FIFTEEN YEARS OF STRATEGIC COASTAL AND SHORELINE MANAGEMENT – EXPERIENCES FROM COMMISSIONS IN THE UK AND CARIBBEAN

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Abstract

Commenced in 1988, the Anglian Sea Defence Management Study was one of the earliest strategic coastal management commissions carried out in the UK. It covered the eastern coastline and intervening estuaries of England between Flamborough Head to the north and the mouth of the Thames estuary to the south, in all more than 400 miles of open coast. Though then in their infancy, it recognised the potential of GIS as a means of bringing together available data sets and provided a means by which spatial variation might be identified and interpreted. Regardless of any system shortcomings, it was the quality and duration of key baseline data sets that determined whether the study's objectives could be realised.

Extensive field survey and numeric modelling studies were undertaken to define the region's character in terms of its wave climate, tidal currents, sediment transport, geology, land use, ecology, infrastructure and shoreline morphology.

The importance of building upon these data sets and having the tools that enable the data to be checked and analysed was recognised in the study. Properly planned and funded regionally focused data collection programmes were established and database systems such as SANDS were spawned. New and increasingly powerful software/GIS made possible tasks of spatial transformation and correlation which had in the past been too complex to analyse quantitatively. These now provide extra insight into coastal change. On the recently completed Futurecoast project, historic maps have been analysed in this way.

Whilst the data sets generated through traditional survey continue to provide the backbone for strategic coastal and shoreline commissions in the UK, as the paper will illustrate, new data collection techniques are being introduced. These include:

LiDAR has been a particularly important new technique. Introduced to the authors on the Barbados Coastal Conservation Programme Phase 1 commission in 1997, the clear Atlantic waters offered ideal conditions for collecting nearshore bathymetric data (up to 40m depth), creating an ideal starting point to the hydrodynamic modelling work that was planned. Since that time in the UK the system has been extensively deployed, primarily by the Environment Agency, to provide them and their consultants with a baseline

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characterisation of the landmass upon which most studies which look into flood risk can now be based.

Other forms of remote sensing continue to offer the potential for adoption but until recently data resolution and cost have precluded their widespread use – from the UK perspective these therefore have continued to be considered as more of an academic tool.

In conjunction with condition surveys of sea defences and coast protection works for the entire coastline of England, which also involved the authors, they and their colleagues have also been involved in helping establish the size of the UK Government's obligation to maintain, enhance or where appropriate retreat from those measures that presently protect the shoreline. The recently completed National Assessment of Defence Needs and Costs for Flood and Coastal Erosion Management commission and related Foresight study builds upon previous high level studies that the Department for the Environment, Fisheries and Rural Affairs (Defra) has instructed, and a range of data sets that it and other national bodies have commissioned. The scope, methodologies and data deficiencies encountered will be explored in the paper, and suggestions as to how such assessments are likely to be improved in the future will be given.

1 Introduction

The Anglian Sea Defence Management Study, which was undertaken between1988 and 1991 marked a significant change in the approach to shoreline management within the UK (Halcrow & National Rivers Authority, 1991). For the first time a truly holistic method was developed to support a regionally strategic approach to the management of 1,200 km of shoreline and tidal estuaries that run between the Humber and Thames estuaries on the East Coast of England.

The prior history of the provision of flood and coastal (erosion) protection along the coast had been once of piecemeal reactive response to localised problems. By the late 1980's this approach was being recognised as untenable. Responding to major region-wide coastal flooding in 1953, new and replacement flood defence provision was typified by hard engineering solutions. Often built without regard to prevailing geomorphic process or wave climate these aging defences were suspected as being partly responsible for exacerbating erosion loss and flood risk. The underpinning principles of the 1988 – 1991 study were to build an understanding of the physical processes operating along the coast (the geomorphic response to prevailing wave and tidal conditions), to set this within the context of existing land use and to develop policy options for long term future coastal flood risk and shoreline management. This approach

- Helped identify appropriate modes of defence provision (hard / soft engineering solutions) in terms of economic value and technical viability
- Took account of future needs arising from climate change
- Provided opportunities for the enhancement of landscape, amenity and conservation

- Helped establish closer links between responsible coastal authorities and organisations, often with conflicting aims and responsibilities, encouraging them to work towards an integrated coastal management approach

At its time the study was unique within the UK and Europe, in terms of its scale and approach. It employed concepts that are now typically recognised as fundamental to the development of Integrated Coastal Management Plans (ICMP) and the measure of its success was that it served as the blue-print for the many regional Shoreline Management Plans that were rolled out throughout the whole of England and Wales from the early 1990's onwards. (Burgess and Purnell, 2005)

The Anglian study approach was underpinned by the diagnosis of active physical process though thematic survey, the use of time-series meteorological, wave and current data, the development of hydrodynamic and sediment transport models and spatial correlation of these using Geographical Information Systems (GIS). It was also responsible for bringing together and rationalising existing monitoring practices, helping establish a coordinated and well founded routine shoreline monitoring programme covering the entire Anglian coastline, this to enable detection of changes in the shoreline character brought about through the enactment of recommended policy. Ongoing monitoring was seen as central to the whole management process by closing the feedback loop in what was termed the "Responsive Management Framework".

The survey of reliable data, its management and renewal through routine monitoring is at the core of this "responsive" approach. In subsequent studies undertaken since 1998 Halcrow has built on this framework. This paper considers some of the approaches to the gathering and use of shoreline data and the technologies used to interpret and manage it within the context of shoreline and coastal management studies. It also illustrates how the development of nationally consistent data sets has enabled the development of consistent methodologies for the assessment of national approaches to risk assessment and investment planning.

2 ICMP Case Study Barbados

Illustrative of the fit between the need to develop an understanding of complex process and the reconciliation of varied thematic data within single analytical environment is the use of GIS and Halcrow's Shoreline And Nearshore Data System (SANDS) within the Barbados Coast Conservation Programme. This three-year multi-disciplinary study was commissioned by the Government of Barbados in 1996. Its aim was the preparation of an Integrated Coastal Management Plan for the Atlantic east coast and the development of the legal and institutional framework to support its implementation.

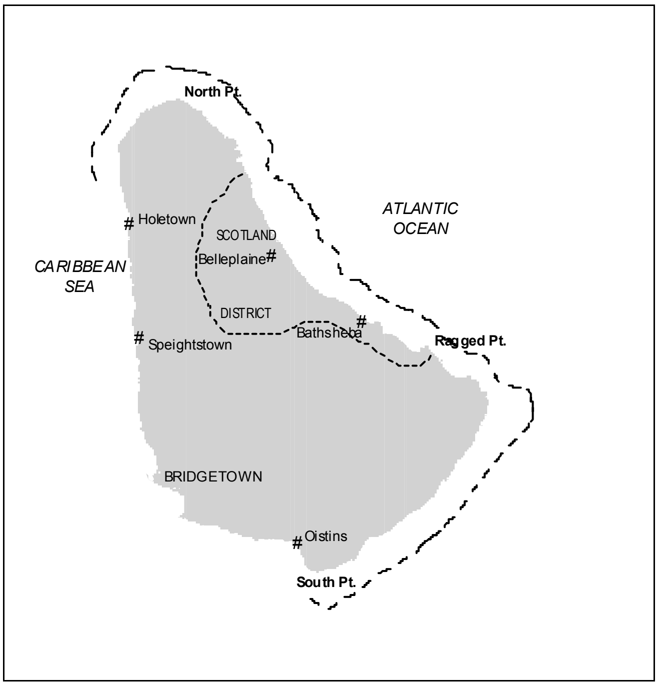

Figure 1 Illustrative extent of the Atlantic Coast Management Plan

The marine environment within the study area, which covered approximately 60 km of coast with an offshore boundary set at the 100m bathymetric contour, was something of an unknown prior to the study. Onland, the socio-economic and terrestrial environments similarly required understanding. Thus the first step in the preparation of the ICMP was to undertake a number of diagnostic studies to gain a fuller knowledge of the interactions between these environments. A number of survey techniques were employed, including the flying of airborne LiDAR to map nearshore bathymetry, the use of radar for surface current monitoring and acoustic survey of offshore bathymetry and seabed type.

The following summarises the data that were collected (Barter, Gubbay and Brewster, 1999).

- Mapping and description of all onshore geology – assisted by 1:5,000 colour aerial photography and the expansion of the field mapping built up over many years by visiting US geology experts.

- Mapping and characterisation of land use – derived from aerial photography classification and ground-truthed through filed survey.

- Mapping and description of terrestrial flora – the land use analysis was used by a locally based expert as the backdrop to his own detailed flora mapping.

- Assessment and description of all engineering structures – with the assistance of the aerial photography and field inspection, all engineering structures were identified and their condition was assessed.

- Socio-economic surveys to establish the characteristics of coastal communities – local survey teams were deployed within a number of coastal communities.

- Telephone surveys – these took place at quarterly intervals over a yearly period and were used to identify and assess the importance of the coastal environment to Barbadians.

- Offshore geophysical and bathymetric survey and interpretation – a field campaign informed by and overlapping with the LIDAR survey. The survey was able to extend the bathymetry out to the 200m isobath. Side-scan and boomer deployments provided information on the nature of the seabed out to 100m depth.

- Sediment sampling and analysis – over 600 samples were recovered for sediment trends and carbonate analysis. In conjunction with other modelling work sediment movements were determined.

- Acoustic Bottom Classification (ABC) – in conjunction with the sediment sampling programme, the ABC provided further information about the likely nature of the seabed.

- Marine and terrestrial water sampling and analysis – samples of groundwater, on-land surface water and marine water were taken at intervals over a period of 10 months.

- Marine habitat mapping and description – the LIDAR provided an initial reference upon which the subsequent diver surveys were based. Later comparison with the findings of the geophysical and ABC surveys allowed for final refinement.

- Oceanographic and meteorological data collection and analysis – a range of available data supplemented by new field collected data provided the basis for a range of modelling work. A short term Ocean Surface Current Radar (OSCR) campaign involving deployments at three different sites provided useful insight into the complex flows around the coast.

- Beach profile data collection and analysis – through a programme instigated in 1983, the island now has an extensive data set upon which to draw. Of the 75 beaches currently surveyed, 21 of them fell within the area of this study. Using SANDS provided under the project, the data available was reviewed and analysed.

- Public consultation and issues analysis – various forms of consultation took place. Key officers within government were consulted. In order to get reaction from the wider public, churches, schools, newspapers, radio and television were used.

Large and diverse datasets were generated through the diagnostic studies, and the survey work to support them accounted for the majority of the project's budgetof around US$ 3.6 million. This represents a huge investment in data. The protection of that investment by ensuring ongoing use and future accessibility of the data was a key concern of the study. Too often costly data and information management systems fall redundant following one-off studies such as those described above. This can occur for a number of reasons (Deakin, Home and Polley, 1999), including

- Physical loss of the data
- Lack of user knowledge of data management systems
- Lack of staff resources to operate data management systems
- Lack of knowledge of the structure, source and fitness for purpose of the data itself

To protect against such risks a combination of extensive client system user training, detailed metadata provision and customised system implementation were undertaken for the Government recipient organisation, the Coastal Zone Management Unit (CZMU). The two key systems handed on to them were a SANDS database and ArcView based GIS database. These have continued to support the coastal management activities of the CZMU as well as being available to subsequent phases of the Barbados Coastal Conservation Programme.

3 Looking back to find a way forward

Uniformity and reliability of data though time are key facets to ensuring its ongoing usefulness and value. We have seen this through the use of SANDS within the context of the Barbados Coastal Conservation Programme, in the shoreline monitoring programme that followed the Anglian Sea Defence Management Study, and more recently in the South-East Coast's regional monitoring programme (Bradbury, Mason and Barter, 2005). Other illustrations of this can be seen through the ability of historic mapping and charting to support investigations into long term geomorphic behaviour in shoreline systems.

Bin, Reeve and Thurston (1999) detail the approach to mapping recurrent morphological variations and stability in offshore banks in the shallow seas off the east coast of England. This work stems from work undertaken during the Anglian Sea Defence Management Study. This has subsequently been taken forward through ensuing Shoreline Management Plans and by specific studies into the suitability of sites for offshore wind farms.

The availability of historic Admiralty charts recording bathymetry at a wide range of dates between 1846 and 1992, enabled the development of a method that compares temporal variation in depth between epochs against mean values, so identifying degrees of relative dynamism and stability within the sandbank systems (the lower the standard deviation the greater the stability in form through time)(Figure 2).

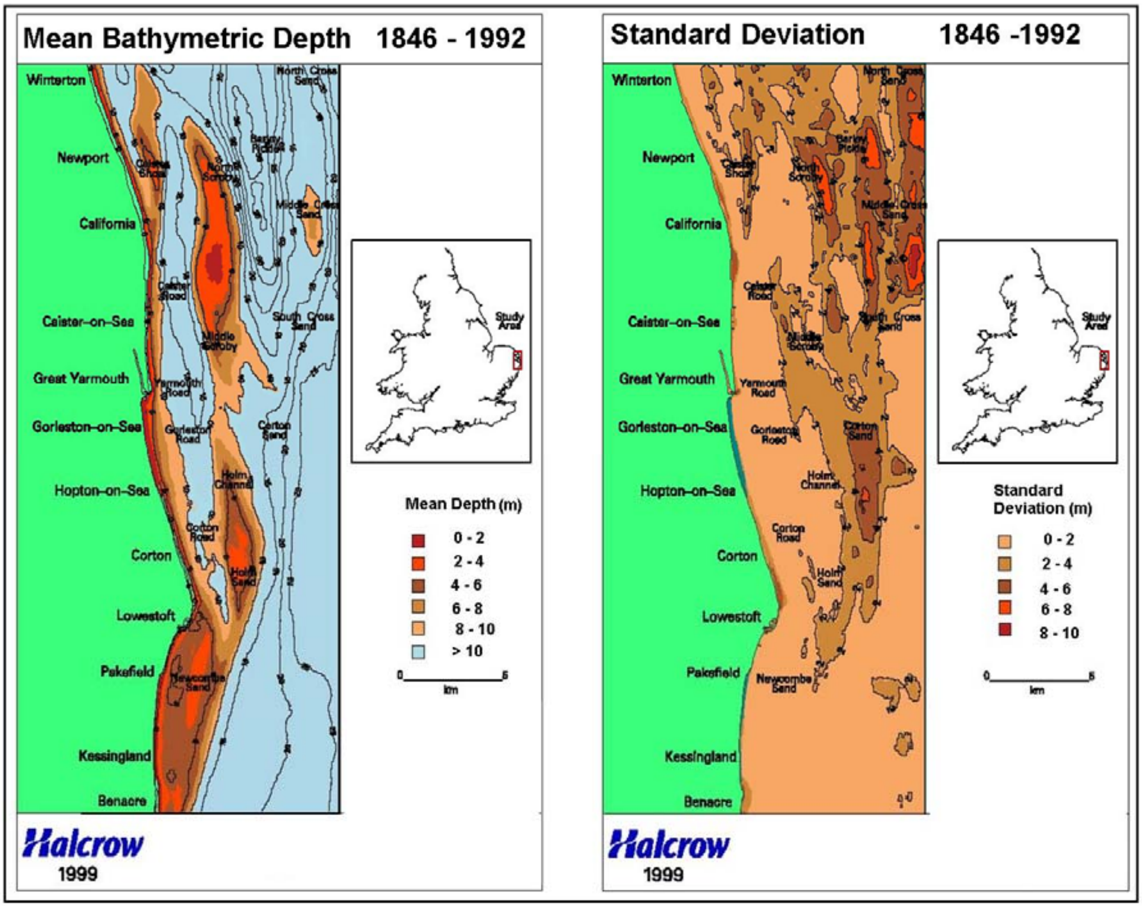

Figure 2 Mean and variation in sandbank depth through time

This method is wholly reliant on the use of GIS to perform chart transformations to a common projection and datum, and the use of surface models within the GIS to analyse changing depth through time. It is also reliant on the consistent definition and understanding of the chart projections used at different dates.

A similar reliance on the use of historic survey data can also be seen in work undertaken by Halcrow to support the Futurecoast study (Defra, 2002). Building on approaches originally developed on the Anglian Sea Defence Management Study, with the benefit of significantly advanced GIS processing, it has mapped long term geomorphic shoreline behaviour throughout England and Wales. The availability of Ordnance Survey topographic mapping at a scale of approximately 1:10,000 for periods from the 1850's and the ability of GIS, once again, to transform these to a common projection has enabled a method to be developed that tracks the movement of high and low water marks, back of beach and cliff line along fixed profiles taken along the coast.

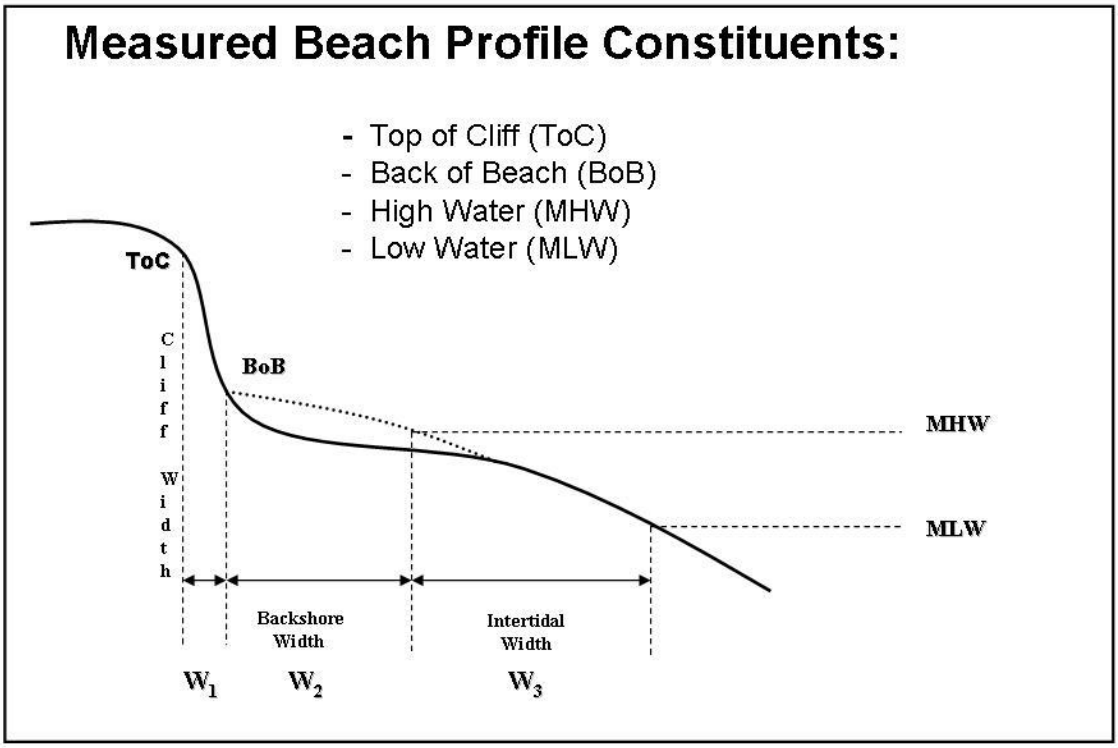

Figure 3 Measured components of beach plan profiles

Measurement of relative change in width of shoreline through time has allowed the classification of the beach into flattening / steeping and narrowing / widening categories. Additionally, rates of erosion or accretion have been established.

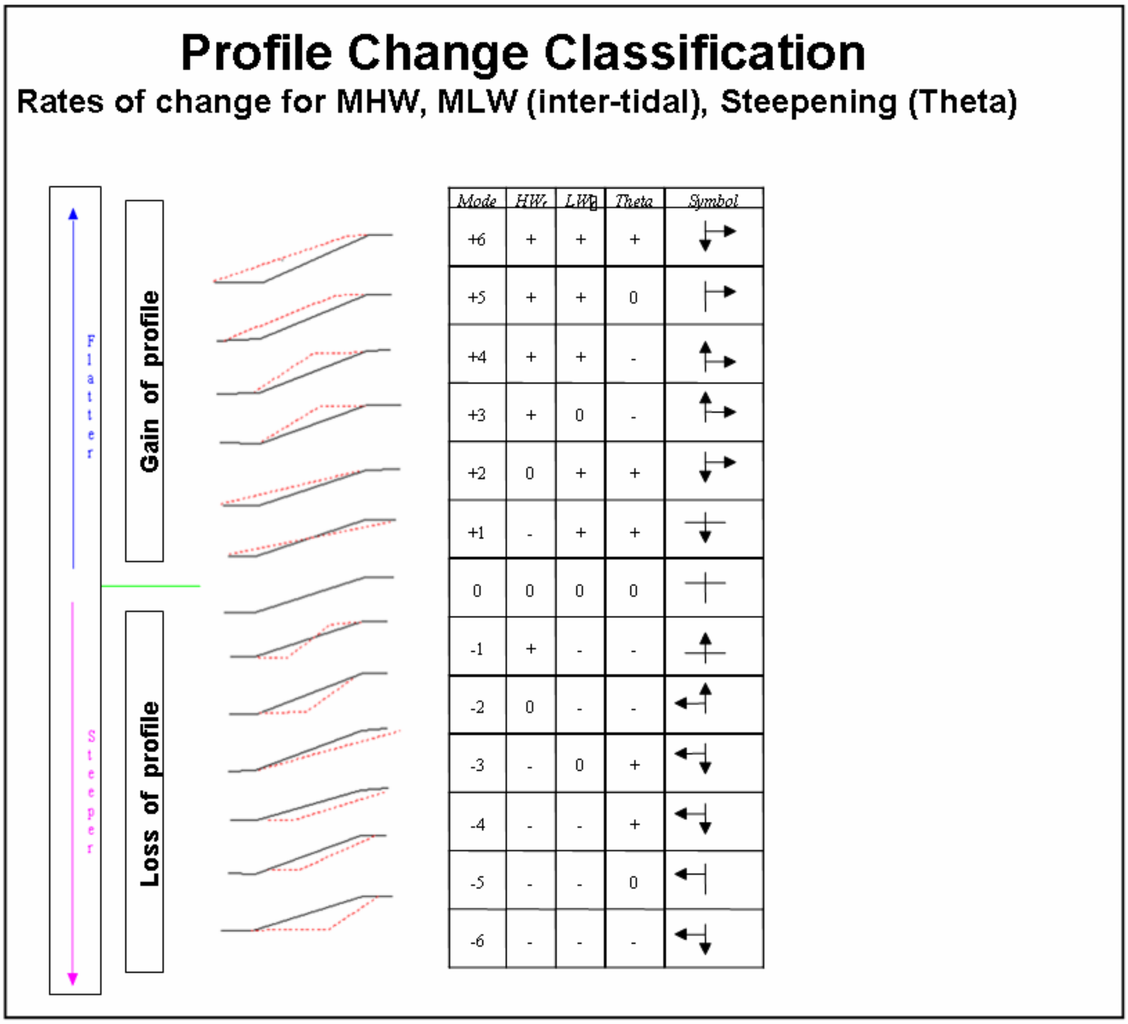

Figure 4 Beach profiles classification

4 Emerging Techniques

The detection of shoreline change (erosion, accretion, steeping, flattening) is a common concern of coastal managers. Traditional profile surveys stored in and analysed with database systems such as SANDS provide an efficient means through which such change can be assessed. New technology is however offering opportunity for more expansive analyses of surface change. This is being enabled by the application of remote survey techniques such as laser scanning (airborne or terrestrial) to generate 3-D surface models in a relatively rapid period of time.

Rixon, Mocke and Hamer (2003) discuss the deployment of terrestrial laser scanning for beach survey and its combination with nearshore, shallow water multi-beam swathe bathymetry. This has enabled the generation continuous surface models across shoreline and nearshore environments. These in turn are acting as new baseline topographies for two major long term shoreline monitoring projects being undertaken by Halcrow.

The advantages that these forms of survey offer over traditional profile surveys is that, if tied in to correct GPS control, problems frequently associated with maintaining consistent profile origins and orientations are removed. Using surface modelling techniques profiles, if required, can be dynamically generated at any time after the survey has taken place. Estimations of volume changes in beach materials can be much more effectively achieved, and it is also possible to integrate the surface models with other thematic data, such as material types, habitat classifications or even just aerial photography for visualisation purposes.

5 National Data and Policy Planning

We have illustrated the importance of consistency in data capture and recording by reference to tracking morphological change in the shoreline environment. Additionally, over the last decade within the UK there has been mushrooming of the availability and use of nationally consistent digital data sets. The UK Government, through the Environment Agency and Defra, has sought to employ such national data sets to develop consistent methods of national risk assessment relating to flooding and coastal erosion.

In 1999 Halcrow, the Flood Hazard Research Centre of Middlesex University and HR Wallingford were asked by Defra to jointly consider the development and application of a method that would enable assessment of the economic risk to the nation from flooding and erosion. In the two studies that followed, the National Appraisal of Assets at Risk from Flooding and Coastal Erosion (Defra, 2001) Halcrow was responsible for generating national data sets of land use, property type and economic damage. This was only made possible due to the recent availability of common digital data sets produced by Ordnance Survey and Defra (covering the entire coastline of England and Wales) in combination with national datasets of flood defence provision and coastal protection that Halcrow had developed over the preceding decade (through the National Sea Defence Survey and Coast Protection Survey of England).

Further development of consistent flood defence datasets by the Environment Agency within their National Flood and Coastal Defence Database (NFCDD) has since enabled the development of more sophisticated flood risk assessment methodologies (Hall *et al*, 2003). This builds on the availability of consistent economic, property, environment loading and flood defence structure information. Calculated risk is expressed as an annual average economic damage derived from the probability of flooding occurring.

The consistent baseline data and methods developed through these studies have enabled the assessment of economic damages at a national scale. These “risks” measured in monetary terms have then been set against the budgets available for defence provision. This in turn has allowed evaluations of the benefit / cost associated with national budgets for flood and coast protection provision. These assessments have helped to guide Government decisions on the level of funding needed from the Treasury Department, and has resulted in significant increases nationally from levels of around £220 million in 1999 to around £360 million in 2004.

The consistency in the method applied at a national scale has also allowed for the development of "what if" scenarios, where the variables modified can include the investment in and standard of defences, the number and value of assets at risk and the return period frequency of flood events or variation in the rates of erosion. These last two factors have been the focus for significant research into the potential effects of climate change under a range possible combined economic development and carbon emission "futures".

Figure 5 The four Foresight future economic development scenarios

This work has been sponsored by the UK Government through the Foresight project into Future Flooding (Office of Science and Technology, 2004). The results of this work are now being used to formulate long term policy responses to the impacts of climate change within the UK, and are also being used to lobby for policy changes in carbon emissions reduction in the global community.

6 Conclusion

The recognition of spatial patterns within, and interactions between, physical and socio-economic processes in the shoreline and coastal environment is vital to establishing our understanding of the coastal zone, and our ability to manage it effectively. This understanding must also include that of temporal changes operating over a range of scales.

The development of data storage and analysis technologies allied to the fields of geographical information systems and remote sensing analysis are demonstrably well suited to the tasks of data assimilation, analysis and dissemination that support this. They provide the ability to correlate diverse thematic data to common spatial and temporal reference frameworks.

The range of survey techniques that can be employed is as equally diverse as the phenomena that we have to account for in our management of the shoreline. The regimes of routine monitoring that we employ to assist in change detection are of key importance, both to the detection of change and in informing us of the effectiveness of the management policies that we adopt. The quality of the data that we use is therefore directly correlated to the quality of the management decisions that we make. Adequate investment in data gathering and management is therefore vital.

In some circumstances we have demonstrated that it is possible to look back to the recent historic record to enable us to detect patterns of change. We have also seen that as supporting technologies have developed through time so has the availability of consistently modelled spatial data. Within the UK the development of such national data set has enabled the iterative development of flood and coastal erosion risk assessment methodologies that are now being employed by central Government agencies to support medium term national funding decisions, and also to develop future risk and investment scenarios that account for a range of policy responses and socio-economic and climatic conditions.

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