrument 2007 no.1067: The Environmental Impact Assessment and Natural Habitats (Extraction of Minerals by Marine Dredging) (England and Northern Ireland) Regulations*, London: TSO

Department for Communities and Local Government, 2010a: *Planning Policy Statement 5: Planning for the historic environment*, London: TSO

Department for Communities and Local Government/DCMS/English Heritage, 2010b: *PPS 5 Planning for the historic environment: Historic Environment Planning Practice Guide,* London:

Department for Communities and Local Government, 2010c: *Planning Policy Statement 25 Supplement: Development and Coastal Change*, London:

Department for Transport, 2002: *A project appraisal framework for ports*, London, DfT

Devereux, B.J. Amable, G.S. Crow, P. and Cliff, A.D. 2005: The potential of airborne lidar for detection of archaeological features under woodland canopies, *Antiquity*, **79** (305), 648-660

Devoy, R.J. N. 1979: Flandrian sea level changes and vegetational history of the lower Thames estuary, *Philosophical Transactions of the Royal Society of London*, B, **285**, 355-410

Devoy, R.J. 1982: Analysis of the geological evidence for Holocene sea-level movements in southeast England, *Proceedings of the Geologist's Association*, **93(1)**, 65-90

Devoy, R.J.N. 1987: The estuary of the Western Yar, Isle of Wight: sea-level changes in the Solent region, *in* Barber. K E (ed) *Wessex and the Isle of Wight: Field Guide*, Cambridge: Quaternary Research Association, 115-122

DOE/Welsh Office, 1990: *Planning Policy Guidance 16: Archaeology and Planning*

DOE/Welsh Office, 1992: *Planning Policy Guidance: Coastal Planning (PPG 20)*

DOE/Welsh Office, 1994: *Planning Policy Guidance 15: Planning and the historic environment*

Dickson, M.E. Walkden, M.J.A. and Hall. J.W. 2007: Systemic impacts of climate change on an eroding coastal region over the twenty-first century, *Climate Change*, **84**, 141-166

Dix, J.K. 2001: The geology of the Solent River system, *in* Wenban-Smith, F.F. and Hosfield, R.T. (eds) *Palaeolithic archaeology of the Solent River*, London: Lithic Studies Society Occasional Paper no. 7, 7-14

Dorset Coast Forum, undated: *Submerged landscapes*, (www.dorsetforyou.com/index.jsp?articleid=21146) [accessed 19 August 2009]

Draper, J C, 1951: Stone industries from Rainbow Bar, Hants, *Archaeol Newsl* **3**(9), 147-149

Dunning, G.C. 1931: A late Bronze Age urnfield at Barnes, Isle of Wight, and notes on the late Bronze Age in the Isle of Wight, *Proceedings of the Isle of Wight Natural History and Archaeological Society*, **2**, 108-117

Dunning, G.C. 1935: Belgic hut and barrows in the Isle of Wight, *Antiquaries Journal*, **15**, 355-358

Dunning. G.C. 1939: A thirteenth century midden at Windcliff, near Niton, *Proceedings of the Isle of Wight Natural History and Archaeological Society*, **3**, 128-137

Dunning, G .C. 1977: Mortars, *in* Clarke, H. and Carter, A. *Excavations in Kings Lynn 1963-1970*, Norfolk: Society of Medieval Archaeology Monograph 7, 320-347

Dyer, K.R. 1975: The buried channels of the 'Solent River', Southern England, *Proceedings of the Geologists' Association*, **86**, 239-245

Dyson, L. Heppell, E. Johnson, C. and Pieters, M. 2006: *Archaeological evaluation of wetlands in the Planarch area of north west Europe*, Maidstone: Kent County Council

Ecroyd Smith, H. 1866: Notabilia of the archaeology and natural history of the Mersey District during 3 years, 1863-4-5, part 1, *Transactions of the Historical Society of Lancashire and Cheshire*, **18**, 195-266

Englefield, Sir H.C. 1816: *A description of the principal beauties, antiquities and geological phenomena of the Isle of Wight*, London:

English Heritage, 1999: *A Brief for Rapid Coastal Zone Assessment Surveys*, English Heritage/RCHME

English Heritage, 2002: *State of the Historic Environment Report 2002*

English Heritage, 2003: *State of the Historic Environment Report 2003*

English Heritage, 2004: *State of the Historic Environment Report 2004*

English Heritage, 2005: *Discovering the past, shaping the future. Research Strategy 2005-2010*, English Heritage

English Heritage, 2006a *Shoreline Management Plan review and the Historic Environment: English Heritage guidance*, London: English Heritage

English Heritage, 2006b: *Severn Estuary Rapid Coastal Zone Assessment, English Heritage summaries 2005/2006* (www.english-heritage.org.uk/server/show/ConWebDoc.6025) [accessed 5 May 2008]

English Heritage, 2006c: *Ports: the impact of development on the maritime historic environment*, English Heritage

English Heritage, 2006d: *Isle of Wight Coastal Assessment Enhancement , English Heritage summaries 2006/2007*, (www.english-heritage.org.uk/server/show/ConWebDoc.13669) [accessed 24 October 2009]

English Heritage, 2007a: *A brief for English Heritage Rapid Coastal Zone Assessment Surveys*, Version 10, February 2007, English Heritage

English Heritage, 2007b: *Heritage Counts 2007: England*, London: English Heritage

English Heritage, 2008a: *Intertidal and coastal peat resource database* (www.english-heritage.org.uk/professional/research/heritage-science/environmental-studies/Environmental-Studies-Resources/intertidal-peat-database/) [accessed 19 August 2009]

English Heritage, 2008b: *Heritage Counts 2008: England*, London: English Heritage

English Heritage, 2008c: *Climate change and the historic environment*, English Heritage

English Heritage, undated a: *Rapid Coastal Zone Assessment and Beyond - research and management of the Essex Coast*, (www.english-heritage.org.uk/server/show/nav.001002005007003) [accessed 4th June 2006]

English Heritage, undated b: *Historic Seascape Characterisation (*www.english-heritage.org.uk/professional/research/landscapes-and-areas/characterisation/historic-seascape-character/), [accessed 12 June 2011]

English Heritage, undated c: *Rapid Coastal Zone Assessment Surveys (RCZAS)*, (www.english-heritage.org.uk/professional/advice/advice-by-topic/marine-planning/shoreline-management-plans/rapid-coastal-zone-assessments/)
[accessed 22 June 2011]

English Heritage, undated d: *Mendip Hills Lidar*, (www.english-heritage.org.uk/server/show/nav.10591) [accessed 3 January 2010]

English Heritage, undated e: *Savernake Forest Lidar*, (www.english-heritage.org.uk/server/show/nav.18665) [accessed 3 January 2010]

English Nature, 2005: *Integrated Coastal Zone Management and the planning system in England*, Peterborough: English Nature Research Reports 643

EN/EA/CCMS 2000: *Coastal Habitat Management Plans: an interim guide to content and structure*, Peterborough: EN/EA/CCMS

Entec, 2010: *The Isle of Wight Strategic Flood Risk Assessment*, London: Entec UK Ltd

Environment Agency, 2004: *Catchment Flood Management Plans. Volume 1 – Policy Guidance*, Bristol: Environment Agency

Environment Agency, 2011: *Geomatics Group: LIDAR* (www.geomatics-group.co.uk/GeoCMS/Products/LIDAR.aspx) [accessed 21 February 2011]

Environment Agency, not dated: Science and research: LIDAR (www.environment-agency.gov.uk/science/monitoring/131047/?lang=_e) [accessed 27 April 2006]

Erlandson, J.M. and Moss, M.L. 1999: The systematic use of radiocarbon dating in archaeological surveys in coastal and other erosional environments, *American Antiquity*, **64.3**, 431-443

European Parliament and Council, 2002: *Recommendation of the European Parliament and of the Council of 30 May 2002 concerning the implementation of Integrated Coastal Zone Management in Europe*, (2002/413/EC) (eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32002H0413:EN:NOT) [accessed 14 September 2011]

Europa Nostra, June 2005: *Declaration on Coastal Culture*, (www.europanostra.org/declaration_coastalculture.htm) [accessed 9 May 2008]

European Commission, 1999: *Towards a European Integrated Coastal Zone Management (ICZM) strategy: general principles and policy options*, Luxembourg: European Communities

European Union, 1992: *Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora*, (eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31992L0043:EN:NOT) [accessed 14 September 2011]

European Union, 2009: *Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds (codified version of Directive 79/409/EEC as amended)*, (eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:020:0007:0025:EN:PDF) [accessed 14 September 2011]

Evans, C.D.R. Crosby, A. Wingfield, R.T.R. James, J.W.C. Slater, M.P. and Mewsham, R. 1998: *Inshore seabed characterisation of selected sectors of the English Coast*. BGS Technical Report WB 98/45

Evans, J. 1872: *The ancient stone implements, weapons and ornaments of Great Britain*, London: Longmans, Green, Reader and Dyer

Everard, C.E. 1954: The Solent River: a geomorphological study, *Transactions of the Institute of British Geographers*, **20**, 41-58

Everett, L. Allan, D. and McLannahan, C. 2003: *Assessment Report: Rapid field survey of the Suffolk coast and intertidal zone, May 2002 - March 2003*, Ipswich: Suffolk County Council.

Ferrari, B. and Adams, J. 1990: Biogenic modifications of marine sediments and their influence on archaeological material, *International Journal of Nautical Archaeology*, **19(2)**, 139-151

Fielding, H. 1755: *Journal of a voyage to Lisbon*,

Firn, J. and McGlashen, D. 2001: *A Coastal Management Trust for Scotland: A concept development and feasibility study*, Edinburgh: Scottish Executive Central Research Unit (www.scotland.gov.uk/Resource/Doc/156730/0042131.pdf) [accessed 9 May 2008]

Firth, C.R. and Stewart, I.S. 2000: Postglacial tectonics of the Scottish glacio-isostatic uplift centre, *Quaternary Science Reviews*, **19**, 1469-1493

Fishbourne Residents Group, undated: *Fishbourne Isle of Wight has a problem…* (http://homepages.rya-online.net/wootton-creek/index.html) [accessed 2 May 2009]

Fitzpatrick, S. 2004: Synthesizing island archaeology, *in* Fitzpatrick, S. (ed) *Voyages of discovery: the archaeology of islands*, Greenwood Press, 3-18

Flatman, J. 2009: A climate of fear: recent British policy and management of coastal heritage, *Public Archaeology*, **8(1)**, 3-19

Flint, K.E. 1982: Chines on the Isle of Wight: channel adjustment and basin morphology in relation to cliff retreat, *The geographical Journal* **148(2)**, 225-236

Foss, K. 2004: *The book of Newtown with Porchfield, Locks Green and Shalfleet: ancient capital of the Isle of Wight*, Tiverton: Halsgrove

Fowler, S.L. 1999: *Guidelines for managing the collection of bait and other shoreline animals within UK European marine sites*, Newbury: The Nature Conservation Bureau Ltd

Fox, W.D. 1862: When and how was the Isle of Wight separated from the mainland? *Geologist*, **5**, 452-454

Frazer, O. 1990: *The Natural History of the Isle of Wight*, Wimborne, Dorset: The Dovecote Press

French, J.R. and Burningham, H. 2009: Coastal geomorphology: trends and challenges, *Progress in Physical Geography*, **33**(1), 117-129

Fulford, M. and Champion, T. 1997: Potential and priorities, *in* Fulford, M. Champion, T. and Long, A. (eds) *England's Coastal Heritage: a survey for English Heritage and the RCHME*, London: English Heritage Archaeological Report 15, 215-233

Fulford, M. Champion, T. and Long, A. (eds) 1997: *England's Coastal Heritage: a survey for English Heritage and the RCHME*, London: English Heritage Archaeological Report 15

Garel, E. Lopez Fernandez, L. and Collins, M. 2008: Sediment resuspension events induced by the wake wash of deep-draft vessels, *Geomarine Letters*, **28**, 205-211

Giordano, A. and Gelpke, R. 2003: Geographic Information Technologies and the history of a shoreline: the case of Chapter 91 in New Bedford, Massachusetts, *The Professional Geographer*, **55(3)**, 329-342

Godbold, S. And Turner, R.C. 1993: Medieval fishtraps in the Severn Estuary, *Medieval Archaeology*, **38**, 19-54

Godwin, H. 1943: Coastal Peat Beds of the British Isles and North Sea: Presidential Address to the British Ecological Society 1943, *Journal of Ecology*, **31**(2), 199-247

Godwin, H. 1945: Coastal peat-beds of the North Sea region as indices of land and sea-level changes, *New Phytologist* , **44(1)**, 29-69

Godwin, H. and Godwin, M E, 1940: Submerged peat at Southampton; data for the study of postglacial history, *New Phytologist*, **39**, 303-307

Gonzalez, S. and Cowell, R.W. 2007: Neolithic coastal archaeology and environment around Liverpool Bay, *in* Sidell, J. and Haughey, F. (eds), *Neolithic archaeology in the intertidal zone*, Oxford: Oxbow Books, 11-25

Green, J.F.N. 1946: The terraces of Bournemouth, Hampshire, *Proceedings of the Geologists' Association*, **57**, 82-101

Griffiths, D. Philpott, R.A. and Egan, G. 2007: *Meols: The archaeology of the north Wirrell coast. Discoveries and observations in the 19th and 20th* *centuries with a catalogue of collections*, Oxford: Oxford School of Archaeology Monograph 68

Gubbay, S. 1991: *A definition of the 'coastal zone' for UK coastal zone management programmes*, Ross-on-Wye: Marine Conservation Society

Gubbay, S. 2002: *Just coasting: an assessment of the commitment of the devolved administrations and the English regions to Integrated Coastal Management*, WWF-UK (www.wwf.org.uk/filelibrary/pdf/just_coasting.pdf) [accessed 22 May 2008]

Gubbay, S. 2005: *A review of marine aggregate extraction in England and Wales, 1970-2005*, London: The Crown Estate

Gubbay, S. and Knapman, P.A. 1999: *A review of the effects of fishing within UK European marine sites*, Peterborough: English Nature

H R Wallingford, 1997: *East Solent Shoreline Management Plan* (www.havant.gov.uk/council/Coastal/MainContents.htm) [accessed 29 December 2011]

H R Wallingford, 2009: *Wightlink Ferries, Lymington: Shoreline management and geomorphological advice to Natural England*, H R Wallingford Ltd. Report EX 5937 release 3

Haigh, I. 2006: *Appendix B: Mean Sea Level at Portsmouth: unpublished report to the BRANCH Project*, Centre for Coastal Processes, Engineering and Management, University of Southampton

Halcrow, W. and Partners, 1997: *Isle of Wight Coast, Shoreline Management Plan, (2 vols.)*. Report to Isle of Wight Council and Environment Agency

Halcrow Group, 2005: *Developing Integrated Coastal Zone Management (ICZM) options for England and Wales*, London: Halcrow Group Ltd. Report prepared for the Environment Agency, English Nature and the Countryside Council for Wales

Hale, A. and Cressey, M. 2003: Assessment survey: the Inner Moray Firth, *in* Dawson, T. (ed), *Coastal archaeology and erosion in Scotland*, Edinburgh: Historic Scotland, 99-106

Hamblin, R.J.O., and Harrison, D.J., 1989: *Marine aggregate survey, phase 2: south coast*, Nottingham: British Geological Survey

Hampshire and Wight Trust for Maritime Archaeology, 2006: *SCOPAC archaeology and coastal change: project report*, Southampton: HWTMA

Hampshire and Wight Trust for Maritime Archaeology, 2007: *Archaeology within marine aggregate Environmental Statements.* Aggregate Levy Sustainability Fund: marine aggregates and the historic environment. EH project 4740 (ads.ahds.ac.uk/catalogue/archive/aama_eh_2007/index.cfm) [accessed 8 March 2008]

Harlow, D.A. 1980: *Sediment movements in Wootton Creek and the likely effect of the proposed dredging*, Report to Fishbourne and Wootton Creek Protection Association

Haynes, F.M. and Coulson, M.G. 1982: The decline of *spartina* in Langstone Harbour, Hampshire, *Proceedings of the Hampshire Field Club and Archaeological Society*, **38**, 5-18

Hegarty, C. And Newsome, S. 2005: *The archaeology of the Suffolk coast and intertidal zone: a report for the National Mapping Programme*, Bury St Edmunds: Suffolk County Council and English Heritage

Heppell, E. 2004: *Greater Thames Estuary, Essex Zone. Monitoring survey: Assessment and updated project design*, Issue 2. Essex: Essex County Council/English Heritage

Heppell, E. and Brown N. 2001: *Greater Thames Estuary Essex Zone. Archaeological Assessment Report an Updated Project Design*, Essex: Essex County Council Heritage Conservation

Heppell, E.N. and Brown, N. 2008: Rapid coastal zone survey and beyond: research and management of the Essex Coast, UK, *Journal of Wetland Archaeology*, **8**, 26-52

Herring, P. 1998: *Cornwall's Historic Landscape*. *Presenting a method of historic landscape character assessment.* Truro: Cornwall County Council and English Heritage

Heyworth, A. and Kidson, C. 1982: Sea-level changes in southwest England and Wales, *Proceedings of the Geologist's Association*, **93(1)**, 91-11

Hillam, J. forthcoming: Tree-ring analysis of oak timbers from the Wootton-Quarr survey, *in* Tomalin, D.J. Loader. R.D. and Scaife. R.G. (eds) *Coastal archaeology in a dynamic setting: a Solent case study*, Oxford: BAR

Himmelstoss, E.A. and Miller, T. 2005: *User Guide and tutorial for the Digital Shoreline Analysis System (DSAS) version 3.2, extension for ArcGIS v.9.0*, Woods Hole: USGS

Historic Scotland, 1996: *Archaeology procedure paper 4: coastal zone assessment survey*, Edinburgh: Historic Scotland

HM Government, 2009: *Marine and Coastal Access Act*, London: HMSO

HM Government, 2011: *UK Marine Policy Statement*, London: HMSO

Hogan, D. Jones, M. and Simpson, P. 2006: *Reburial of organic archaeological remains,* Final report to English Heritage (ads.ahds.ac.uk/catalogue/archive/reburial_eh_2007/) [accessed 6 February 2008]

Holden, J. West, L.J. Howard, A.J. Maxfield, E. Panter, I. and Oxley, J. 2006: Hydrological controls of *in situ* preservation of waterlogged archaeological deposits, *Earth Science Reviews*, **78**, 59-83

Holgate, R. 1986: Prehistoric sites threatened by coastal erosion between Seaford Head and Beachy Head, East Sussex, *Sussex Archaeological Collections*, **124**, 243-244

Holyoak, D.T. and Preece, R.C. 1983: Evidence of a high Middle Pleisetocene sea-level from estuarine deposits at Bembridge, Isle of Wight, England, *Proceedings of the Geologists Association*, **94(3)**, 231-244

Hookey, T.P. 1951: The Romano-British site at Sudmoor, *Proceedings of the Isle of Wight Natural History and Archaeological Society*, **4**, 215-216

Hooley, D. 2003: *Catching the tide: inter-tidal and maritime characterisation project design* consultation draft; English Heritage

Huddart, D. Gonzalez, S. and Roberts, G. 1999: The archaeological record and mid-Holocene marginal coastal palaeoenvironments around Liverpool Bay, *Quaternary Proceedings*, **7**, 563-574

Hughes, R.G. and Paramor, O.A.L. 2004: On the loss of saltmarshes in South-East England and methods for their restoration, *Journal of Applied Ecology*, **41**, 440-448

Hutchinson, J.N. 1987: Some coastal landslides of the southern Isle of Wight, *in* Barber. K E (ed) *Wessex and the Isle of Wight: Field Guide*, Cambridge: Quaternary Research Association, 123-135

Hutchinson, J.N. 1991: The landslides forming the South Wight Undercliff, *in* Chandler, R.J. (ed) *Slope stability engineering: developments and* *applications. Proceedings of the International Conference on Slope Stability*, London: Thomas Telford, 157-168

Hutchinson, J.N. Bromhead, E.N. and Chandler, M.P. 1991: Investigations of landslides at St Catherine's Point, Isle of Wight, *in* Chandler, R.J. (ed) *Slope stability engineering: developments and applications. Proceedings of the International Conference on Slope Stability*, London: Thomas Telford, 169-179

Hydraulics Research Ltd, 1980: *Wootton Creek, Isle of Wight. Effects of Sealink Operations*. Report EX932, Wallingford: Hydraulics Research Ltd.

Hydraulics Research Ltd, 1988: *Wootton Hard, Fishbourne, Isle of Wight: factors causing erosion of a shingle bank*, Report EX1723, Wallingford: Hydraulics Research Ltd.

Insole, A. Daley, A. and Gale, A. 1998: *The Isle of Wight*, London: The Geologists' Association Guide no.60

Isle of Wight AONB Partnership, 2004: *Isle of Wight Area of Outstanding Natural Beauty Management Plan 2004-2009*, Isle of Wight: Isle of Wight AONB Partnership

Isle of Wight AONB Partnership, 2009: *Isle of Wight AONB Management Plan 2009-2014*, Isle of Wight: Isle of Wight AONB Partnership

Isle of Wight Centre for the Coastal Environment, 2009: *Isle of Wight Coastal Plans and Studies: Isle of Wight environmental mitigation study*, (www.coastalwight.gov.uk/studies.htm) [accessed 21 April 2009]

Isle of Wight Council, 2005a: *Isle of Wight North-East Coastal Defence Strategy Study*, Isle of Wight: Isle of Wight Council

Isle of Wight Council, 2005b: *A case study documenting the UK South-East Regional Strategic Coastal Monitoring Programme: prepared in the framework of the MESSINA project*

Isle of Wight Council, 2008: *An introduction to the HEAP: the Isle of Wight Historic Environment Action Plan*, Newport, Isle of Wight: Isle of Wight Council

Isle of Wight Council, forthcoming a: *Undercliff Coastal Defence Strategy Study*

Isle of Wight Council, forthcoming b: *West Wight Coastal Defence Strategy Study*

Isle of Wight Council, Environment Agency, and Royal Haskoning, 2010: *Isle of Wight Shoreline Management Plan 2 Review Sub-cell 5d+e*, Isle of Wight: Isle of Wight Council

Isle of Wight County Press, 2010: *Landslip hits Military Road*, (www.iwcp.co.uk/news/news/landslip-hits-military-road-31417.aspx) [accessed 26 February 2010]

James, H. 1847: On a section exposed by the excavation at the new steam basin in Portsmouth Dockyard, *Quart J Geol Soc*, **3**, 249-251

Johns, C. Larn, R. and Tapper, B.P. 2004: *Rapid Coastal Zone Assessment for the Isles of Scilly*, Truro: Historic Environment Service, Cornwall County Council

Johnson, B. 2009: *North West Rapid Coastal Zone Assessment (NWRCZA)*, Gateshead: Archaeological Research Services Ltd. Report 2009/53

JNAPC, 2006: *Code of practice for seabed developers*

Keen, D.H. 1975: *Some aspects of the Pleistocene succession in areas adjoining the English Channel*, PhD thesis, Univ. London

Kell, Rev. E. 1866: An account of the discovery of a Roman building in Gurnard Bay, Isle of Wight, and its relation to the ancient British tin-trade in the Island, *Journal of the British Archaeological Association*, **22**, 351-368

Kelleher, C.E. 1998: *The maritime archaeological landscape of Baltimore, Co. Cork*, unpubl. MA Thesis, University College Cork

King, S.D. and Green, D.R. 2001: Redefining the limits of the coastal zone: bridging the gap between land and sea using remote sensing, GIS, and the Internet, *GeoCoast*, **2(1)**, 1-15

Lambeck, K. 1995: Late Devensian and Holocene shorelines of the British Isles and North Sea from models of glacio-hydro-isostatic rebound, *Journal of the Geological Society*, **152**, 437-448

Larn, R. 1985: The wreck of the Dutch East Indiaman Campen on the Needles Rock, Isle of Wight, *International Journal of Nautical Archaeology*, **14**, 1-31

Larsonneur, C. Bouysee, P. and Auffret, J-P. 1982: The superficial sediments of the English Channel and its Western Approaches, *Sedimentology*, **29**, 851-864

Leatherman, S.P. 1990: Modelling shore response to sea-level rise on sedimentary coasts, *Progress in Physical Geography*, **14**, 447-464

Lee, E.M. 2005: Coastal cliff recession risk: a simple judgement based model, *Quarterly Journal of Engineering Geology and Hydrogeology*, **38**, 89-104

Lee, E.M. 2008: Coastal cliff behaviour: observations on the relationship between beach levels and recession rates, *Geomorphology*, **101**, 558-571

Leyland, J. and Darby, S.E. 2008: An empirical-conceptual gully evolution model for channelled sea cliffs, *Geomorphology*, **102**, 419-434

Lillie, M. and Smith, R. 2007: The *in situ* preservation of archaeological remains: using lysimeters to assess the impacts of saturation and seasonality, *Journal of Archaeological Science*, **34**, 1494-1504

Lillie, M. Smith, R. Reed, J. Inglis, R. 2008: Southwest Scottish Crannogs: using *in situ* studies to assess preservation in wetland archaeological contexts, *Journal of Archaeological Science*, **35**, 1886-1900

Loader, R.D. 2001: Priory Bay, Isle of Wight: a review of current knowledge, *in* Wenban-Smith, F.F. and Hosfield, R.T. (eds) *Palaeolithic archaeology of the Solent River*, London: Lithic Studies Society Occasional Paper no. 7, 71-76

Loader, R.D. 2006: *Isle of Wight Coastal Assessment Enhancement. Project Proposal (Project 4842)*, MAP2 project proposal prepared by the Isle of Wight County Archaeology and Historic Environment Service

Loader, R.D. 2008: *Wootton-Quarr Beach Monitoring. Final report*, unpubl. report for English Heritage

Loader, R.D. 2009: *Isle of Wight Coastal Assessment Enhancement (Project 4842)*, unpubl. report for English Heritage

Loader, R.D. in preparation: *Isle of Wight Coastal Historic Environment Action Plan*

Loader, R.D. and Basford, F.E. 2000: *Isle of Wight Coastal Audit*, unpubl. report for English Heritage

Loader, R. Westmore, I. and Tomalin, D. 1997: *Time and Tide: an archaeological survey of the Wootton-Quarr coast*, Newport, Isle of Wight: Isle of Wight Council

Long, A.J. and Roberts, D.H. 1997: Sea-level change, *in* Fulford, M. Champion, T. and Long, A.(eds), *England's Coastal Heritage: a survey for English Heritage and the RCHME*, London: English Heritage Archaeological Report 15, 25-49

Long, A. J. and Scaife, R.G. forthcoming: Solent sea-level record *in* Tomalin, D.J. Loader. R.D. and Scaife. R.G. (eds) *Coastal archaeology in a dynamic setting: a Solent case study*, Oxford: BAR

Long, A.J. Scaife, R.G. and Tomalin, D.J. forthcoming: Phasing the Holocene shoreline changes of northern Isle of Wight, *in* Tomalin, D.J. Loader. R.D. and Scaife. R.G. (eds) *Coastal archaeology in a dynamic setting: a Solent case study*, Oxford: BAR

Lowe, J. A. Howard, T. P. Pardaens, A. Tinker, J. Holt, J. Wakelin, S. Milne, G. Leake, J. Wolf, J. Horsburgh, K. Reeder, T. Jenkins, G. Ridley, J. Dye, S. Bradley, S. 2009: *UK Climate Projections science report: Marine and coastal projections*. Exeter: Met Office Hadley Centre

Lyell, C. 1830-33: *Principles of geology*, London: John Murray

Lymington River Association 2008: *Information for Appropriate Assessment. Proposed replacement ferries by Wightlink Ltd for the Lymington to Yarmouth route. Summary and technical report. Draft for discussion with Natural England. (*www.lymingtonriver.co.uk/LRA%20AA%20E.pdf*) [accessed 17 April 2009]*

MAFF/Welsh Office 1993: *Strategy for flood and coastal defence in England and Wales*, London: MAFF

MAFF 1995: *Shoreline Management Plans: a guide for coastal defence authorities*, London: MAFF

MAFF 1999: *High Level Targets for flood and coastal defence and elaboration of the Environment Agency's flood defence supervisory duty*, London: MAFF

MAFF 2000: *A review of shoreline management plans, 1996 to 1999*, London: MAFF

MARINET undated a: *Marine aggregate dredging*, (www.marinet.org.uk/mad.html) [accessed 9 September 2008]

MARINET undated b: (www.marinet.org.uk/mad/coastalerosion.html) [accessed 9 September 2008]

Maritime Archaeology Ltd, 2008: *New Forest Rapid Coastal Zone Assessment Survey: Project Proposal*, Southampton: Maritime Archaeology Ltd

Masselink, G. and Hughes, M.G. 2003: *Introduction to coastal processes and geomorphology*, London: Arnold

Matthews, A. 2010: *Lidar – start to finish*. South East Regional Coastal Monitoring Programme, Annual Review 2010, (www.channelcoast.org/southeast/latest/index.php?link=&dla=download&id=116&cat=4/6_LIDAR) [accessed 8 May 2011]

May, V. 2007: Impacts on beach and cliff stability associated with extraction of sediments from beaches and offshore: understanding the communities' responses to perceived risk, *Proceedings of Coastal Zone 07, Portland, Oregon, July 22 to 26, 2007*, (www.csc.noaa.gov/cz/2007/Coastal_Zone_07_Proceedings/PDFs/Monday_Abstracts/3107.May.pdf) [accessed 18 August 2009]

May, V.J. and Heeps, C. 1985: The nature and rates of change on chalk coastlines, *in* Bird, E.C.F. (ed) *Geomorphology of Changing Coastlines*, Zeitschrift für Geomorphologie, Supplementband, **57**, Berlin: Gebrüder Borntraeger, 81–94

Mazik, K. Musk, W.A. Scott, G. and Travers, S. 2005: *Underboulder communities in the Menai Strait and Conwy Bay SAC. The impact of boulder turning for bait collection*. Report by the Institute of Estuarine and Coastal Studies for CCW

McErlean, T. McConkey, R. and Forsythe, W. 2002: *Strangford Lough: an archaeological survey of the maritime landscape*, Belfast: Blackstaff Press & Environment and Heritage Service

MCEU 2008: *Marine Consents and Environment Unit consents for marine works: control of dredging operations*, (www.mceu.gov.uk/MCEU_LOCAL/FEPA/Dredging-controls.htm) [accessed 14 September 2008]

McInnes, R. 2003: *Coastal defence: a non-technical guide*, Isle of Wight: SCOPAC

McInnes, R.G. 2006: *The book of the Isle of Wight coast*, Chale, Isle of Wight: Cross Publishing

McInnes, R.G. Jewell, S. and Roberts, H. 1998: Coastal Management on the Isle of Wight, *The Geographical Journal*, **164(3)**, 291-306

McInnes, R.G. Tomalin, D.J. and Jakeways, J. (eds), 2000: *Coastal change, climate and instability, final technical report*, LIFE report no.97 ENV/UK 00510. Ventnor: Isle of Wight Centre for the Coastal Environment (3 vols)

McNeary, R. And Westley, K. 2010: Airborne lidar, a welcome addition to the maritime archaeologist's toolbox, *NIEA Coast*, **6**, 12-17

McQuade, M. and O'Donnell, L. 2007: Late Mesolithic fish traps from the Liffy estuary, Dublin, Ireland, *Antiquity*, **81**, 569-584

Miller, P. Mills, J. Edwards, S. Bryan, P. Marsh, S. Mitchell, H. and Hobbs, P. 2008: A robust surface matching technique for coastal geohazard assessment and management, *ISPRS Journal of Photogrammetry and Remote Sensing*, **63**, 529-542

Momber, G. 1991: *Gorad Beuno*: investigation of an ancient fish-trap in Caernarfon Bay, N. Wales, *International Journal of Nautical Archaeology*, **20(2)**, 95-109

Momber, G. 2000: Drowned and deserted: a submerged prehistoric landscape in the Solent, England, *International Journal of Nautical Archaeology*, **29(1)**, 86-99

Momber, G. 2004: The inundated landscape of the western Solent, *in* Flemming, N.C. (ed) *Submarine prehistoric archaeology of the North Sea: research priorities and collaboration with industry*, York: Council for British Archaeology, research report 141, 37-42

Momber, G. Satchell, J. And Gillespie, J. 2009: Occupation in a submerged Mesolithic landscape, *in* McCartan, S. Schulting, R. Warren, G. and Woodman, P. (eds), *Mesolithic Horizons. Papers presented at the seventh international conference on the Mesolithic in Europe, Belfast 2005. Volume 1*, Oxford and Oakville: Oxbow Books, 324-330

Momber, G. Tomalin, D. Scaife, R. Satchell, J. and Gillespie, J. (eds), 2011: *Mesolithic occupation at Bouldnor Cliff and the submerged prehistoric landscapes of the Solent*, York: CBA Research Report **164**

Moore, H. 2003: Focal study: Coastal site assessment in Orkney, *in* Dawson, T. (ed), *Coastal archaeology and erosion in Scotland*, Edinburgh: Historic Scotland, 145-153

Moore, L.J. and Griggs, G.B. 2002: Long term cliff retreat and erosion hotspots along the central shores of the Monterey Bay National Marine Sanctuary, *Marine Geology*, **181**, 265-283

Motkin, D.L. 1990: Edwin Smith and his discovery of Roman occupation in Gurnard Bay, 1864 to 1880, *Proceedings of the Isle of Wight Natural History and Archaeology Society*, **10**, 139-147

Motkin, D.L. forthcoming: Erosion and redistribution in the East Shore Zone at Wootton Haven, *in* Tomalin, D.J. Loader. R.D. and Scaife. R.G. (eds), *Coastal archaeology in a dynamic setting: a Solent case study*, Oxford: BAR

Mullin, D. 2005: *Rapid Coastal Zone Assessment for the Severn Estuary: Project design*, Gloucester: Gloucestershire County Council

Munt, M.C. and Burke, A. 1986: The Pleistocene geology and faunas at Newtown, Isle of Wight, *Proceedings of the Isle of Wight Natural History and Archaeological Society* **8(1)**, 7-14

Murphy, P. 2004: Context 215 wood preservation, *in* Heppell, E. *Greater Thames Estuary, Essex Zone. Monitoring survey: Assessment and updated project design*, Issue 2. Essex: Essex County Council/English Heritage, 27-30

Murphy, P. 2007: *Managing change in the coastal zone*. CBA conference 'Adapting Archaeology: foresight for climate change. London, 10th July 2007'. (www.britarch.ac.uk/sites/www.britarch.ac.uk/files/node-files/PP3_Peter_Murphy_English_Heritage.pdf) [accessed 31 July 2007]

Murphy, P. 2009: *The English coast: a history and a prospect*, London: Continuum

Murphy, P. Thackray, D. And Wilson, E. 2009: Coastal heritage and climate change in England: assessing threats and priorities, *Conservation and Management of Archaeological Sites*, **11(1)**, 9-15

Murphy, P. and Trow, S. 2004: Coastal change and the historic environment, *in* Nixon, T. (ed), *Preserving archaeological remains* in situ*?: proceedings of the 2nd conference 12-14 September 2001*, London: Museum of London Archaeology Service, 209-218

Murphy, P. and Trow, S. 2005: Coastal change and the historic environment: building the evidence base, *English Heritage Conservation Bulletin*, **48**, 8-12

Museum of London Archaeology Service, 2009: *England's Historic Seascapes: Withernsea to Skegness pilot study. Revised final report*, London: Museum of London Archaeology Service

National Trust, 2005a: *Shifting Shores: living with a changing coastline*, London: The National Trust

National Trust, 2005b: *The National Trust Coastal Policy*, updated March 2005

Natural England and JNCC, 2010: *Marine Conservation Zone Project: Project delivery guidance on the process to select Marine Conservation Zones*, Natural England and JNCC

Neumann, H. with contributions by M. Bell and A. Woodward, 2000: The intertidal peat survey, *in* Bell, M. Caseldine, A. and Neumann. *Prehistoric intertidal archaeology in the Welsh Severn Estuary*, York: Council for British Archaeology, research report 120, 282-321

Nicholls, R.J. 1987: The evolution of the upper reaches of the Solent River and the formation of Poole and Christchurch Bays, *in* Barber, K.E. (ed) *Wessex and the Isle of Wight: Field Guide*, Cambridge: Quaternary Research Association, 99-114

North Eastern Sea Fisheries Committee, undated: *Intertidal code of conduct*, (www.neseafish.gov.uk/nesfc/publications.html) [accessed 23 May 2008]

Northumberland County Council, 1994: *A strategy for coastal archaeology in Northumberland*, Morpeth: Northumberland County Council

Nyman, J.A. Carloss, M., DeLaune, R.D. Patrick, W.H. Jr, 1994: Erosion rather than plant dieback as the mechanism of marsh loss in an estuarine marsh, *Earth Surface Processes and Land*forms, **19**, 69–84

O'Connor, J. 2012: *Technical Report: Wooton Creek*, Southampton: Channel Coastal Observatory

ODPM, 2005: *Planning Policy Statement 1: Delivering Sustainable Development*, London: TSO

Oliver, R. 1993: *Ordnance Survey Maps: a concise guide for historians*, London: The Charles Close Society

OPSI 2004: *Explanatory memorandum to the Solent European Marine Site (Prohibition of method of dredging) Order 2004. 2004 No.2696* (www.opsi.gov.uk/si/em2004/uksiem_20042696_en.pdf) [accessed 23 May 2008]

Ordnance Survey 2009: *Monitoring the movement of St Catherine's Point Lighthouse using the Ordnance Survey GPS network by Jared L. Ware*, (www.ordnancesurvey.co.uk/oswebsite/gps/osnetfreeservices/about/casestudies/casestudyp4.html) [accessed 12 November 2009]

O'Sullivan, A. 2001: *Foragers, farmers and fishers in a coastal landscape: an intertidal archaeological survey of the Shannon Estuary*, Dublin: Royal Irish Academy, Discovery Programme Monographs 5

O’Sullivan, A. and Breen, C. 2007: *Maritime Ireland: an archaeology of coastal communities*, Stroud, Gloucestershire: Tempus

Oxford Archaeology, 2007: *England’s Historic Seascapes. Marine HLC Pilot Study: Southwold-to-Clacton. Final Project Report*, Oxford: Oxford Archaeology

Palma, P. 2005: Monitoring of shipwreck sites, *International Journal of Nautical Archaeology*, **34(2)**, 323-331

Papworth, H. 2010: Student research profile: laser scanning for coastal archaeology, *Archaeology Special Interest Group Newsletter, autumn 2010*, 6-7

Parfitt, S.A. Barendregt, R.W. Breda, M. Candy, I. Collins, M.J. Russell Coope, G. Durbidge, P. Field, M.H. Lee, J.R. Lister, A.M. Mutch, R. Penkman, K.E.H. Preece, R.C. Rose, J. Stringer, C.B. Symmons, R. Whittaker, J.E. Wymer, J.J. and Stuart, A.J. 2005: The earliest record of human activity in Northern Europe, *Nature*, **438**, 1008-1012

Parkes, C. 1999: *Fowey Estuary Historic Audit*, Truro: Cornwall Archaeological Unit

Pee, N. Satchell, J. Merritt, O. Earl, G. Sturt, F. and Dix, J. 2007: *England's Historic Seascapes: Solent and Isle of Wight and adjacent Marine Zone Pilot Area. Technical Report*, Southampton: HWTMA/Bournemouth University/ Southampton University

Pontee, N.I. 2004: Saltmarsh loss and maintenance dredging in estuaries, *Maritime Engineering*, **57**, Issue MA2, 71-82

Poole, H.F. 1929: Stone axes found in the Isle of Wight, part 1, *Proceedings of the Isle of Wight Natural History and Archaeological Society*, **1**, 652-658

Poole, H.F. 1936: An outline of the Mesolithic flint cultures of the Isle of Wight, *Proceedings of the Isle of Wight Natural History and Archaeological Society*, **2**, 551-581

Poole, H.F. 1940: Report on pottery from the Rosecliff midden, *Proceedings of the Isle of Wight Natural History and Archaeological Society*, **3**, 237-8

Poole, H.F. undated: Series of manuscript notebooks held by the Isle of Wight Historic Environment Record

Poole, H.F. and Dunning, G.C. 1937: Twelfth-century middens in the Isle of Wight, *Proceedings of the Isle of Wight Natural History and Archaeological Society*, **2**, 671-695

Poole Harbour Steering Group, undated: *Important information for bait diggers in Poole Harbour*, (www.pooleharbouraqmp.co.uk/pdf/bait_digging.pdf) [accessed 15 September 2011]

Posford Duvivier, 1994: *Wootton Creek, Fishbourne (Isle of Wight): coastal study*, Report to Medina Borough Council

Poulton, C.V.L. Lee, J.R. Hobbs, P.R.N. Jones, L. And Hall, M. 2006: Preliminary investigation into monitoring coastal erosion using laser scanning: case study at Happisburgh, Norfolk, *Bulletin of the Geological Society of Norfolk*, **56**, 45-64

Poulton, R.W. 1909: An account of discoveries of Palaeolithic Implements in the Isle of Wight, *in* Morey, F. (ed), *A guide to the natural history of the Isle of Wight*, Newport: Isle of Wight County Press, 37-41

Preece, R.C. 1980: The biostratigraphy and dating of a postglacial slope deposit at Gore Cliff near Blackgang, Isle of Wight, *Journal of Archaeological Science*, **7**, 255-265

Preece, R.C. 1986: Faunal remains from radiocarbon-dated soils within landslip debris from The Undercliff, Isle of Wight, *Journal of Archaeological Science*, **13**, 189-200

Preece, R.C. 1987: Biostratigraphy and environmental archaeology of a post-glacial slope deposit on Gore Cliff, Isle of Wight, in Barber, K.E. (ed), *Wessex and the Isle of Wight: Field Guide*, Cambridge, Quaternary Research Association ASSOCIATION, 150-155

Preece, R.C. and Scourse, J.D. 1987: Pleistocene sea-level history in the Bembridge area of the Isle of Wight, *in* Barber, K.E. (ed), *Wessex and the Isle of Wight: Field Guide*, Cambridge, Quaternary Research Association, 136-149

Preece, R.C. Scourse, J.D. Houghton, S.D. Knudsen, K.L. and Penney, D.N. 1990: The Pleistocene sea-level and neotectonic history of the eastern Solent, Southern England, *Philosophical Transactions of the Royal Society of London*, **B328**, 425-477

Rainbird, P. 2007: *The Archaeology of islands*, Cambridge: Cambridge University Press

Ramsar Convention on Wetlands, 2002: Resolution VIII.4 Principles and guidelines on incorporating wetland issues into Integrated Coastal Zone

Management (ICZM), (www.ramsar.org/res/key_res_viii_04_e.htm) [accessed 9 May 2008]

Ransley, J. Blue, L. Dix, J. and Sturt, F. (eds) forthcoming: *Future Studies in Maritime Archaeology: England's Maritime and Marine Historic Environment Resource Assessment and Research Agenda*

Ratcliffe, J. 1989: *The archaeology of Scilly: an assessment of the resource and recommendations for its future*. Truro: Cornwall Archaeological Unit

Ratcliffe, J. 1997: *Fal Estuary Historic Audit*, Truro: Cornwall County Council

Ratcliffe, J. and Straker, V. 1996: *The early environment of Scilly: palaeoenvironmental assessment of cliff-face and intertidal deposits, 1989-1993*, Truro: Cornwall Archaeological Unit

Reader, F.W. 1911: A Neolithic floor in the bed of the Crouch River, and other discoveries near Rayleight, Essex, *Essex Naturalist*, **16**, 249-66

Reid, C. 1902: The geology of the country around Ringwood, *Memoir of the British Geological Survey, Sheet 314*. London: HMSO

Reid, C. 1905: The island of Ictis [the Isle of Wight, and the ancient trade with Britain for tin], *Archaeologia* **59(2)**, 281-288

Reid, C. 1913: *Submerged Forests*, Cambridge: Cambridge University Press

Reid, C. 1915: The ancient rivers of Bournemouth, *Proceedings of the Bournemouth Natural Science Society*, **7**, 73-82

Reynolds, A. 2000: *Helford Estuary Historic Audit*, Truro: Cornwall Archaeological Unit

Riall, N. forthcoming: *A medieval roof tile kiln at Quarr Abbey, Isle of Wight*

Richardson, L. 2009: *About the project*, (www.thamesdiscovery.org/about/about-the-project) [accessed 22 June 2011]

Robert West and Partners, 1989: *Wootton Creek, Isle of Wight: preliminary re-appraisal of erosion problems*, Report to Medina Borough Council

Robert West and Partners, 1990: *Wootton Creek, Fishbourne, Isle of Wight: evaluation of ferry-induced erosion*, Report to Medina Borough Council

Robert West and Partners, 1993: *Wootton Creek, Fishbourne, Isle of Wight: coast protection effects of dredging works in connection with ferry operations* Report to Medina Borough Council

Roberts, P. and Trow, S. 2002: *Taking to the Water: English Heritage's initial policy for the management of maritime archaeology in England*, London: English Heritage

Robertson, D. Crawley, P. Barker, A. and Whitmore, S. 2005: *Norfolk Rapid Coastal Zone Archaeological Survey. Assessment report and updated project design. Part 1: assessment report* Norfolk Archaeological Unit Report no.1045

Rosser, N.J. Petley, D.N. Lim, M. Dunning, S.A. and Allison, R.J. 2005: Terrestrial laser scanning for monitoring the process of hard rock coastal cliff erosion, *Quarterly Journal of Engineering Geology and Hydrogeology*, **38**, 363-375

Royal Haskoning, 2007: *River Tyne to Flamborough Head Shoreline Management Plan 2. Appendix C: Baseline Process Understanding* (www.northeastsmp2.org.uk/pdf/final_SMP2/appendices/appendix-C-Baseline-Process-Understanding.pdf) *[accessed 25 April 2011]*

Rule, M.H. 1983: *The Mary Rose: The Excavation and Raising of Henry VIII's Flagship,* Second Edition, London: Conway Maritime Press

Samson, F.R. 1976: *Priory Bay: a study of an unstratified Palaeolithic site in the Isle of Wight*, Unpubl. Undergrad. Dissertation, University of Southampton

Saunders, A. 1998: *Fortifications of Portsmouth and the Solent: a review of pre-20th century coastal defence sites and associated remains,* London: English Heritage

Saye, S.E. van der Wal, D. Pye, K. amd Blott, S.J. 2005: Beach-dune morphological relationships and erosion/accretion: an investigation at five sites in England and Wales using LIDAR data, *Geomorphology*, **72**, 128-155

Scaife, R.G. 1987: The Late-Devensian and Flandrian vegetation of the Isle of Wight, *in* Barber, K E (ed), *Wessex and the Isle of Wight: Field Guide*, Cambridge: Quaternary Research Association, 156-180

Scaife, R.G. 2000: Palaeo-environmental investigations of submerged sediment archives in the West Solent study area at Bouldnor and Yarmouth, *in* McInnes, R.G. Tomalin, D.J. and Jakeways, J. (eds), *Coastal change, climate and instability, final technical report*. *Volume 2:*

Palaeoenvironmental Study Areas, LIFE report no.97 ENV/UK 00510. Ventnor: Isle of Wight Centre for the Coastal Environment,

Scaife, R.G. unpublished: The old brickworks, Werrar: pollen analysis and the vegetation environment of H.F. Poole's site, Unpublished report in IWHER

SCAPE Trust, not dated a: *Coastal Surveys* (www.scapetrust.org/html/surveys.html) [accessed 14 July 2007]

SCAPE Trust, not dated b: *Shorewatch: recording the eroding archaeology of Scotland's coasts* (www.shorewatch.co.uk/index.htm) [accessed 9 May 2008]

Schwenninger, J. Rhodes, E.J. Bates, M.R. Briant, R.M. and Wenban-Smith, F.F. 2006: *Optically stimulated luminescence (OSL) dating of Quaternary deposits from the Sussex/Hampshire coastal corridor*, Portsmouth: English Heritage Research Department Report Series 20/2006

SCOPAC, 2003a: *Sediment transport study: north east Isle of Wight (East Cowes to Culver Cliff)*, (www.scopac.org.uk/scopac_sedimentdb/neiow/neiow.htm#intro) [accessed 22 May 2008]

SCOPAC, 2003b: *Sediment transport study: west and south Isle of Wight, (www.scopac.org.uk/scopac_sedimentdb/sow1/sow1.htm#intro) [accessed 2 April 2012]*

SCOPAC, 2003c: *Sediment transport study: north west Isle of Wight*, (www.scopac.org.uk/scopac_sedimentdb/nwiow/nwiow.htm#f3) [accessed 4 September 2011]

SeaZone, 2009: *Characterising our historic seascapes*, (www.seazone.com/uploads/refzone-SZ-Seascapes%20Project%20sheet.pdf) [accessed 12 June 2011]

Sewell, J. and Hiscock, K. 2005: *Effects of fishing within UK European marine sites: guidance for nature conservation agencies*, Report to the Countryside Council for Wales, English Nature and Scottish Natural Heritage from the Marine Biological Association. Plymouth: Marine Biological Association

Shell, C. 2005: The Loughcrew Landscape Project, *Past*, **51**, 1-3

Shennan, I. And Horton, B. 2002: Holocene land- and sea-level changes in Great Britain, *Journal of Quaternary Science*, **17**, 511-526

Sherwin, G.A. unpubl: *Archaeological survey of the Isle of Wight*, manuscript held by the Society of Antiquaries, London; copy in Isle of Wight Historic Environment Record

Sherwin, G.A. 1939: Belgic hut in the Isle of Wight, *Antiquaries Journal*, **19**, 445-446

Shore, T.W. and Elwes, J.W. 1889: The New Dock excavations at Southampton, *Proceedings of the Hampshire Field Club and Archaeological Society*, **1**, 43-56

Sidell. J. and Haughey, F. 2007: *Neolithic Archaeology in the intertidal zone*, Neolithic Studies Group Seminar Papers 8, Oxford: Oxbow Books

Simons, R. and Hollingham, S. 2001: *Marine aggregate dredging: a review of current procedures for assessing coastal processes and impact at the coastline*, Technical Report no. HYD10401. London: Civil and Environmental Engineering Department, University College London

Simpson, P. 1994: *The natural preservation of wooden stakes on the foreshore at Quarr*, Unpubl. MA thesis, University of Durham

Simpson, P. forthcoming, a: The natural preservation of wooden posts on the foreshore at Quarr, *in* Tomalin, D.J. Loader, R.D. and Scaife, R.G. (eds), Coastal *archaeology in a dynamic setting: a Solent case study*, Oxford: BAR

Simpson, P. forthcoming, b: The erosion of alignment Q11 at Quarr, *in* Tomalin, D.J. Loader, R.D. and Scaife, R.G. (eds), *Coastal archaeology in a dynamic setting: a Solent case study*, Oxford: BAR

Simpson, P. and Edmunds, R. 2009: *Project design: practical reburial and environmental monitoring of archaeological timbers: a case study*. English Heritage Project no. 5497

Smith, J.R. and Murray, S.N. 2005: The effects of experimental bait collection and trampling on a *Mytilus californianus* mussel bed in southern California, *Marine Biology*, **147**, 699-706

Smith, J. and Porter, S. 2003: *Fowey Estuary Management Plan*, (www.foweyharbour.co.uk/fep/pdf/femp.pdf) [accessed 1October 2007]

Solent European Marine Site (SEMS), undated: *The bait collectors' code*

Solent Protection Society, 2008: *Summary of Royal Lymington Yacht Club presentation* (www.solentprotection.org/articles/24-summary-of-royal-lymington-yacht-club-presentation) [accessed 17 April 2009]

Spurrell, F.C.J. 1889: On the estuary of the Thames and its alluvium, *Proceedings of the Geologist's Association of London,* **11**, 210-230

Strachan, D, 1995: Problems and potentials of coastal reconnaissance in Essex, *Aerial Archaeology Research Group News*, **10**, 28-35

Strachan, D. 1998: Inter-tidal stationary fishing structures in Essex: some C14 dates, *Essex Archaeology and History*, **29**, 274-282

Tapper, B. 2008: *England's Historic Seascapes, Historic Seascape Characterisation: National HSC Method Statement,* Truro: Historic Environment Service, Cornwall County Council

Tatton-Brown, T. 1980: The use of Quarr Stone in London and East Kent, *Medieval Archaeology*, **24**, 213-215

The Crown Estate, 2004a: *Marine aggregates*, (www.thecrownestate.co.uk/our_portfolio/marine/marine_aggregates.htm) [accessed 31 August 2008]

The Crown Estate, 2004b: *Our portfolio: Marine*, (www.thecrownestate.co.uk/marine) [accessed 6 May 2009]

The Georgian Group, 2010: *Nash building threatened on the Isle of Wight*, (savinggeorgianbuildings.blogspot.com/2010/01/this-startling-image-of-cowes-on-isle.html) [accessed 15 September 2011]

Thieler, E.R. and Danforth, W.W. 1994a: Historical shoreline mapping (I): Improving techniques and reducing positioning errors, *Journal of Coastal Research*, **10(3)**, 549-563

Thieler, E.R. and Danforth, W.W. 1994b: Historical shoreline mapping (II): Application of the Digital Shoreline Mapping and Analysis Systems (DSMS/DSAS) to shoreline change mapping in Puerto Rico, *Journal of Coastal Research*, **10(3)**, 600-620

Tolan-Smith, C. 2008: *North East Rapid Coastal Zone Assessment (NERCZA)*, Gateshead: Archaeological Research Services Ltd Report 2008/81

Tomalin, D. 1990: An early Roman cliff-top salt-working site at Redcliff Battery, Sandown, Isle of Wight, *Proceedings of the Isle of Wight Natural History and Archaeological Society*, **9**, 91-12

Tomalin, D.J. (ed) 1995: *Wootton Haven: an assessment and updated project design for the Wootton-Quarr intertidal survey*, Unpubl. Report, Isle of Wight County Archaeological Unit

Tomalin, D. 1997: Bargaining with nature: considering the sustainability of archaeological sites in the dynamic environment of the intertidal zone, *in* Corfield, M. Hinton, P. Nixon, T. and Pollard, M. (eds). *Preserving Archaeological Remains* in situ, Museum of London/University of Bradford, 144-158

Tomalin, D. 2000a: Geomorphological evolution of the Solent seaway and the severance of Wight: a review, *in* Collins, M. and Ansell, K. *Solent Science: a review*, Elsevier, 9-19

Tomalin, D.J. 2000b: An introduction to archaeological and palaeo-environmental studies and their application to the study of coastal change, *in* McInnes, R.G. Tomalin, D.J. and Jakeways, J. (eds), *Coastal change, climate and instability, final technical report*. *Volume 1,* LIFE report no.97 ENV/UK 00510. Ventnor: Isle of Wight Centre for the Coastal Environment

Tomalin, D.J. 2000c: Discussion and evaluation: archaeology (palaeo-environmental evidence) and coastal change, *in* McInnes, R.G. Tomalin, D.J. and Jakeways, J. (eds), *Coastal change, climate and instability, final technical report*. *Volume 1,* LIFE report no.97 ENV/UK 00510. Ventnor: Isle of Wight Centre for the Coastal Environment

Tomalin, D.J. 2001: The Solent in prehistory, *in* Drummond, M. and McInnes, R. (eds), *The Book of the Solent*, Chale, Isle of Wight: Cross Publishing, 13-32

Tomalin, D. 2011: The assemblage of lithic artefacts from the Mesolithic occupation features on the sea floor at Bouldnor Cliff, *in* Momber, G. Tomalin, D. Scaife, R. Satchell, J. and Gillespie, J. (eds), *Mesolithic occupation at Bouldnor Cliff and the submerged prehistoric landscapes of the Solent*, York: CBA Research Report **164**, 139-154

Tomalin, D.J. forthcoming: The threatened archaeological resource: research aims, *in* Tomalin, D.J. Loader, R.D. and Scaife, R.G. (eds), *Coastal archaeology in a dynamic setting: a Solent case study*, Oxford: BAR

Tomalin, D.J. Loader, R.D. and Scaife, R.G. (eds), forthcoming: *Coastal archaeology in a dynamic setting: a Solent case study*, Oxford: BAR

Tomalin, D.J. Simpson, P. Bingeman, J.M. 2000: Excavation versus sustainability *in situ*: A conclusion on 25 years of archaeological investigations at Goose Rock, a designated historic wreck-site at the

Needles, Isle of Wight, England *International Journal of Nautical Archaeology*, **29(1)**, 3-42

Truscoe, K. 2008: Appendix 4: Severn Estuary RCZAS lidar review, *in* Crowther, S. and Dickson, A. *Severn Estuary Rapid Coastal Zone Assessment Survey: National Mapping Programme*, Gloucester: Gloucestershire County Council, English Heritage, Somerset County Council

Tubbs, C. 1999: *The ecology, conservation and history of the Solent*, Chichester: Packard Publishing Ltd

Turner, R. Allen, J.L.R. and Rippon, S. 2000: The Severn Estuary Levels: ten years past and ten years forward, *in* Rippon, S. (ed), *Estuarine Archaeology: the Severn and beyond*. Archaeology in the Severn Estuary 11, Severn Estuary Levels Research Committee, 1-12

Tyson, H.J. Fulford, M.G. and Crutchley, S. 1997: Survey and recording in the intertidal zone, *in* Fulford, M. Champion, T. and Long, A. (eds), *England's Coastal Heritage: a survey for English Heritage and the RCHME*, London: English Heritage Archaeological Report 15, 74-102

UK Climate Projections, 2009a: *UK Climate Projections. Key findings: South East England, 2080s*, (ukclimateprojections.Defra.gov.uk/content/view/2266/528) [accessed 30 July 2009]

UK Climate Projections 2009b: *UK Climate Projections. Key Findings: Sea level rise*, (ukclimateprojections.Defra.gov.uk/content/view/2145/680/) [accessed 30 July 2009]

UK Climate Projections 2009c: *UK Climate Projections* (ukclimateprojections.Defra.gov.uk/) [accessed 30 July 2009]

UK Marine SACs Project, 2001: *Ships wash*, (www.ukmarinesac.org.uk/activities/ports/ph3_2_1.htm) [accessed 23 September 2008]

UNESCO, 2001: *Convention on the Protection of the Underwater Cultural Heritage*, Paris: UNESCO

United Nations, 1992: Agenda 21 (www.un.org/esa/sustdev/documents/agenda21/english/agenda21toc.htm) [accessed 8 May 2008]

United States Congress, 1972: Coastal Zone Management Act (www.coastalmanagement.noaa.gov/about/media/CZMA_10_11_06.pdf) [accessed 9 May 2008]

Van de Noort, R. and Davies, P. 1993: *Wetland Heritage: an archaeological assessment of the Humber Wetlands*, Kingston upon Hull: Humber Wetlands Project

Van de Noort, R. And Ellis, S. 2000: The Humber Estuary: managing the archaeological resource in a dynamic environment, *in* Pye, K. and Allen, J.R.L. (eds), *Coastal and estuarine environments: sedimentology, geomorphology and geoarchaeology*, London: Geological Society of London Special Publications, **175**, 419-427

Velegrakis, A.F. Dix, J.K. and Collins, M.B. 1999: Late Quaternary evolution of the upper reaches of the Solent River, Southern England, based upon marine geophysical evidence, *Journal of the Geological Society, London*, **156**, 73-87

Walkden, M. and Dickson, M. 2008: Equilibrium erosion of soft rock shores with a shallow or absent beach under increased sea-level rise, *Marine Geology*, **251**, 75-84

Waller, M.P. and Long, A.J. 2003: Holocene coastal evolution and sea-level change on the southern coast of England: a review, *Journal of Quaternary Science*, **18**, 351-359

Warren, S.H. 1900: Palaeolithic implements of the Isle of Wight, *Geological Magazine* Decade 4, **9**, 406-412

Warren, S.H. 1911: On the correlation of the prehistoric ‘floor’ at Hullbridge with similar beds elsewhere, *Essex Naturalist*, **16**, 265-282

Warren, S.H. 1912: The classification of the prehistoric remains of East Essex, *Journal of the Royal Anthropological Institute*, **42**, 91-127

Warren, S.H. 1919: The dating of surface flint implements and the evidence of the submerged peat surface, *Proceedings of the Prehistoric Society of East Anglia*, **3(1)**, 94-104

Warren, S.H. Piggott, S. Clark, J.G.D. Burkitt, M.C. Godwin, H. and Godwin, M.E. 1936: Archaeology of the submerged land-surface of the Essex Coast, *Proceedings of the Prehistoric Society*, **2(2)**, 178-210

Waughman, M. 2005: *Archaeology and environment of submerged landscapes in Hartlepool Bay, England*, Hartlepool: Tees Archaeology Monograph Series volume 2

Wenban-Smith, F.F. 2003: *Priory Bay Lower Palaeolithic Site, Isle of Wight: Field Evaluation, final report*, Unpubl. report for English Heritage

Wenban-Smith, F.F. Bates, M.R. Bridgeland, D.R. Marshall, G.D. and Schwenninger, J-L. 2009: The Pleistocene sequence at Priory Bay, Isle of Wight (SZ 635 900), *in* Briant, R.M. Bates, M.R. Hosfield, R.T, and Wenban-Smith, F.F. (eds), *The Quaternary of the Solent Basin and West Sussex Raised Beaches Field Guide*, London, Quaternary Research Association, 123-137

Wenban-Smith, F.F. and Loader, R.D. 2007: *The Isle of Wight: a review of the Lower and Middle Palaeolithic resource* (http://thehumanjourney.net/pdf_store/sthames/IoW%20Paleo.pdf) [accessed 2 April 2012]

Wenban-Smith, F.F. Schwenninger, J-L. and Scaife, R. 2005: New OSL dates and pollen records from the Bembridge Raised Beach sequence, Isle of Wight (UK), *Quaternary Newsletter* **107**, 1–19

Wessex Archaeology, 1999: *Shoreline Management Plans and the Historic Environment: final report of a strategic study for English Heritage*, Salisbury: Wessex Archaeology

Wessex Archaeology, 2000: *Historic environment of the North Kent Coast. Rapid coastal zone assessment survey. Survey Phase 1: Final report*, Salisbury: Wessex Archaeology Ref: 46561

Wessex Archaeology, 2002: *North Kent Coast: Rapid coastal zone assessment survey, Phase II: preliminary field investigation*, Salisbury: Wessex Archaeology Ref: 46564.01

Wessex Archaeology, 2003: *Marine Aggregate Dredging and the Historic Environment: assessing, evaluating, mitigating and monitoring the archaeological effects of marine aggregate dredging. Guidance Note*, London and Salisbury: BMAPA, English Heritage and Wessex Archaeology

Wessex Archaeology, 2004a: *North Kent Coast: Rapid coastal zone assessment survey, Phase II: field assessment pilot*, Salisbury: Wessex Archaeology Ref: 46564.02

Wessex Archaeology, 2004b: *Historic Environment of the Dorset Coast: Rapid Coastal Zone Survey. Survey phase 1: Project Report (draft)*. Ref: 51958.05. Salisbury: Wessex Archaeology

Wessex Archaeology, 2004c: *Dorset Coast: Historic Environment Research Framework (draft)*. Ref: 51958.06. Salisbury: Wessex Archaeology

Wessex Archaeology, 2004d: *Coastal Protection at the Duver, Isle of Wight: Archaeological Assessment and Survey*, Salisbury: Wessex Archaeology Report Ref. 52668.01

Wessex Archaeology, 2005a: *North Kent Coast: Rapid coastal zone assessment survey, Phase II: field assessment year one report*, Salisbury: Wessex Archaeology Ref: 56750.02

Wessex Archaeology, 2005b: *England's Historic Seascapes: historic environment characterisation in England's intertidal and marine zones. Proposal for pilot project*, Salisbury: Wessex Archaeology

Wessex Archaeology, 2005c: England's Historic Seascapes: Liverpool Bay pilot area, (www.wessexarch.co.uk/projects/marine/eh/seascapes/pilot_area.html) [accessed 3 September 2007]

Wessex Archaeology, 2005d: *Protocol for reporting finds of archaeological interest: full text*, London and Salisbury: BMAPA, English Heritage and Wessex Archaeology

Wessex Archaeology, 2006: *North Kent Coast Rapid Coastal Zone Assessment Survey. Phase II: Field Assessment Year Two. Final Report*, Salisbury: Wessex Archaeology, Ref: 56751.01

Wessex Archaeology, 2008: *ALSF Artefacts from the Sea*, (www.wessexarch.co.uk/projects/marine/alsf/artefacts_sea) [accessed 5 September 2011]

Wessex Archaeology, 2010: *New Forest Rapid Coastal Zone Assessment Survey. Phase 1: main report*, Salisbury: Wessex Archaeology, Ref: 72200.02

Wessex Archaeology, 2011a: *Rapid Coastal Zone Assessment Survey of South East England*, (www.wessexarch.co.uk/projects/marine/rczas/south-east) [accessed 22 June 2011]

Wessex Archaeology, 2011b: *New Forest Rapid Coastal Zone Assessment Survey. Phase 1: field assessment*, Salisbury: Wessex Archaeology, Ref: 72201.01

West, I.M. 2008: *The Geology of the Isle of Wight: Select Bibliography*. (www.soton.ac.uk/~imw/iow.htm) [accessed 27 December 2009]

Westmore, I. Basford, F. And Tomalin, D, forthcoming: An assessment of the evidence of the early sources and shipment of Bembridge limestone building stone on the Wootton-Quarr coast of the Isle of Wight, *in* Tomalin, D.J. Loader, R.D. and Scaife, R.G. (eds), *Coastal archaeology in a dynamic setting: a Solent case study*, Oxford: BAR

White, H.J.O. 1921: *A short account of the Geology of the Isle of Wight*, Memoirs of the Geological Survey of England and Wales. London: HMSO

Wightlink, undated: *Environmental Impact*, (www.wightlink.co.uk/new-ships/environmental-impact.aspx) [accessed 17 April 2009]

Wilkinson, T.J. and Murphy, P.L 1995: *The archaeology of the Essex coast: Volume 1 the Hullbridge survey*, Chelmsford: Essex County Council, East Anglian Archaeology 71

Wilkinson, T.J. and Murphy, P.L. forthcoming: *The archaeology of the Essex Coast: Volume 2: the Stumble*

Williams, J. And Brown, N. 1999: *An archaeological research framework for the Greater Thames Estuary*, Chelmsford: Essex County Council, Kent County Council and English Heritage

Wilson, G. 2003: Assessment survey: Shetland, *in* Dawson, T. (ed), *Coastal archaeology and erosion in Scotland*, Edinburgh: Historic Scotland, 99-106

Winterbotham, Brig. H.St.J.L. 1934: *The National Plans*, Ordnance Survey Professional Papers, New Series, no.16. London: HMSO

Wright, P. 1982: *Aspects of the coastal dynamics of Poole and Christchurch Bays*, PhD thesis, Univ Southampton

Wymer, J. 1999: *The Lower Palaeolithic Occupation of Britain*, Salisbury: Wessex Archaeology and English Heritage (2 vols)

Wynberg, R.P. and Branch, G.M. 1997: Trampling associated with bait-collection for sandprawns callianassa kraussi stebbing: effects on the biota of an intertidal sandflat, *Environmental Conservation*, **24**, 139-148

Yarmouth Coastal Defence Working Group, 2010: *Adapting to coastal flooding in the Yarmouth area in the 21st century*, (www.visionwebsites.co.uk/Uploads/Site157/Files/YCDWGfinalreport2010incmaps.pdf) [accessed 8 September 2011