DEVELOPMENTS IN COASTAL ENGINEERING MANAGEMENT IN THE UNITED KINGDOM

by

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1.0 Introduction

During the recent past considerable attention has been focused globally on the need to support Coastal Development Programmes and a fair proportion of investment has been made by government authorities and international agencies for this purpose.

The coastal zone is an area of high activity with respect to economic, urban and maritime development as well as leisure time pursuits. It also contains many important features of nature conservation ranging from unique geological features such as coastal cliffs to ecological systems such as salt marshes, dune systems, estuaries and inter-tidal areas which are sanctuaries for marine communities and wildlife. It is not surprising therefore, that engineering proposals relating to development projects are in conflict with the conservation of the natural environmental system.

2.0 Present Scenario

A large proportion of the coastal and sea defences in the United Kingdom have not been built to modern standards and their maintenance, repair and replacement now pose a serious problem. Even structures built following the floods in 1953 are in some cases nearing the end of their design life. The impact of the rise in sea level has added another dimension to the overall problem, with greater areas of land at risk from natural erosive processes. The significance of these environmental changes for existing and future sea defences will be dependent on the location. It is evident that coastal structures would be subjected to further pressure from environmental loads. Failure to provide adequate coastal and flood defences will result in the loss of life, property and land.

The United Kingdom is faced with severe coastline problems in several regions. The coastline is of the order of 4200 km of which approximately 23% is protected by hard edge solutions and 12% by soft edge solutions. Approximately 65% of the coast is not defended or in a natural state.

Significant areas of valuable agricultural land, urban communities and industrial establishments have been protected against the highest storm surges experienced since the catastrophic tidal flooding of 1953 in East Anglia which resulted in the death of 300 inhabitants and caused considerable damage to flood defences and agricultural land. In addition to many areas which have been heavily developed by residential, commercial and industrial zones, 720,000 ha of Grades I and III land lie below 5m and this includes some of the best agricultural land (Fig. 1). The most extensive coastal lowland in the United Kingdom is the Finland of East Anglia and most of this is Grade I agricultural land which is already well below +5 m and therefore at risk.

It is difficult to identify with accuracy the current capital value of the existing coastal and flood defences, but it is probably in excess of £ 4000 M. The estimated current expenditure on repair and replacement in order to maintain the present level of protection is in the order of £ 150M per year. Coastal and flood protection is expensive and construction costs for sea walls are in the order of £ 5M per km.

3.0 Responsibilities and the Administration of Flood Defence and Coast Protection Schemes

Coastal and flood defences in England and Wales are governed by the main Acts of Parliament, the Coast Protection Act 1949 and the Land Drainage Act 1976. In general the latter is applied to low areas liable to flooding and the defence works are referred to as sea defences. The Coast Protection Act relates to protection against erosion. The Ministry of Agriculture, Food and Fisheries (MAFF) is responsible for administering the Acts in England and the Secretary of State for Wales is responsible for the same in Wales. In Scotland, the Secretary of State for Scotland has similar responsibilities in administering the Coast Protection Act 1949, Land Drainage (Scotland) Act 1958, the Flood Prevention (Scotland) Act 1961. In Northern Ireland, the Secretary of State for Northern Ireland is responsible for administering the Drainage Order 1973. Reference is made to Table 1 which summarises the principal administrative structure.

Responsibilities for the actual flood defences in the coastal zone fall to the various Regional Divisions of the National Rivers Authority (NRA) which have taken over the flood defence role from the former water authorities.

Coastal defences, defined as coastal protection under the Coast Protection Act, are the responsibility of local authorities such as District Councils. There are 88 of these Coast Protection Authorities in England. If the equivalent authorities in Wales, Scotland and Northern Ireland are considered together with the established ports then the total number of authorities concerned with the coast is of the order of 240.

4.0 The Need to Adopt a Strategic Approach

The coastline is a highly sensitive and complex interface between the land and the sea. It responds in a most significant manner to any environmental change, either natural or man made. The dynamic behaviour of the coastline is dependent on both local and regional conditions. The origins of a particular problem at a given location may well be traced to the introduction of works further away from the problem area. The time scale of events which take place along the coast line varies widely from a period of a few days to decades.

The study of the coastline requires a sound understanding of the changes in the coastal regime. This demands a detailed examination both at local and regional scale, of the natural processes involved and the historical effects of man's intervention on the shoreline. A fair proportion of problems have been attributed to ill-conceived schemes in neighbouring stretches of coast.

Environmental factors such as wind, waves, tides and surges as well as sea and land level changes do not recognize administrative boundaries. The lack of coordination between different authorities responsible for coastal and flood defences has in the past resulted in the implementation of local schemes which did not take into consideration their potential impact on adjacent areas. Consequently the protection of one area has resulted in erosion in a neighbouring region. Although every effort is taken at present to avoid this type of impact, it may still be unavoidable when works are carried out as a matter of emergency, which is frequently the case.

These observations identify the need to adopt a strategic approach for a given coastal region. Coastal Management is characterized by its integral nature arising principally because of the close inter-relationships between land use, coastal protection and overall management control. The potential physical interaction between adjoining coastal regions and the need to make use of various disciplines and techniques reinforce the adoption of an integral approach.

Coastal Management Planning commences with the identification of the need. Once a proper understanding of the coastal regime is made, the next stage may be the planning of an appropriate investment scheme. However, prior to that it may become necessary to undertake a field monitoring programme, for example, to estimate sediment movement and change of profile. An appreciation of the coastal sediment budget plays a vital role in any coastal engineering project. This requires extensive collection and analysis of data. When considering large coastal schemes the manipulation of data can become very complex. In such circumstances it may become necessary to adopt, for the long term benefit of the client and for efficient management, an appropriate Geographical Information System (GIS). This type of information system will permit coastal responses to be assessed continuously and will be of immense benefit to all planners working in that coastal zone.

5.0 Impact of Sea Level Changes in Coastal Regions

In adopting a strategic approach towards Coastal Zone Management Planning, due attention has to be focused on the impact of sea level rise in the coastal regions. The two main areas of interest are to identify the impact of sea level rise on the existing coastline and on coastal structures.

Globally sea levels have been increasing by 0.1 m to 0.15 m per century since 1870 and it is, therefore necessary to understand the effects which a rise in sea level would produce.

It was identified that a large proportion of the flood defences have reached the end of their useful life and need major refurbishing or rebuilding. In planning the rehabilitation of these structures it is important to identify the impact of possible rise in sea levels of the order of 0.2 m by the year 2030 and 0.65 m by 2100, an average of 60 mm per decade, with a range of 30-100 mm.

On the assumption that a significant rise in sea level will take place it is important to assess the influence of climate change on the frequency and severity of storms. Increased water levels and more severe wave attack will result in overtopping and damage to coastal and flood defences.

Structures designed for existing conditions will require replacement or refurbishment as overtopping becomes increasingly more probable. Groynes will need to be raised and extended landwards together with revetments. Sand dunes will likewise come under increased attack. A probabilistic design approach will have to be adopted giving due consideration to the predicted loss or damage in each locality.

The uncertainties associated in the prediction of future rise in sea level as well as its impact on the environment focuses attention on the need to adopt a flexible approach in current design practice by making provision for the increase in the height of defences over the life of the structure. Currently, a relative sea level rise of 0.3 m per century is taken into account in designing sea defences.

The greatest impact of rise in sea level would be on soft coasts protected by coastal and flood defences. As the sea rises, erosive processes would become dominant and there would be considerable losses, especially of fine sediments. This will result in steeper slopes and the sea walls would have to withstand increased erosion.

Failure to provide adequate coastal and flood defences, will result in the loss of life, property and land, not only in areas of low grade marginal land but also in areas of high environmental value such as the wetlands of the Severn and Thames Estuaries and the peripheral land around the Wash. A considerable area will be at risk from rising salt levels and destruction of the freshwater habitat.

6.0 Response by the Government and Other Institutions

Major storms which occurred during the 1989/90 winter and growing fears over the effects of sea level rise due to global warming have led to the development of a coordinated response from the Government of the United Kingdom on coastal and flood defence works.

As a first step the National Rivers Authority (NRA) launched a national survey to identify assets controlled by them and those controlled by the local authorities or under private ownership. This survey is identified principally as a base line survey for future development work. Information gathered will be used to identify priorities and to formulate strategies such as rehabilitation and overall development of old defence works and the construction of barrages. Five civil engineering consulting firms assisted the NRA in this survey.

On behalf of the Institution of Civil Engineers and the Maritime Engineering Board, the Coastal Engineering Research Advisory Committee (CERAC) initiated a major study, including the development of an extensive database for efficient coastal zone management. Further surveys by using detailed questionnaires have also been carried out to assess damage in the wake of the February 1990 storm and other associated damage.

Local authorities have formed regional coastal groups and are making efforts to collect, collate and disseminate local information and collaborate in the study of problems of mutual interest. The unfavourable effects of local schemes which have been implemented without taking into account the potential impact on adjacent areas were identified earlier. Hence a coordinated approach will contribute towards well organised coast defence management programmes in which local schemes are based on regional strategic plans. This will enable the best disposition of the extra funds required to take account of the anticipated effects of sea level rise due to climatic change on existing defences and to identify priority areas of land which require protection. Figure 1 also illustrates the areas covered by the different Coastal Study Groups which have been formed.

Sir William Halcrow & Partners have recently completed the first stage of a comprehensive sea defence management study for Anglian Water (now the National Rivers Authority). This study illustrates a typical application of a Computational Database and a Geographical Information System (GIS) to produce a Coastal Management System.

Anglian Water are responsible for an extensive length of sea defences on the east coast of England (Figures 2 and 3). Many of these are now nearing the end of their design life and are progressively being replaced. The situation is complicated because many of the beaches on this shore are falling or receding. In order to ensure that the programme of works are effectively planned the Anglian Sea Defence Management Study was initiated to gain a regional understanding of the causes of foreshore erosion. To assess this problem and thereby develop a suitable management policy, a large number and a variety of variables were considered for the different coastal units which were identified along the shoreline (Figure 4 and Table 2). The inter-relationships among such a range of variables are clearly complex.

The philosophy adopted for the study was to try to make maximum use of existing data sources as well as those obtained from investigations specially commissioned for this programme by gathering them together into a unified format which would permit rapid manipulation and analysis. This was achieved by setting up a Geographical Information System (GIS) incorporating a database with enquiry facilities designed to meet the projects analytical needs. The system was developed so that information could be easily stored, retrieved, updated and rapidly reviewed. In doing so the full resolution and completeness of the original information was preserved. This project led to the development of the Anglian Coastal Management Atlas, the first of its kind in the United Kingdom. It serves as a very useful set of maps for overall management control. Figure 5 illustrates the map from this atlas which refers to the tidal flood areas.

The National Rivers Authority (NRA) is at present reviewing coastal and esturial research and development work related to Flood Defence. It has been identified that their research and development programme needs to be structured towards improving the efficiency and effectiveness of the NRA in undertaking its flood defence duties, and to ensuring that the planning, construction and management of coastal defences is undertaken in a manner which is both cost-effective and takes into account conservation interests. The Department of the Environment is also initiating a study on planning policy for the coast and earth science information in support of coastal planning and management.

7.0 Current Issues

In preserving the coastline every effort should be made to utilize natural sea defences and preserve the coastline in its natural environment. This will demand close monitoring and maintenance. For example, the profiles of natural storm barriers are subjected to considerable change during storm attack and maintenance is of vital importance. This identifies the need to have a clear understanding of the sediment budget for the different coastal units of the regional or local data base. Figure 6 is a typical illustration of the various elements of the sediment budget.

Recent advances in coastal hydrodynamics and coastal structures have enabled the maritime engineer to obtain a clear understanding of coastal processes, propagation of waves into shallow waters and the mechanics of wave-structure interaction. Developments in numerical modelling of nearshore regions and the results from extensive field studies have led to the implementation of innovative schemes moving away, where possible from the traditional hard solution of sea walls, or revetments. The recent introduction of several offshore breakwaters, as well as fish tail groynes are examples of this type of development. Introduction of works away from the problem area, on some occasions have proved to be very effective in providing the optimum solution. Figure 7 illustrates the layout of offshore breakwaters in Leasowe Bay and its impact on beach levels. Figure 8 represents a typical output from a mathematical model study on wave-structure interaction in the vicinity of a offshore breakwater.

Coastal structures must be carefully designed to ensure that the design objectives are achieved while maintaining a high hydraulic efficiency in the long term at reduced maintenance costs. Hard defence systems of any kind have the potential of contributing to their own failure. The high magnitude of reflection of the seaward face generates turbulence leading to erosion of beach material, thus undermining its stability. Most environments in which coastal works are located are subject to changes and it is very necessary to understand the implications of these changes in the design process.

Some typical cross sections of sea walls observed around the United Kingdom are illustrated in Figures 9a to 9f. It is evident that certain areas require site specific solutions and Fig. 9a illustrates a structure used for cliff stabilisation along the coastline.

The implementation of coastal protection schemes can have a substantial impact upon the environment of the area to be protected and its consequences need to be properly addressed. It is important to ensure that they have least impact in generating an environmental imbalance. Issues of conservation of sites of scientific interest and the environmental impact of coastal works are now considered major issues. Beach pollution resulting from outfalls and the risks to the thousands of holiday makers who bathe in the polluted coastal waters have been highlighted in relation to EEC regulations. Some of the relevant aspects of the quality of beaches in the south east are illustrated in Figure 10. The need for an environmentally sensitive approach to all work concerned with the coast is now established.

Agencies which fund coastal development programmes are increasingly expressing concern about the investment of limited resources on coastal management and on the overall scheme worthiness. The overall benefit to society from investing in coast protection and management should identify the scale of any proposed scheme. Considering the fact that investments in coastal management schemes are often high it is necessary to ensure that proposed development schemes will achieve their design objectives as well as the anticipated long-term benefit to society. Table 3 illustrates a benefit-cost appraisal balance sheet for a typical coastal project.

The cost of flood and coastal protection is expensive and current construction costs for seawalls are in the order of £5M/km. The Anglian region alone has identified the need to spend £ 130M in the next decade. The NRA is scheduled to spend around £ 90M in defending the shores by mid 1990 against a background of £ 500M £ 8000M worth of engineering work required to maintain the present level of marine flood protection.

It is evident that funding is not available to replace all structures which have been subjected to extensive deterioration. Hence priority should be given to the upgrading of existing old structures and to ensure that these structures are not undermined by falling beach levels and erosion (Refer Fig. 9f). This demands planned refurbishment of existing coastal works. In doing so attention should be focused not only to improve their structural stability but also their hydraulic performance. Increased levels of wave energy dissipation over a longer period will generate a very favourable impact on the environment and the resulting long term effects would be most beneficial. Figure 11 illustrates results from a study relating to the upgrading of a vertical sea wall. It is evident that by adopting appropriate protection measures the hydraulic performance, on this occasion estimated by reflection coefficients of the structure, could be greatly improved.

8.0 Concluding Remarks

This paper has reviewed recent developments in Coastal Engineering Management in the United Kingdom. It has also identified important issues which have to be considered in overall Coastal Zone Management Planning.

There is an overwhelming need to ensure coordination of the numerous councils, authorities and groups having responsibility for flood and coastal protection. This coordination must lead to the implementation of national strategies for overall Coastal Zone Management Planning. Such coordination would no doubt contribute to the reduction of adverse effects so evident at present resulting from numerous authorities working independently along the coastline. A national policy on research and development as well as to determine appropriate protection methods along the coastline should be adopted at the earliest. There is a strong need to establish a coherent coastal zone legislation that satisfies most needs of the community while giving due consideration to the preservation of the heritage of the coastline and protection of the environment.

It is evident that there will be land areas where protection is neither vital nor economically justified. For the purpose of grant aid, the governmental authorities cannot justify protecting ordinary agricultural land due to its low value and this identifies the need to adopt a strategy for zoning land on a priority basis. In doing so due attention should be focused on the state of existing protective measures and this will necessarily require the study of various options, including raising the existing sea walls, building new sea walls further inland and building storm surge barriers. Uncertainties in the possible future rise in sea level has identified the importance of adopting a flexible approach in the design of coastal structures. Provision should be made available to increase the height of the defences if required.

One of the advantages of zoning land is that attention could be focused on vulnerable areas thereby adopting appropriate management policies. For example, land below +5 m OD already at risk from storm surges and high tides should be identified as areas which should not be developed for industrial, residential or strategic purposes. All development plans must consider these risks and ensure that the risk is neither extended nor intensified by land use changes resulting from proposed projects.

The intangible benefits of amenity, recreation and the preservation of the environment must be given due consideration in the cost benefit studies relating to flood and coastal defence projects. Considerable difficulties have been experienced in justifying protection schemes in the face of the downturn in agricultural output values. It is accepted that funding of defence structures which is provided partly by the Ministry (MAFF) and partly through levies on councils is a heavy burden on local residents. There is a strong need to recognise flood and coastal protection as a national problem and hence the provision of central funding to ease disparities especially between regions.

It is apparent that there is a strong need for the establishment of a central body to coordinate research and development activities. Such a body could produce, for example, a national plan for the continuing collection of wave data in areas sensitive to flooding or erosion, identify appropriate protection methods and liaise between different institutions to ensure that available funds are utilised effectively. Research activities should be oriented towards understanding the natural processes along both the coastline and estuaries. Developing and using solutions which are in accordance with natural processes should be given high priority, thus attempting to minimize the impact on the environment and on the heritage.

9.0 Acknowledgements

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Ove Arup & Partners, London. Chris Fleming, Director, Sir William Halcrow & Partners, Swindon.

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Further Reading

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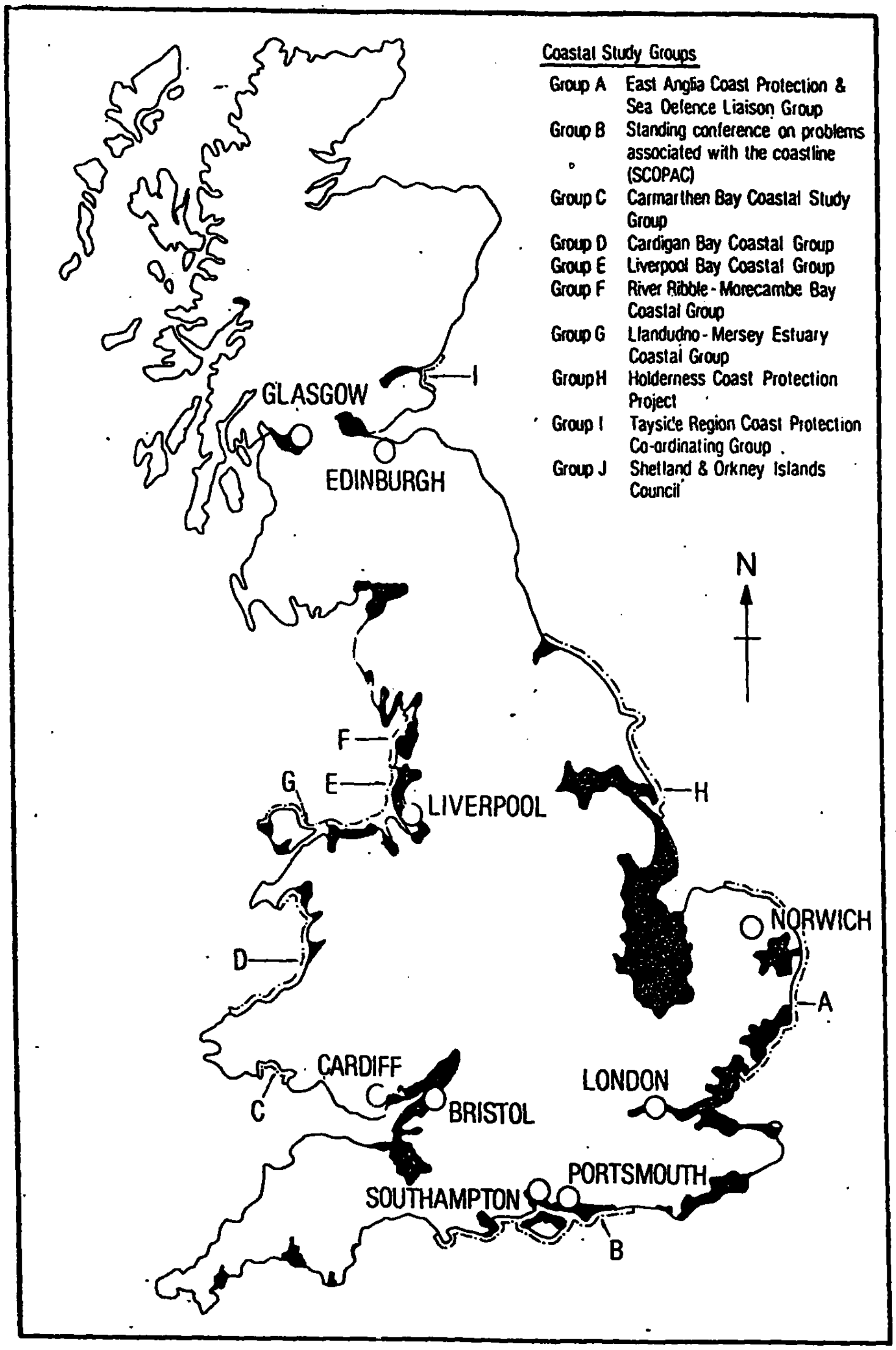


Fig.1 Areas below 5m Ordnance Datum already in need of protection from storm surges and sea level rise (from MAFF information). (Ref.1)

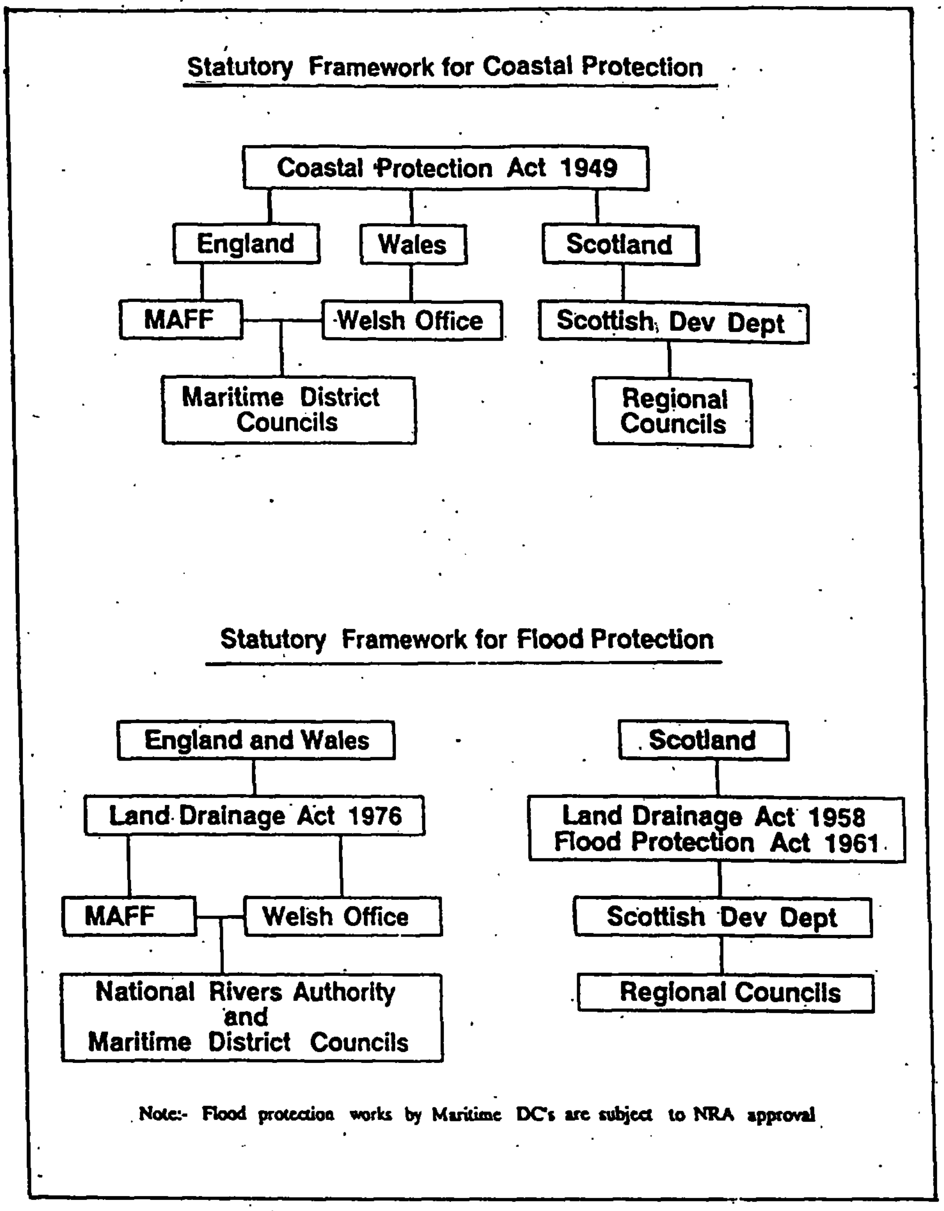


Table 1 Statutory Framework for Coastal and Flood Protection

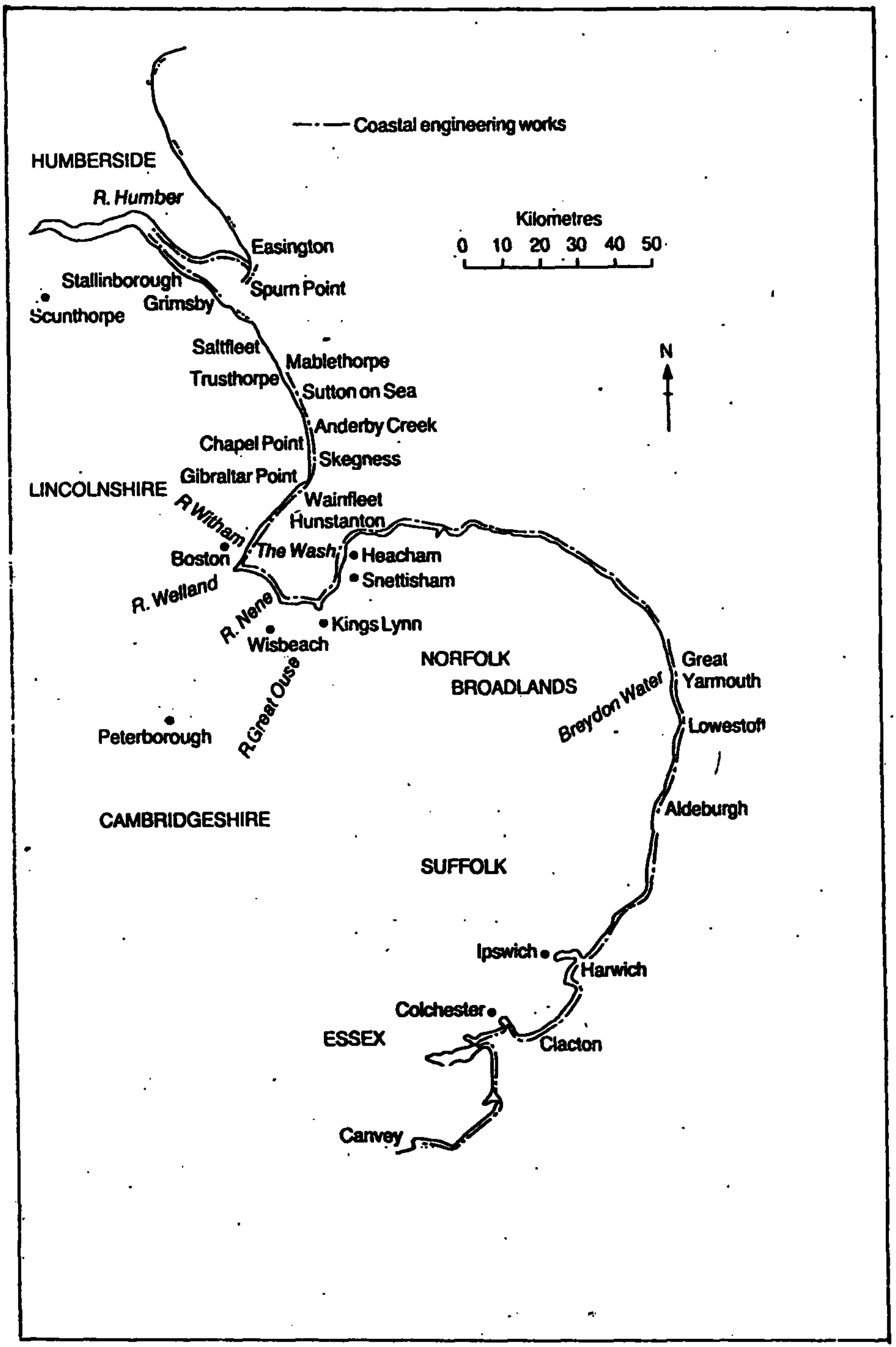


Fig.2 Extent of coastal works along the Anglian Coastline. (Ref.2)

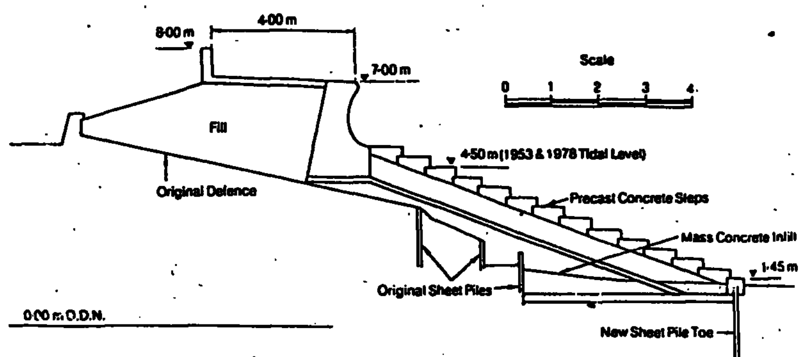


Fig.3a Cleethorpes sea defences

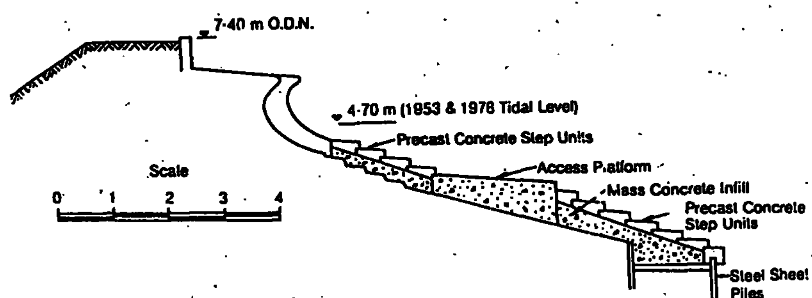


Fig.3b Mablethorpe to Huttoft stepwork scheme

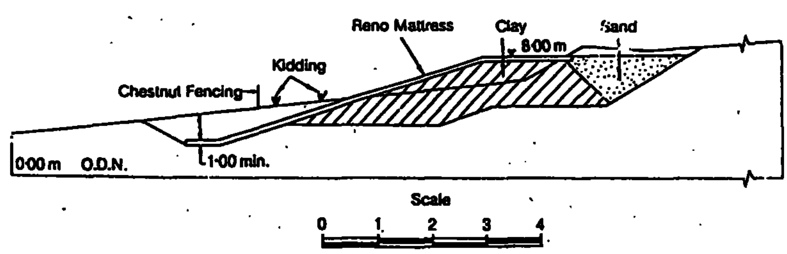


Fig.3c Skegness sea defences

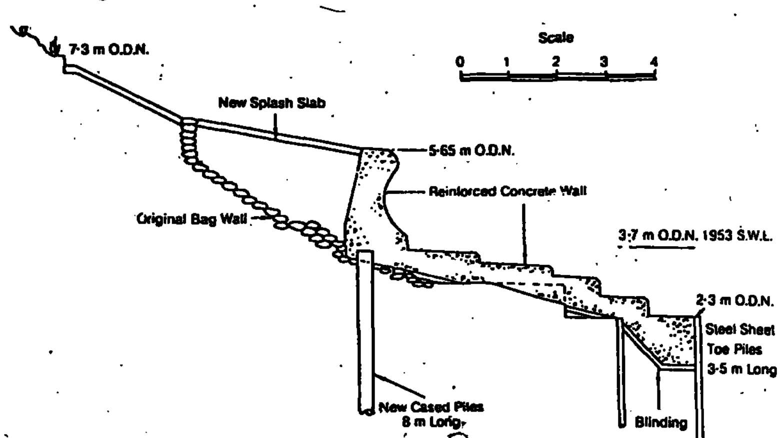


Fig.3d Happisburgh to Winterton sea defences

Fig.3 Coastal Structures along the Anglian Coastline. (Ref.3)

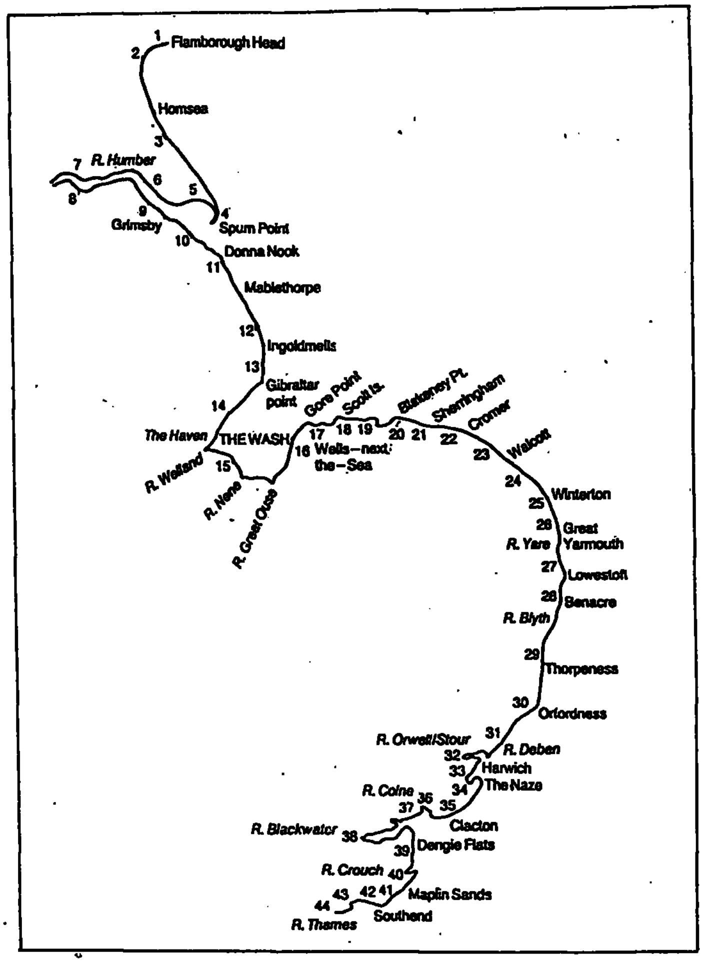


Fig.4 The coastal units of the Sea Defence Management Study for the Anglian Region. (Ref.4)

Net beach level changes September 1959 to April 1985 (m/yr)

Site	Distance offshore (m)						
	0	20	40	60	80	100	120
Mablethorpe	-0.03	-0.03	-0.03	-0.02	-0.02	-0.02	-0.01
Trusthorpe	-0.02	-0.02	-0.02	-0.02	-0.01	-0.01	-0.01
Anderby Creek	+0.03	+0.03	+0.03	+0.02	0	0	+0.01

Average beach level variations (m/yr) over 0-100m width of beach, based on 3-year means

Site			
Mablethorpe	0 (1962-74)	-0.10 (1974-80)	+0.04 (1980-83)
Trusthorpe	-0.01 (1962-74)	-0.07 (1974-80)	-0.07 (1980-83)
Anderby Creek	0 (1965-78)	+0.10 (1977-83)	

Table 2 Beach level information along the Anglian Coastline. (Ref.2)

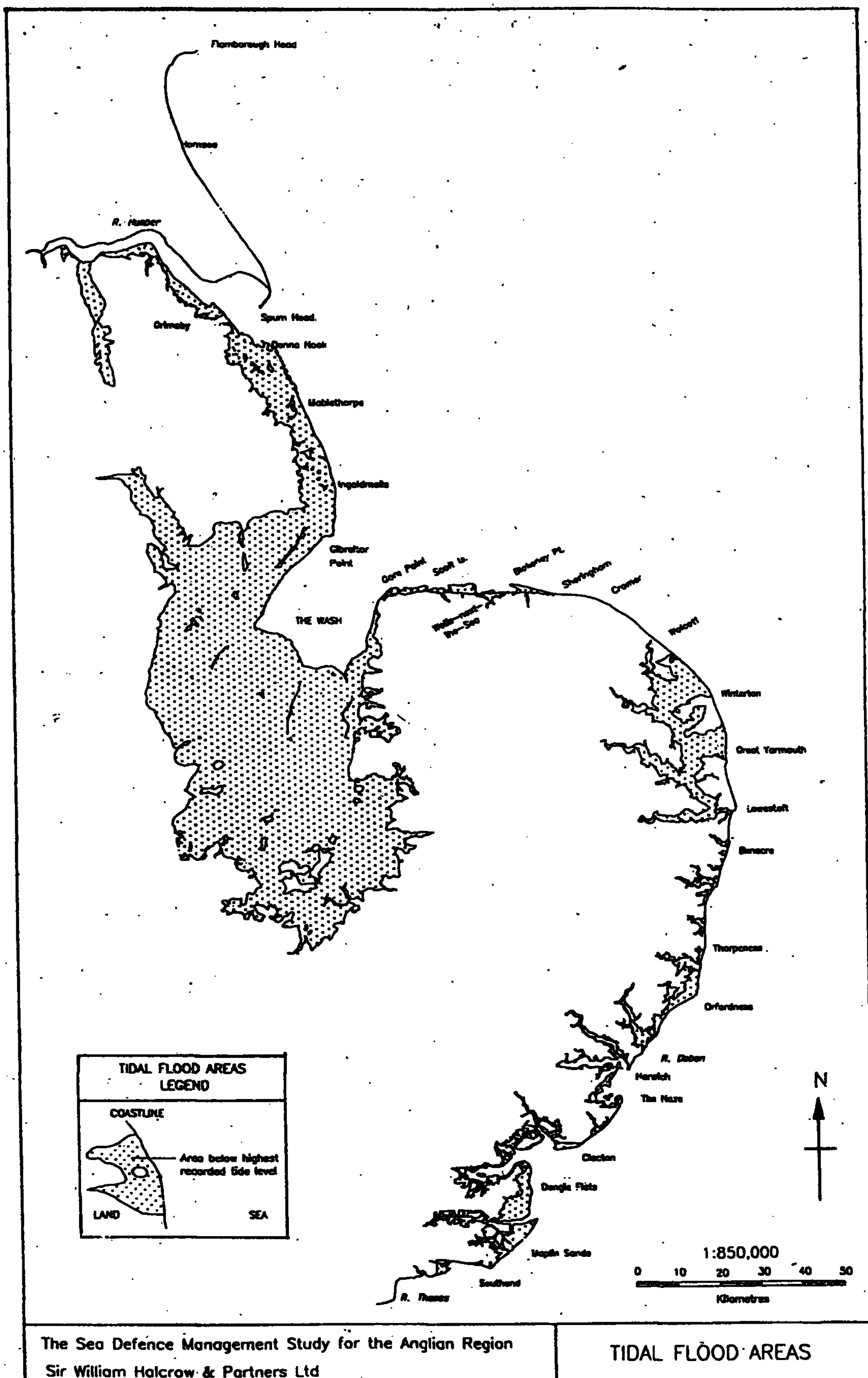


Fig.5 The map on Tidal Flood Areas from the Anglian Coastal Management Atlas. (Ref.5)

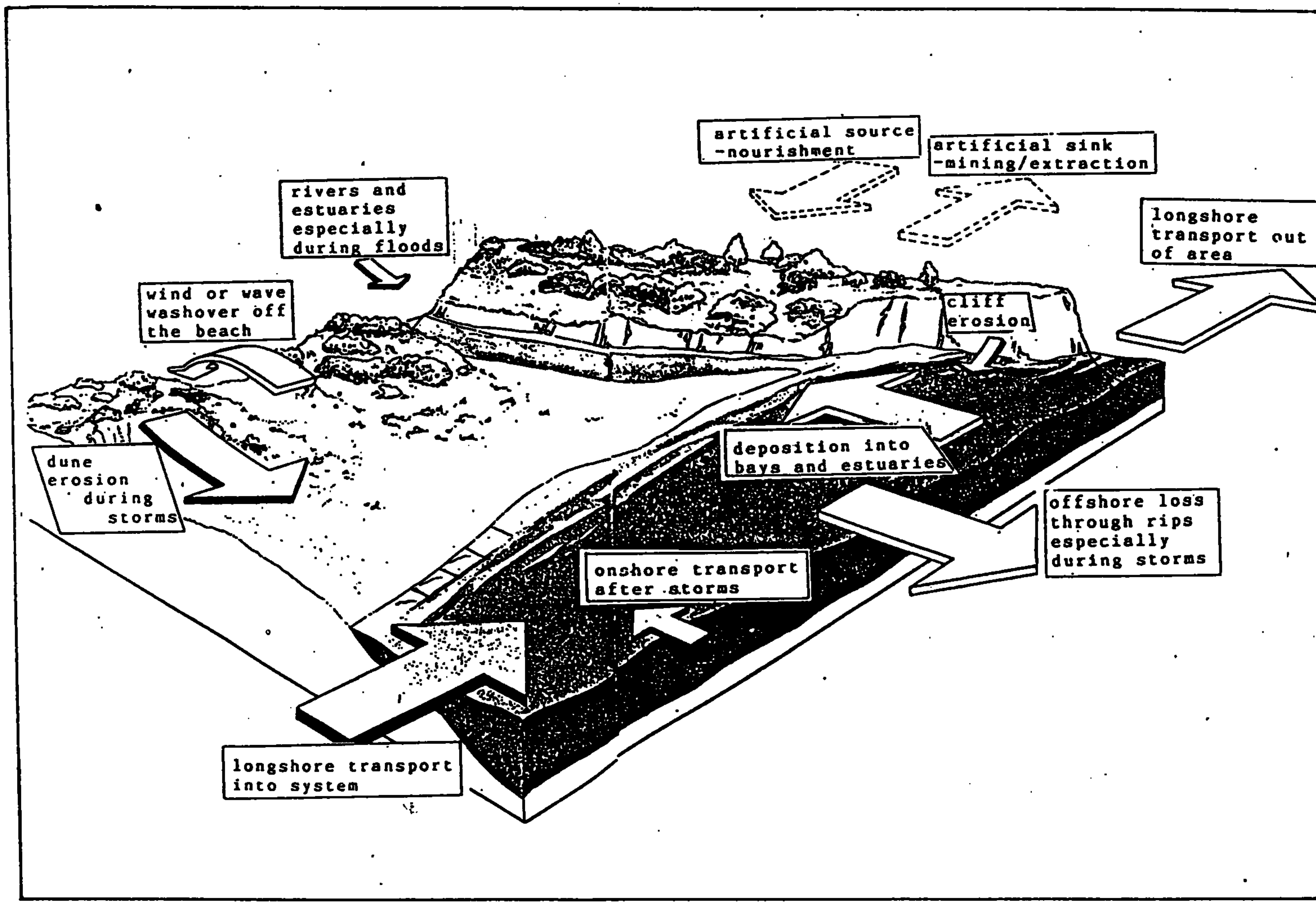


Fig.6 The different elements of the sediment budget

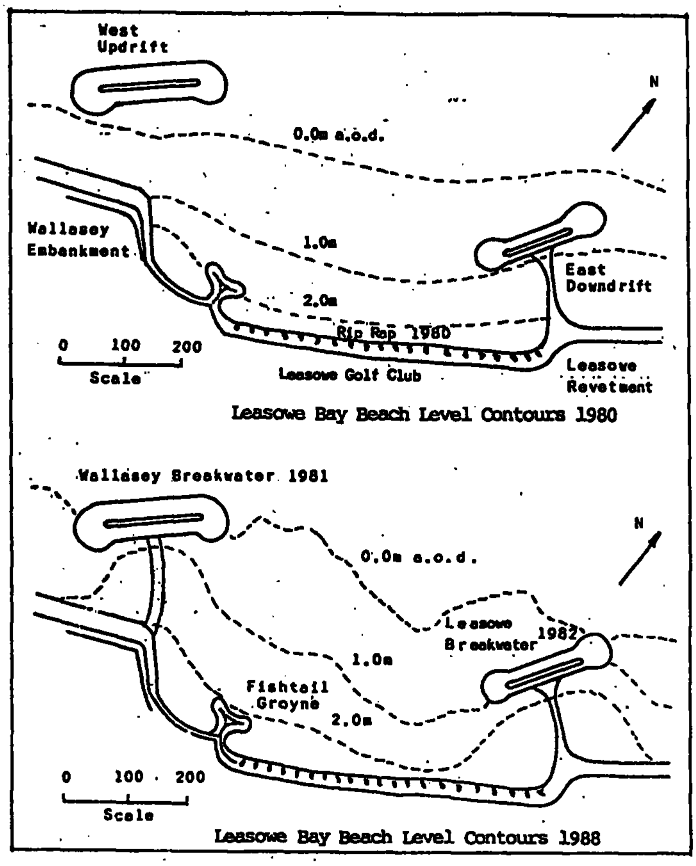


Fig.7 Offshore breakwaters in Leasowe Bay. (Ref.6)

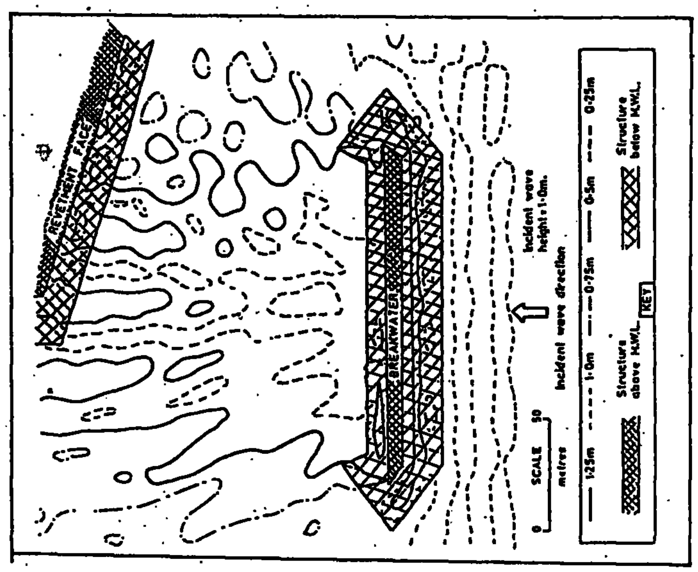


Fig.8 Predicted wave heights around the Leasowe Bay breakwater from a unit wave approaching the breakwater normally. (Ref.7)

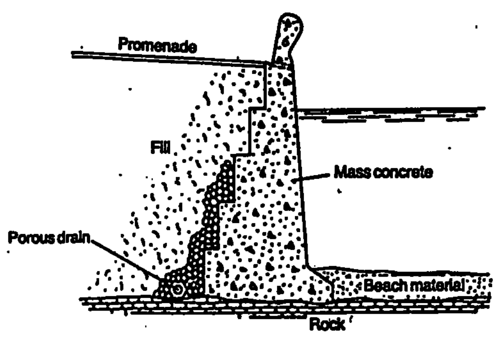


Fig.9a

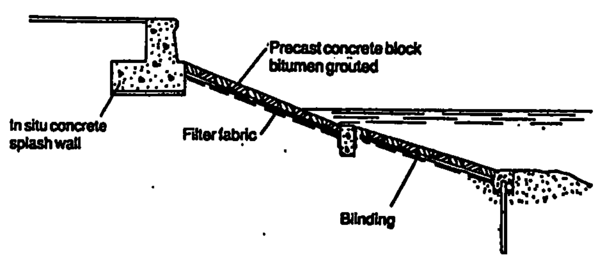


Fig.9b

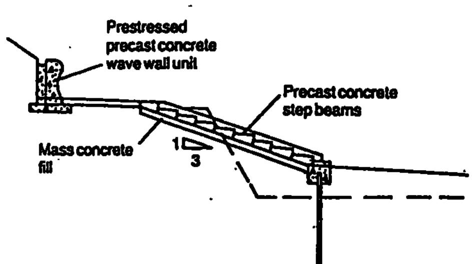


Fig.9c

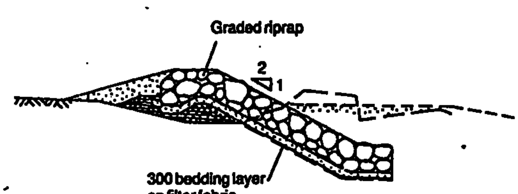


Fig.9d

Fig.9 Cross-sections of sea walls. (Ref.8)

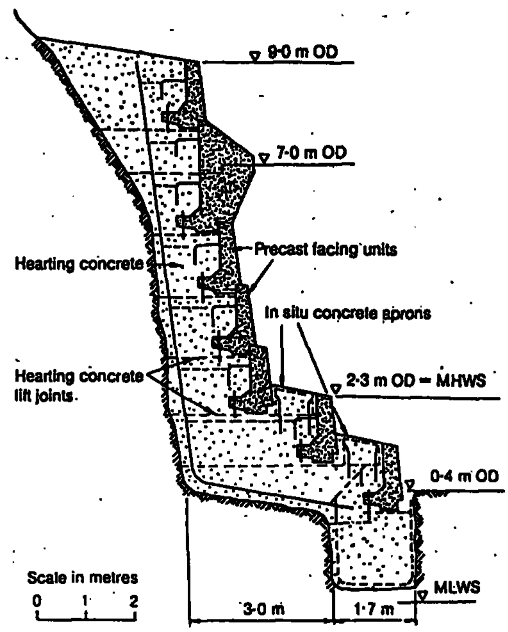


Fig.9e Collywell Bay Sea Wall. (Ref.9)

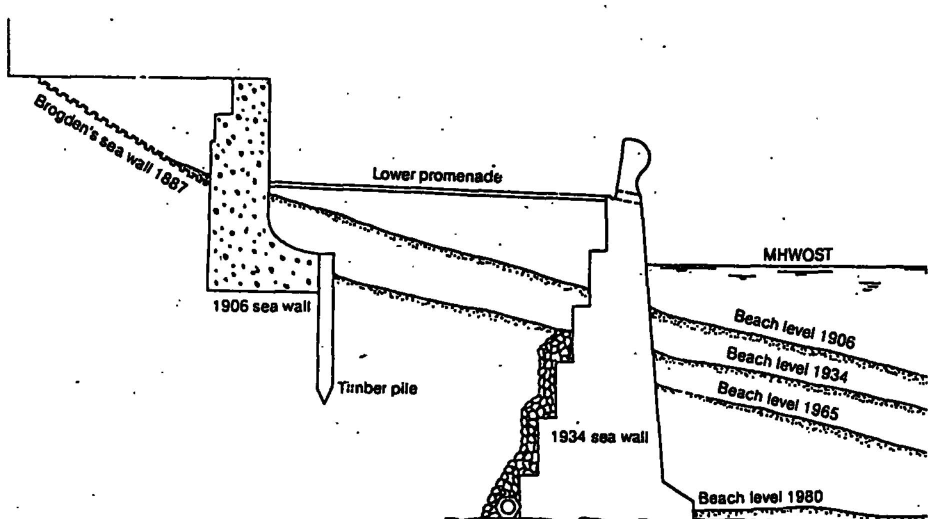
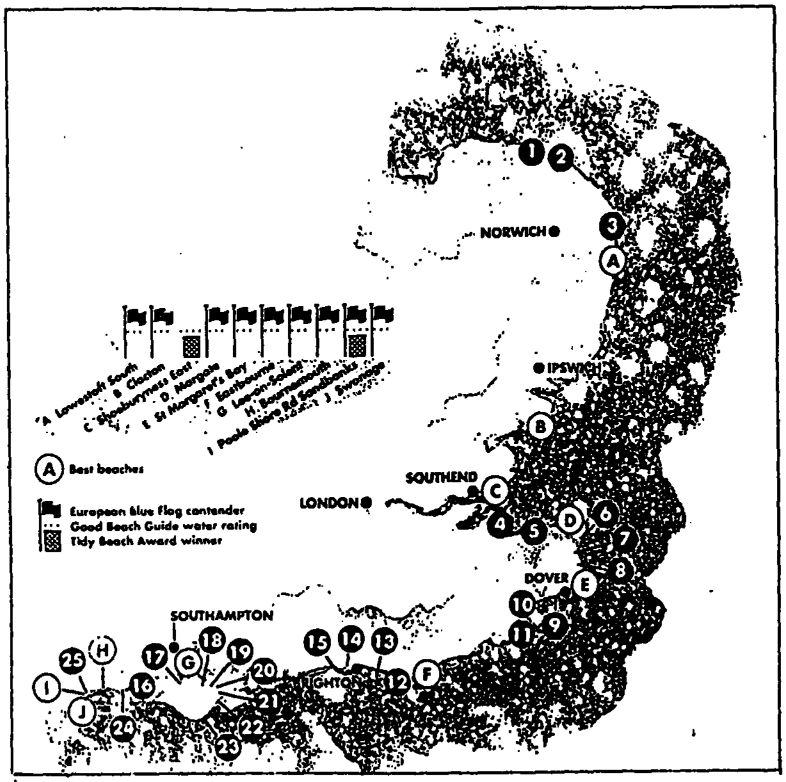


Fig.9f Various levels of the Esplanade Beach, Porthcawl, S.Wales. (Ref.10)

Fig.9 continued. Cross sections of sea walls.



BEACHES THAT FAILED THE EC BATHING WATER STANDARD	TYPE OF SEWAGE	SEWAGE OUTLET	LITTER	YEARS FAILED BY EC
1 Sheringham	prelim	below	M	3
2 Cromer	raw	below	M	3
3 Gt Yarmouth South	☆	-	MS	3
4 Leysdown	-	-	-	2
5 Herne Bay	prelim	below	MS	3
6 Ramsgate	prelim	below	-	3
7 Sandwich Bay	-	-	MS	3
8 Deal Castle	prelim	below	MS	3
9 Folkestone	prelim	above	MS	3
10 Dymchurch	secondary	above	-	3
11 Littlestone	-	-	MS	3
12 Seaford	raw	above	MC	3
13 Newhaven	-	-	MC	3
14 Hove	-	-	MC	3
15 South Lancing	-	-	MC	3
16 Milford-on-sea	-	-	MC	3
17 Cowes	raw	varies	MC	3
18 Ryde	prelim	below	-	3
19 Seagrove	raw	-	MC	2
20 St Helens	raw	-	MC	3
21 Bembridge	prelim	below	MC	3
22 Whitecliff Bay	-	-	MC	2
23 Ventnor	prelim	above	MC	3
24 Christchurch Avon Beach	☆	-	MC	3
25 Poole Harbour Sandbanks	-	-	-	1

TYPE OF SEWAGE raw goes straight from lavatory, sink or gutter to sea **preliminary** sewage screened (sieved for large non-biodegradable solids) and/or macerated (mashed) **primary** sewage passes through settlement tanks to remove large organic and other solids **secondary** after primary treatment sewage is chemically treated to destroy bacteria ☆ sewage discharged into a river flowing into the sea
SEWAGE OUTLET above or below low water mark ☆☆ sewage outlet is in nearby channel.
LITTER M significant marine debris S significant sewage solids C occasional findings of hazardous chemicals (ratings given by The Observer with help from Dr Trevor Dixon, marine biologist, consultant to Tidy Britain Group)
NO. YEARS FAILED BY EUROPEAN COMMUNITY (out of last three years)

Fig.10 Quality of beaches in the south east. (Ref.11)

Extended benefit-cost appraisal 'balance sheet': Wessex Water Authority Scheme; 1.5 mm per year sea level rise; recreational loss valued as boat journey; scheme life 50 years.

Impacts	*Without Coast Protection*	*With Coast Protection*
Annual flooding of property		
Number of properties affected by 1:1000 extreme tide	1630	400
PV of flood losses (50 years)	£3.11 million	£0.81 million
Permanent loss		
Property lost (due to frequent flooding with a breach)	61	0
PV property loss (50 years)	£0.85 million	0
Area of open space lost to erosion and a breach	19ha	0
Recreation and harbour use		
Recreational visits hindered per year	740,000	0
PV of lost recreation and extra economic costs	£0.82 million	0
Fraction of harbour uses affected adversely	3/7	0
Ecology and environment		
Ecological diversity (Shannon-Weaver index)	2.11 (if breach)	2.75
Fraction of ecological divisions adversely affected by: erosion	3/11	0
breach	5/11	0
Archaeology		
Fraction of sites adversely affected by erosion	7/8(2/3)[a]	0
Fraction of sites adversely affected by breach	6/8(2/3)[a]	0
Geology: status of Head	nationally important	negligible
Net economic cost to nation	£4.78 million (minimum)	£4.52 million (protection) works and residual flooding

[a] Figure for 'international' status archaeology sites.

Table 3 Benefit-Cost appraisal balance sheet. (Ref.13)

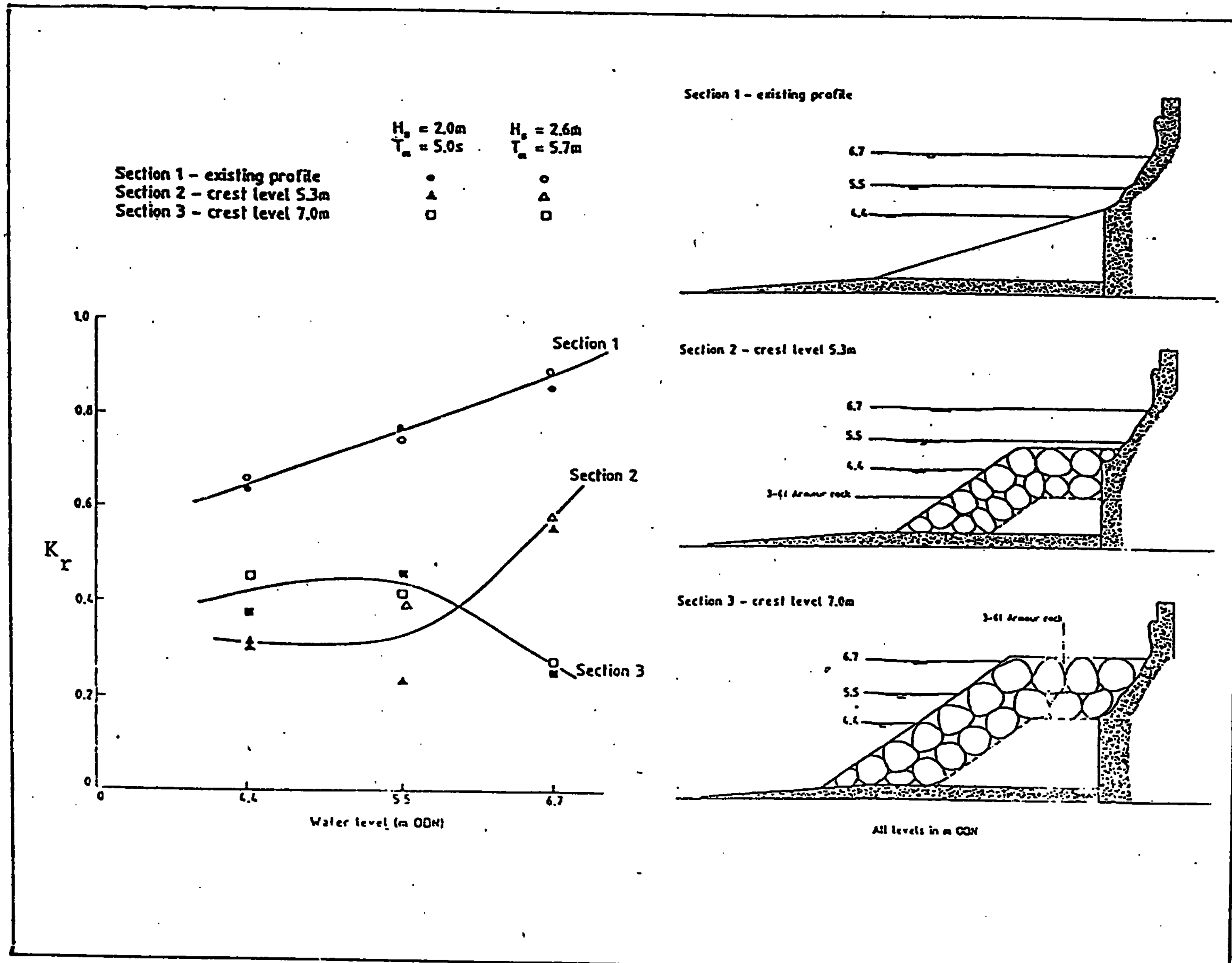


Fig.11 Performance of rock protection to an existing wall (Ref.12)